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Consolidation of performance measures in a supply chain environment

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Abstract

Purpose – Many researchers have stressed the importance of using the right measures and metrics to manage a supply chain efficiently and effectively and have developed them from different perspectives. The basic purpose of this paper is to consolidate the measures and metrics that have been developed so far, verify the relevance of these measures from the practitioners, produce a usable list with proper classification (database), and demonstrate the use of this database through a case study.

Design/methodology/approach – An initial list of metrics and measures is consolidated after analyzing the literature (journals and books) and web sites that deal with supply chains and conducting interviews with industry practitioners. A questionnaire is designed with these measures and metrics and is sent to 300 companies within the electronics industry in Malaysia to obtain feedback from the industry practitioners about the relevance of these measures. A case study is conducted with an electronics manufacturing company to demonstrate the use of the database to identify relevant measures and metrics.

Findings – About 838 performance measures form the initial list. From these, the practitioners consider 159 important and very important measures and 135 are in use in the industry. The entire list of measures is classified into the following metrics: Fund flow, Internal process flow, Material flow, Sales and services flow, Information flow, and Partner evaluation. These metrics are further classified into different groups of measures using confirmatory factor analysis.

Research limitations/implications – Only the industry practitioners from electronics industry in Malaysia participate in the study to identify the relevant measures and metrics.

Originality/value – The paper will be valuable to the academicians and practitioners working to develop measures and metrics for manufacturing supply chains.

Keywords Supply chain management, Electronics industry, Performance measures, Consolidation, Malaysia

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1. Introduction

According to Neely *et al.* (2005), a process cannot be managed if its performance cannot be measured. Many researchers have stressed the importance of using the right metrics to manage a supply chain efficiently and effectively (Gunasekaran *et al.*, 2001; Lambert

and Pohlen, 2001; Neely *et al.*, 2005). According to Melynk *et al.* (2004), metrics and measures provide essential links between strategy, execution, and ultimate value creation. In this study, we treat the terms measure and metric differently. We define measure as a more objective or concrete attribute that is observed and measured and metric as an abstract, higher-level latent attribute that can have many measures. There are several factors that have contributed to the requirement for measures and metrics to manage a supply chain which:

- need to go beyond internal measures and metrics and look at the supply chain as a whole;
- need to link the supply chain performance and corporate objectives;
- need to expand "line of sight" within the supply chain;
- need to allocate benefits and shift burdens resulting from functional shifts within the supply chain;
- need to encourage co-operative behavior within the supply chain;
- need to enhance motivation, improve communication, and diagnose problems within the supply chain; and
- need to improve the performance of the supply chain and thus provide competitive advantage (Chan and Qi, 2003; Lambert and Pohlen, 2001).

In the last decade, much has been written about:

- the need to have a balanced approach in developing supply chain metrics (Beamon, 1999; Gunasekaran *et al.*, 2001; Kaplan and Norton, 1992; Lambert and Pohlen, 2001);
- different types of performance measurement system (PMS) and the barriers in implementing a performance measurement system (Cooper, 1997; Neely *et al.* 2005);
- the need to align supply chain metrics with strategic objectives (Adams *et al.*, 1995; Eccles, 1991; Holmberg, 1997; Hausman, 2002);
- the need for the metrics to cover the entire supply chain (Lambert and Pohlen, 2001; Lee and Billington, 1992); and
- the need to have a few relevant supply chain metrics rather than many irrelevant metrics (Melnyk and Stewart, 2002).

A few papers (Beamon, 1998, 1999; Bhagwat and Sharma, 2007; Chan and Qi, 2003; Gunasekaran *et al.*, 2001; Holmberg, 2000; Lambert and Pohlen, 2001; Narasimhan and Jayaram, 1998; Neely *et al.*, 2005; Van Hoek, 1998) have specifically dealt with performance measures for a supply chain. The researchers have continued to build measures and metrics from different perspectives. After analyzing the literature on supply-chain performance measures and metrics, we have three basic questions:

(1) How many such measures and metrics exist? In this research, we have consolidated the supply chain measures and metrics that are available in the literature, irrespective of the industry.

(2) How many of these measure and metrics are actually perceived important and used by the mangers? Do all the supply chain members perceive the importance

and usage of measures in the same way? At this point, it is worth noting that measures and metrics can be different for different industries and even within an industry, they can be different for different companies. In this research, we have chosen only one industry, electronics industry in Malaysia, to study the importance and usage.

(3) How can a company identify the relevant measures and metrics to be used? To address this question we have conducted a case study with an electronics manufacturing company.

The answers to these questions are important for many reasons. First, the consolidated list can give an idea about the supply chain metrics and measures that have been developed so far by researchers and practitioners. Second, it is important to assess the relevance of these measures to the practitioners. Measures that do not have any practical value must be discarded and future efforts to develop measures must take into account the practical relevance. Third, the academicians and practitioners can use the consolidated list of measures with proper classification as a database. This database can become a "ready reference" while developing measures and metrics for a supply chain. Academicians and practitioners from Electronics Industry can use the validated list developed in this study. Fourth, the managers need to have a database to identify relevant measures and metrics to ensure that a firm's supply chain strategic objectives are met.

The organization of this paper is as follows. Section 2 briefly describes the evolution of performance measurement research and the framework for classifying the consolidated measures. Section 3 describes the methodology for the study. Section 4 reports analysis based on Part One of the questionnaire. Section 5 discusses the analysis based on Part Two of the questionnaire and the validation procedure to identify the "important" measures from the consolidated list. Section 6 discusses the case study. Section 7 discusses the results of the study. Conclusions and limitations are presented in Section 8. Finally, lessons learnt are given in Section 9.

2. Evolution of performance measurement research

Research in the area of performance measurement started as early as 1978 and to date about 1,352 papers have been published (Neely, 2005). According to Neely (2005), only ten out of these papers have been cited more frequently (Banker *et al.*, 2000; Charnes *et al.*, 1978; Dixon *et al.*, 1990; Eccles, 1991; Lynch and Cross, 1995; Kaplan and Norton, 1992, 1993, 1996; Neely *et al.*, 1995). The evolutionary cycle in performance management research can be categorized into five phases: problem identification, proposed frameworks, method of application, empirical investigation, and theoretical verification (Neely, 2005). The research in 1980s dominated the problem identification phase. During this phase, the researchers studied the problems associated with performance measurement systems, especially, short-term nature of measurement and its impact on competitive advantage. The researchers in early 1990s concentrated on developing frameworks to overcome problems with measurement systems. A notable contribution during this phase was balanced scorecard by Kaplan and Norton (1992). The approach was intuitively and logically appealing to the researchers and practitioners. They were very enthusiastic to implement the approach. This "methods of application" dominated the research in late 1990s. Many companies started

implementing the balanced scorecard approach and this helped the researchers to study the impact of implementation through empirical investigation (Banker *et al.*, 2000; Neely *et al.*, 2005). Many companies failed to realize significant benefits through implementing balanced scorecard approach and had problems in designing and deploying strategy maps that are a basic requirement. These problems made the researchers to question the static and linear assumptions of strategy maps (Brignall, 2002). The researchers have now gone to the "drawing board" to design and develop measurement systems:

- that are dynamic and that focus on enterprise performance management instead of performance measurement alone;
- that can measure performance across entire supply chain;
- that can measure the performance of intangible and tangible assets;
- that are flexible to cope with organizational changes; and
- that are "forward looking" and that can help assess the potential of the company to succeed in the future (Neely, 2005).

Bhagwat and Sharma (2007) have developed performance measures for supply chain based on the balanced scorecard approach. It is sad to note that after the balanced scorecard approach, there has been no significant contribution. Therefore, research in performance measurement holds a promising future and much is required to be done. Organizations that implement any form of PMS can use the consolidated list developed in this research to come up with appropriate performance measures. While a group of researchers concentrated on the PMSs, another group of researchers worked on developing specific performance measures for the supply chains (Beamon, 1998, 1999; Chan and Qi, 2003; Gunasekaran *et al.*, 2001; Holmberg, 2000; Lambert and Pohlen, 2001; Narasimhan and Jayaram, 1998; Neely *et al.*, 2005; Van Hoek, 1998).

2.1 Toward a framework for classifying the consolidated performance measures

Supply chain management (SCM), analysis, and improvement are becoming increasingly important to meet the challenges of an increasingly competitive and dynamic environment (Cousins *et al.*, 2008). Performance measures are critical to achieve these tasks. According to Gunasekaran *et al.* (2001, p. 85), performance measures in a supply chain are required "to streamline the flow of material, information, and cash, simplify the decision-making procedures, and eliminate non-value adding activities". Many researchers have utilized different frameworks to develop performance measures. Table I provides the list of different frameworks used by the researchers to develop performance measures. In this research, we consolidate the performance measures that have already been developed by various researchers. A consolidation without proper classification does not add value to the practitioners. Before discussing the classification scheme, it is useful to define what a supply chain is. A supply chain is a network of firms that includes material suppliers, production facilities, distribution services, and customers linked together via the flows of materials, information, and funds (Gunasekaran *et al.*, 2001). Figure 1 illustrates a supply chain with different flows. Since a supply chain can be visualized as a network of flows, we propose a framework that is an extension of the framework proposed by Dixon *et al.* (1990). This has been done so that the performance measures can be

Table I.
Sources used to consolidate existing performance measures

Metric	Measure	Source
Cost in supply chain	Total cost, distribution cost, manufacturing cost, inventory cost	Beamon (1998)
Profitability	ROI	
Customer responsiveness	Time required to produce, Number of orders delivered on time, Number of units produced, Fill rate, Stockout probability, Number of backorders, Number of stockouts, Customer response time, Average lead time, Shipping errors, Customer complaints	
Flexibility	Volume flexibility, Delivery flexibility, Mix flexibility, New product flexibility	
Planned order procedures	Order lead time, Customer order path	Gunasekaran *et al.* (2001)
Supply chain partnership	Level and degree of information sharing, Buyer-vendor cost saving initiatives, extent of mutual co-operation leading to improved quality, Extent of mutual assistance in problem solving efforts, The entity and stage at which supplier is involved	
Production level metric	Range of products and services, Effectiveness of scheduling techniques, Capacity utilization,	
Delivery performance	Delivery-to-request data, Delivery-to-commit date, Order fill lead time, Number of faultless notes invoiced, Flexibility of delivery systems to meet customer needs, Total distribution cost, Delivery lead time	
Customer service and satisfaction	Flexibility, Customer query time, Post transaction measures of customer service, customer perception of service	
Supply chain finance and logistics cost	Cost associated with assets and ROI, Total inventory cost, Total cash flow time	
Cost performance	Material cost, Labor cost, Machinery energy cost, Machinery material consumption, Inventory and WIP level, Total productivity, Direct labor productivity, Fixed capital productivity, Indirect labor productivity, Working capital productivity, Value added productivity	De Toni and Tonchia, 2001
Internal and external time performance	Time to market, Distribution lead time, Delivery reliability, Supplier lead time, Supplier reliability, Manufacturing lead time, Standard run time, Setup time, Wait time, Move time, Inventory turn-over, Order carrying-out time	
Quality performance	SPC measures, Machine reliability, Rework, Quality system cost, Inbound quality, Vendor quality rating, Customer satisfaction, Technical assistance, Returned goods	
Customer relationship management	Measures not discussed	Lambert and Pohlen, 2001
Supplier relationship management	Measures not discussed	
Order fulfillment process	Measures not discussed	

(*continued*)

Metric	Measure	Source
Economic value added	Measures not discussed	
Cost	Measures not discussed	Chan and Qi, 2003
Time	Measures not discussed	
Capacity	Measures not discussed	
Capability	Measures not discussed	
Effectiveness	Measures not discussed	
Reliability	Measures not discussed	
Availability	Measures not discussed	
Flexibility	Measures not discussed	
Productivity	Measures not discussed	
Utilization	Measures not discussed	
Delivery reliability	Delivery performance	Huan *et al.*, 2004 (SCOR model)
	Fill rate	
	Order fulfillment lead time	
	Perfect order fulfillment	
Flexibility and responsiveness	Supply chain responsiveness	
	Production flexibility	
Cost	Value-added employee productivity	
	Total logistics management cost	
	Warranty costs	
Assets	Cash-to-cash cycle time	
	Inventory days of supply	
	Inventory turns	
Product range	Measures not discussed	Holmberg, 2000
Quality	Measures not discussed	
Cost	Measures not discussed	
Availability	Measures not discussed	
Service	Measures not discussed	
Cost effectiveness	Measures not discussed	Remko Van Hoek (1998)
Customer service	Measures not discussed	
Supply chain integration	Measures not discussed	

(*continued*)

Table I.

Table I.

Metric	Measure	Source
Operational scorecard	On-time delivery, product availability, inventory velocity, quality, customer satisfaction, throughput-dollar days, inventory-dollar days	Simatupang and Sridharan (2004)
Improvement scorecard	Forecast accuracy, Responsiveness, Cash-to-cash cycle, Flexibility	
Global scorecard	Growth, Profit, Sales, Inventory turns	
External focus	Measures not discussed	Ron Basu (2001)
Power to consumer	Measures not discussed	
Value-based competition	Measures not discussed	
Network performance	Measures not discussed	
Intellectual capital	Measures not discussed	
Delivery performance	Delivery to request date, Delivery-to-commit date, Order fill lead time	Stewart (1995)
Flexibility and responsiveness	Production flexibility, re-plan cycle time, make cycle time	
Logistics cost	Total logistics cost, Order management cost	
Asset management	Inventory days of supply, Days of sale outstanding	
Financial perspective	Profit, Revenue, EVA, ROI, ROA	Sengun Yeniyurt (2003)
Customer perspective	Market share, Repeat sales level, Customer retention, Customer satisfaction, Perceived quality, Brand equity, Number of customer complaints	
Internal processes	Production cycle time, Defect rates, Productivity, Cost	
Innovation perspective	New product development cycle time, Number of new products, Margin of new products, Revenue from new products, Number of process innovations	
Organizational culture/climate	Market orientation, Employee training hours, Employee turnover rates, Employee satisfaction index	
Internal assets	Equipment productivity, Surface utilization, Volume utilization	Carlo Rafele (2004)
External assets	Trucks fill rate, Accident impact	
Personnel	Personnel efficiency, Accident severity rate	
Inventory availability	Stock turnover, Stock out, Number of slow/fast moving items	
Flexibility	Flexibility	
Service care	Punctuality, Regularity, Completeness, Correctness, Harmfulness	
Supply conditions	Delivery frequency, Shipped quantity	
Lead time	Total order cycle time	
Marketing action	Range completeness, Information on products	

(continued)

Table I.

Metric	Measure	Source
Order management	Document management, Number of client contacts, Order advancement state	
After sales service	Back orders, Claims management	
E-information	Web site completeness, Ease of ordering, Data security	
Cash-to-cash	Cash-to-cash cycle time	Farris and Hutchison (2002)
Quality	Customer complaint statistics, Defects per unit, Defectivity percentage, First pass ratio percentage, Incoming material quality level, Mean time between failures, Number of rework units, Percent of defect free vendor-deliveries, Percent of field failures, Process yield percentage, Supplier outgoing quality level	Lockamy and Spencer (1998)
Financial dimension	Sales per employee, Profit per employee, ROI, ROCE	Webster *et al.* (2004)
Non-financial dimension	Nature of operations management, Extent of outsourcing, Distribution of internal competencies, Form of supply chain relationships	
Planned order procedures	Order entry method, order lead time, customer order path	Bhagwat and Sharma (2007)
Partnership related metric	Not discussed	
Customer service and satisfaction	Flexibility, customer query time, post transaction measure	
Production level metric	Range of products and services, capacity utilization, effectiveness of scheduling techniques	
Delivery related metric	Delivery performance evaluation	
Supply chain finance and logistic cost	ROI, ROA, Total inventory cost	
Supply chain practice	Not discussed	
Information sharing	Not discussed	
Supply chain dynamism	Not discussed	Zhou and Benton (2007)
Delivery performance	Not discussed	
e-Business capabilities	Not discussed	Devaraj *et al.* (2007)
Production information integration	Not discussed	
Operational performance	Percent returns, percent defects, delivery speed, delivery reliability, production cost, production lead time, flexibility	
Manufacturing flexibility	Product flexibility, volume flexibility, launch flexibility	Ndubisi *et al.* (2005)

(*continued*)

Table I.

Metric	Measure	Source
Supply chain uncertainty	Late delivery by suppliers, quality of incoming materials, forecast error	Milgate (2001)
Supply chain technological intricacy	Breadth of raw materials (parts/product)	
Supply chain organizational systems	Product line concentration, breadth of supply base, export orientation	
Delivery performance	Delivery lead time, throughput time, percent of late deliveries, average lateness	

Sources: Websites that were accessed to extract supply chain metrics and measures: www.fpm.com/journal/mattison.htm; www.supply-chain.org; www.softchain.com/; www.mhia.org/articles; www.industryweek.com/columns/asp/columns.asp?ColumnID=724; www.napm.org/ConfPastAndOnlineDaily/Files/Jun02/MA-Minahan.pdf; www.ascet.com/documents.asp?grID=147&d_ID=1122; www.ascet.com/documents.asp?d_ID=283; www.ecommercetimes.com/story/31491.html; www.infochain.org/; www.ism.ws/; www.econbiz.de/; www.prtm.com/index.html
Other sources: Steven A. Melnyk: Research reports on Metrics and Supply Chain: An Exploratory Study – funded by APICS; Stefan Holmberg: Supply chain integration through performance measurement – PhD dissertation; Daniel Knudsen: Procurement performance measurement system – PhD dissertation; Research Reports Supply Chain Management: A Recommendation Performance: Measurement Scorecard, Logistic Management Institute Industry practitioners and Consultants

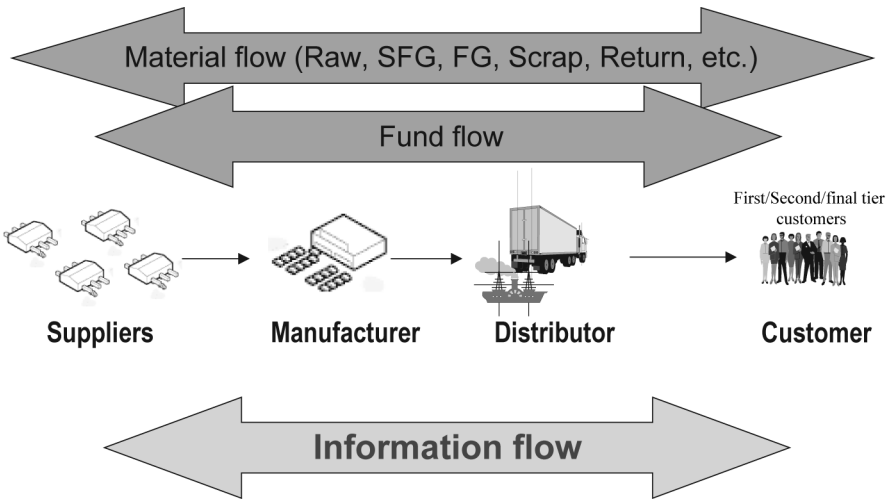

Figure 1.
Illustration of product/material, information, and fund flow across the supply chain

assigned to the appropriate process flow where the supply chain managers can best use them. We have classified the performance measures into the following metrics:

- fund flow (cost and profitability);
- internal process flow (production level flexibility, order fulfillment, and quality);
- material flow (inventory, internal time performance);
- sales and services flow (delivery performance, customer responsiveness, and customer satisfaction);
- information flow (information technology and systems, e-business initiatives); and
- partner relationship process flow (supplier evaluation, sharing of information with suppliers and customers).

3. Methodology

The methodology has been designed to address the three basic questions indicated in Section 1. In this section, we provide a background of Malaysia's electronics industry.

3.1 How many performance measures and metrics pertaining to supply chains exist?

To address the question, an initial list of metrics and measures was consolidated after analyzing the literature (journals, dissertations, and books) and web sites that deal with supply chains and conducting interviews with practitioners from the manufacturing industry. The interviews with industry practitioners were done in two phases. In the first phase, we compiled the performance measures in use in their organizations. Eight experts (five senior managers from manufacturing and three senior managers from consulting) were interviewed. The criteria used to select the experts were: willingness to participate in the study and industry/consulting experience of more than ten years in Logistics/SCM. The experts were from the following companies: Acer Computers, Hitachi Manufacturing, Sony Corporation, HP/Compaq Computers, SCM Consulting, and SAP Consulting. During the second phase, the experts were presented with an entire list

of performance measures and were asked to identify the measures they considered "useful" in a manufacturing-supply-chain environment. The list at this stage contained 816 performance measures. The list did not contain specific measures pertaining to e-business initiatives. A focus group discussion was conducted with experts (from the companies mentioned earlier) in the field of e-supply chain to develop performance measures for e-business initiatives. The group came up with 22 different performance measures (Sambasivan *et al.*, 2009) making the total number to 838. This formed the initial consolidated list. Table II gives a partial list of performance measures (interested readers can contact the authors for a complete list). We classified these measures into the metrics (Fund flow, Internal process flow, Material flow, Sales and services flow, Information flow, and Partner evaluation) as described earlier. Out of these, about 33 percent were financial measures and the remaining 67 percent were non-financial measures.

3.2 How many performance measures and metrics are actually perceived important and used by the managers?

To address this question, the list was presented to 26 experts from the electronics industry (industry practitioners and consultants) to filter out the important measures. After the filtering process, the number of measures in the list reduced from 838 to "important" and "very important" 159. A questionnaire was developed with 159 measures to gauge the importance and frequency of use of these measures in the industry. We adapted the performance management questionnaire (PMQ) developed by Dixon *et al.* (1990). The questionnaire consisted of four sets one each for the Supplier, Manufacturer, Distributor, and Customer. A respondent company (unit of analysis) filled the set depending upon its role in a supply chain and a company was allowed to fill multiple sets depending upon its role in different supply chains. The questionnaire consisted of two parts. The first part gathered information about the company's goals and supply chain goals, competitiveness of the company, partnership evaluation done by the company, and its e-business activities. The second part gathered information about the measures related to material flow, information and document flow, fund flow, internal process flow, and sales and service flow. The "items" in the second part of the questionnaire were numerical values or perceptual Likert scales. For each of the measures, the respondents were asked to rate the importance of the measures on a five-point scale, ranging from "not very important" to "very important" and the frequency of use of the measures on a five-point scale, ranging from "don't know" to "annually".

The target group for the questionnaire was supply chain managers from electronic components manufacturing companies in Malaysia. The sampling frame consisted of 2,000 companies listed in:

- *Federation of Malaysian Manufacturers' Directory*.
- a list of Japanese businesses in Malaysia; and
- a list of e-business hosting companies.

We approached all the companies in the sampling frame and questionnaires were sent to 300 companies that agreed to participate in the study.

Table II. Partial list of performance measures

SNo	Class.	Performance measure	SNo	Class.	Performance measure
1	MF	Percentage accuracy in shelf locations for FG stored in warehouse	21	FF	Percentage invoices processed
2	IPF	Percentage agreements negotiated with suppliers without error	22	IPF	Percentage of accuracy of manufacturing master data
3	MF	Percentage capacity utilization of containers	23	IPF	Percentage of accuracy of labor master data
4	IPF	Percentage completed preventive maintenance work orders	24	MF	Percentage of backlog of the total order quantity (with reasons)
5	MF	Percentage defective products received from subcontractors/ vendors	25	MF	Percentage of callbacks as a percentage of total inquiries
6	MF	Percentage defective products transferred from store to production location	26	MF	Percentage of changes accommodated by PP as per the sales request
7	MF	Percentage defective products transferred to subcontractors	27	MF	Percentage of damaged customer shipments
8	MF	Percentage downtime due to non-availability of WIP	29	MF	Percentage of delays in-transit caused due to non compliance to Govt. Regulations
9	IPF	Percentage engineering change orders implemented in time	30	MF	Percentage of delays caused due to non compliance to Govt. Regulations
10	IPF	Time in training (days/years)	31	MF	Percentage of dispatch instructions requiring amendments
11	IPF	Investment in research ($)	32	MF	Number of dispatch instructions
12	MF	Percentage equipment utilization for handling/storage of return inventory	33	IPF	Percentage of engineering change orders accepted after mass production started
13	MF	Percentage equipment utilization for handling/storage of RM Inventory	34	MF	Percentage of failures due to employee negligence
14	MF	Percentage equipment utilization for handling/storage of WIP Inventory	35	SSF	Percentage of faultless invoices to customers
15	MF	Percentage equipment utilization for handling/storage of FG	36	MF	Percentage of FG parts rejected
16	MF	Percentage excess capacity available with suppliers	37	IPF	Percentage of inactive capital assets loaned to supplier
17	MF	Percentage excess manufacturing capacity available	38	IPF	Percentage of active capital assets loaned to Supplier
18	MF	Percentage incoming parts received at point of use	39	MF	Percentage of manufacturing batches produced without corrective action
19	FF	Percentage invoice receipts & payment generated via EDI for transactions with suppliers	40	MF	Percentage of manufacturing parts rejected
20	FF	Invoices processed without issues/errors to suppliers	41	MF	Percentage of manufacturing performance standards completed on time

(*continued*)

Table II.

SNo	Class.	Performance measure	SNo	Class.	Performance measure
42	IPF	Percentage of new or modified equipments available for manufacturing when needed	62	MF	Percentage orders received on-time to meet actual demand
791	IPF	Percentages of full time employees (percent)	811	PRPF	Percent of suppliers getting shared forecast
792	IF	Percent of demand/supply on VMI/CRP	812	PRPF	Invoice presentation and payment: streamline the number of process of invoice presentation
793	FF	Pick error cost	813	PRPF	Invoice presentation and payment: collaboration dispute resolution cycle time
794	IPF	Pick list fill rate	814	IF	Invoice presentation and payment: payment and reconciliation cycle time
795	IPF	Plant space utilization	815	IF	Web enabled service: global visibility through near real time data
796	FF	Premium freight charges	816	IF	Web enabled service: system response time
797	IPF	Real time planning/execution linkage	817	IF	Web enabled service: security of data/information
798	MF	Production yields by line	818	IF	Web enabled service: traffic by page and site (SRM/e-proc)
799	SSF	Percent of products representing 80 percent of sales	819	IF	Intranet: efficiency improvement by reducing administration time
800	FF	Raw material cost down target/achievement annually/term	820	IF	Intranet: efficiency improvement by standardizing number of steps of procurement cycle
801	FF	R&D expenses/total expenses (percent)	821	IF	Intranet: efficiency improvement by shortening the procurement cycle time
802	FF	Shipment error cost	822	IF	Intranet: efficiency improvement by supplier-buyer response time in procurement operation
803	IPF	Routing accuracy	823	IF	Efficiency improvement: cycle time for purchasing process from requisition to receipt
831	PRPF	Level and degree of information sharing	835	PRPF	Response to quality problems
832	PRPF	Supplier-manufacturer cost saving initiatives	836	PRPF	The entity and stage at which a supplier should be involved
833	PRPF	Cooperation leading to improved quality	837	PRPF	Extent of mutual assistance in problem-solving efforts
834	IF	E-response: quick response to information updated via web application	838	PRPF	Interest in developing partnership

Notes: MF – material flow; IPF – internal process flow; FF – fund flow; SSF – sales and service flow; IF – information flow; PRPF – partner relationship process flow

3.3 How can a company identify the relevant measures and metrics to be used?
After consolidating and validating the measures and metrics, we conducted a case study with an electronics manufacturing company to address this question. The company was presented with the validated list of measures and it identified the relevant measures and metrics from the list based on its supply chain objectives.

3.4 Some prefatory remarks on Malaysian electronics industry
The electronic industry is Malaysia's main engine that powers country's economy. In 2006, the industry contributed to 62 percent of manufactured exports of Malaysia (Research Report, 2008). Malaysia is home to MNCs from the USA, Japan, Europe, Taiwan, and Korea, manufacturing products ranging from semiconductor devices to consumer and industrial electronics. Malaysia is one of the world's largest exporters of semiconductor devices and audio-visual equipments. The value of exports in 2007 was more than US$ 50 billion. Leading companies in the electronics industry such as Intel, Motorola, Agilent, AMD, National Semiconductor, Fairchild, Hitachi, NEC, Fujitsu, Toshiba, Infineon and STMicroelectronics have operations in Malaysia (MIDA, 2004).

4. Analysis based on part one of the questionnaire

The basic purpose of this section is to understand the profile of the participating companies, the importance of supply chain to these companies, and supply chain activities performed by them.

4.1 Profile of the respondents
The questionnaire was sent to 300 electronics manufacturing companies in Malaysia. Out of these, 150 questionnaires were returned (response rate = 50 percent) and only 120 questionnaires were usable. The respondent companies, based on their major activity, were: manufacturers (40 percent), suppliers (30 percent), distributors (12 percent), and customers (18 percent). About 52 percent of the respondents performed more than one supply chain activity. About 88 percent of the respondents were either senior managers or managers of logistics function who had more than seven years of experience. In terms of size of the respondent organizations, about 60 percent had more than 500 employees and about 20 percent had between 100 to 500 employees.

4.2 Supply chain activities of the responding companies
This section of the questionnaire provides an understanding about the respondent company's supply chain objectives and strategies; supply chain performance evaluation criteria; important supply chain initiatives undertaken by the respondent companies; primary roles of supply chain in the next five years as seen by the companies; and e-business activities undertaken by the respondent companies.

The supply-chain objectives of the respondent companies are given in the order of importance are:

(1) minimizing costs (41 percent);
(2) improving service (25 percent);
(3) improving quality (18 percent); and
(4) supporting growth (16 percent).

The top five supply chain performance evaluation criteria of the respondent companies are:

(1) inventory turnover (61.8 percent);
(2) cycle time (48 percent);
(3) fulfillment rates (20.2 percent);
(4) supply chain service (20.2 percent); and
(5) perfect order (14.6 percent).

The important supply chain initiatives undertaken by the various respondents are:

- improving customer relations (31 percent);
- implementation of ERP (28 percent);
- improving supplier relations (21 percent);
- conducting cost reduction exercises (12 percent);
- improving process design (7 percent); and
- consolidating the operations (1 percent).

The top five primary roles to be played by the supply chain in the next five years in the respondent companies in the order of importance are:

(1) reducing costs (37.4 percent);
(2) improving service (30.9 percent);
(3) enabling flexibility (28.5 percent);
(4) satisfying competitive requirements (20.3 percent); and
(5) improving time to market (16.3 percent).

E-business activities undertaken by the respondent companies are given in Figure 2 and the scenario depicted is typical of any developing country. Some of the e-business activities that are popular among the supply chain members are: EDI, PO management,

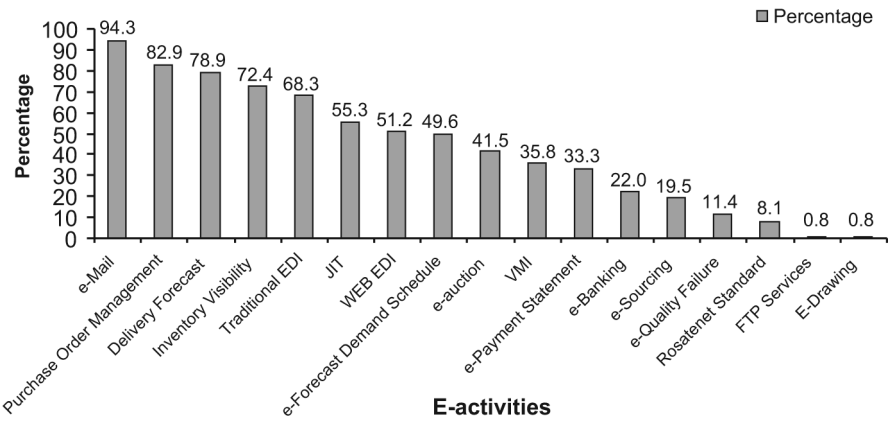

Figure 2.
E-activities undertaken by the responding companies

Note: EDI – Electronic data interchange; JIT – just in time; FTP – file transfer protocol

use of e-mail to exchange information, inventory visibility to all partners in the supply chain, and e-forecast.

From the above discussions, it can be concluded that the respondent companies have a reasonable background, in terms of supply chain objectives and practices, to participate in this study and the data provided by them can be used for further analysis.

5. Analysis based on part two of the questionnaire

This section of the questionnaire captured the importance of the measures and the extent of their usage in the electronics industry in Malaysia. The initial list of 838 measures was exhaustive and we went to the industry practitioners to identify the measures that are important for measuring the performance in a supply chain environment. Many industry practitioners refused to identify the relevant measures since the list contained too many measures. We decided to "weed out" the less important measures. We sent the questionnaire along with the list to 26 experts (practitioners and consultants) who agreed to participate in the "weeding out" operation and they came up with a list of 159 "important" and "very important" measures. At this stage, the experts were required to only indicate a measure as important or very important. Table III gives the 159 performance measures that came out from the original list of 838 measures. A questionnaire was constructed with these 159 measures and was sent to 300 manufacturing companies in Malaysia. The respondents were asked to indicate the importance and extent of usage. Table III gives the perception of the respondents on the importance and the extent of usage (includes frequent and infrequent use) of these measures.

According to more than 70 percent of the respondents, 135 measures (highlighted in Table III) of the 159 measures were in use in the industries. However, the extent of usage was observed to be low for measures under information and document flow. A probable reason for this phenomenon could be that the companies were in the process of implementing and using various e-business initiatives as shown in Figure 2. Of the different metrics addressed in this section, all supply chain members were requested to answer about the performance measures related to fund flow, material flow, and information and document flow. Do all the supply chain members perceive the importance and usage of measures in the same way? We performed ANOVA to test this question. Based on the analysis, we observed the following: for measures under material flow, there were no significant differences between the supply chain members for the importance of measures (F-value = 0.4615, p-value = 0.71) but there were significant differences for the usage of measures (F-value = 5.9, p-value = 0.001). On further analysis, we found that the suppliers and the manufacturers were using the measures more than the distributors and the customers; for measures under funds flow, there were no significant differences between the supply chain members for the importance of measures (F-value = 0.17, p-value = 0.92) and the usage of measures (F-value = 1.23, p-value = 0.31). This result is not surprising as these measures are prevalent among all the members in the supply chain; for measures under information and document flow, there were significant differences between supply chain members for the importance of measures (F-value = 6.5, p-value = 0.001) and the usage of measures (F-value = 5.4, p-value = 0.009). On further analysis, we found that the suppliers and manufacturers value the importance and therefore, use these measures more than the distributors and customers. This outcome may be due to manufacturers

and suppliers implementing e-business initiatives in a big way when compared to distributors and customers. The main differences between these groups are in efficiency improvement measures e-response measures. Table III indicates the perception of the different supply chain members (customers, distributors, manufacturers, and suppliers) about the importance of different measures and metrics.

As indicated earlier, we extended the classification scheme for metrics as proposed by Dixon *et al.* (1990) and a pertinent question at this point is: Is the scheme valid? We addressed this question by using confirmatory factor analysis (CFA) on the 135 measures. We ran CFA using Lisrel 8.52. The results of the analysis are presented in Table IV. From the results, it can be seen that we have identified more relevant groups of measures for each metric than the ones proposed by Dixon *et al.* (1990) and the different groupings obtained through CFA are shown in Table III.

6. A case study

A case study was conducted in a company manufacturing hard disks for personal computers to demonstrate the process of identifying the relevant measures and metrics from the database to ensure that the supply chain objectives are met. The company chosen for the study is one of the largest in Malaysia with headquarters in Tokyo, Japan. The company is very progressive in implementing new technologies and has implemented SAP to manage the entire operations. The company has strong links with its suppliers and customers. The supply chain objectives of the company are:

- to achieve cost efficiency through information and material flow with lower inventories and to eliminate unnecessary overhead costs;
- to gain a competitive edge by being flexible, quick, dependable, and cost efficient;
- to establish partnership programs with suppliers to have an effective supply chain management; and
- to use e-business initiatives effectively.

Based on these objectives, the top management of the company identified the following key metrics:

- delivery performance;
- order fulfillment lead-time;
- flexibility and productivity;
- inventory days of supply;
- cost management; and
- e-business measures.

The management of the company was presented with the validated database that contained 135 measures. The managers identified 94 measures from this database that could help them achieve the objectives and these measures are indicated in Table III. The managers acknowledged the ease of identifying performance measures if a database was available. The databases (a master database with 838 measures and the database with 135 measures for electronics industry), can be used as a ready reference by the managers to identify the relevant measures and metrics depending upon the supply chain objectives.

Table III. List of "important" and "very important" performance measures

SNo	Important for	Classification	Performance measure	Percentage considered important	Percentage using the measure
1	M	FF4	Average labor cost[a]	83	83
2	C, D	FF4	Shipment error cost[a]	61	38
3	C, D, M, S	FF3	Cash to cash cycle time[a]	88	88
4		Fund flow	Cost of administrative error/management revenues (%)		
5	M, S	FF4	Cost per unit produced[a]	90	90
6	C, D, M, S	FF4	Inbound and outbound logistics cost[a]	83	81
7	M	FF5	Frequency of price changes	91	61
8	C, D, M, S	FF4	Information carrying cost[a]	60	37
9	M	FF3	Invoice error	66	66
10	M, S	FF4	Manufacturing cost[a]	93	93
11	S	FF2	Material acquisition cost[a]	88	88
12	M	FF4	Operational cost per operation hour	86	83
13	M, S	FF1	Order management cost[a]	64	48
14	C, D, M, S	FF3	Payment term	95	92
15		Fund flow	Pick error cost		
16	C, D, M, S	FF2	Profit margin (%)[a]	100	100
17	C, D, M, S	FF2	ROA[a]	100	100
18	C, D, M, S	FF2	Return on capital employed	100	100
19	C, D, M, S	FF2	ROI[a]	100	100
20	C, D, M, S	FF2	Revenue[a]	100	100
21	M, S	FF2	Sales volume by customer[a]	84	84
22		Fund flow	Smoothed month end cycle		
23	C, D, S	FF4	Total distribution cost[a]	83	81
24	M, S	FF1	Unit purchase cost[a]	96	91
25		Fund flow	Warehouse labor cost		
26	D, M, S	FF4	Warehousing costs[a]	77	77
27	M, S	FF5	Warranty cost[a]	58	58
28	D, M, S	FF5	Company's pricing compared to market[a]	80	80
29	M	IPF4	Adherence-to-schedule[a]	88	88
30	M	IPF2	BOM accuracy[a]	95	86

(continued)

Table III.

SNo	Important for	Classification	Performance measure	Percentage considered important	Percentage using the measure
31	M, S	IPF2	Capacity utilization[a]	90	90
32	M	IPF5	ECO changes after mass production	67	51
33	M	IPF1	Effectiveness of MPS[a]	68	61
34	M	IPF1	Effectiveness of dist. planning schedule	64	55
35	M, S	IPF3	Manufacturing productivity[a]	98	98
36	M	IPF3	New product time-to-market[a]	77	74
37	M	IPF5	Overtime usage[a]	90	’90
38	M	IPF2	Planning process cycle time[a]	65	61
39	M	IPF3	Production order fill rate[a]	90	90
40	M	IPF3	Production yields by line[a]	88	88
41	M	IPF4	Production/process cycle time[a]	90	90
42		Int. process flow	Real time planning/execution linkage		
43	M, S	IPF5	Defects in ppm[a]	85	85
44	M	IPF1	Routing accuracy	77	77
45	M, S	IPF1	Schedule changes[a]	88	85
46	M, S	IPF3	Setup/changeover costs	78	78
47	M	IPF2	Upside-production flexibility[a]	65	55
48	M	IPF4	Throughput[a]	80	80
49	M	IPF1	Effectiveness of scheduling[a]	65	58
50	M, S	IPF3	Productivity (%)[a]	89	89
51	M	IPF4	Lead time, product development (no.)[a]	85	85
52	M	IPF4	Line breakdowns[a]	98	98
53		Int. process flow	Lines picked/hour		
54	M, S	MF1	Ontime delivery to commit %[a]	79	79
55	M	MF1	Ontime delivery to request % by vendor[a]	85	85
56		Material flow	Average time for decision making		
57		Material flow	Average truck turnaround time		
58		FF5	Commitment to annual cost reductions		
59	C, M	Material flow	Container utilization	80	80
60		Material flow	Courier service cycle time		

(continued)

Table III.

SNo	Important for	Classification	Performance measure	Percentage considered important	Percentage using the measure
61	D, M, S	MF4	Critical order lead time[a]	94	87
62	M, S	MF2	Customer returns[a]	75	73
63	D, M, S	MF2	Damage free delivery[a]	73	73
64	D, M, S	MF2	Defect free delivery[a]	77	70
65		Material flow	Design capability		
66	M	MF3	End-of-life inventory[a]	90	90
67		Material Flow	Expediting activities		
68	C, D, M	MF3	Finished goods inventory days of supply[a]	90	90
69	C, D, M, S	MF1	Flexible delivery/shipment[a]	77	42
70	M	MF6	Forecast accuracy[a]	80	80
71	C, D, M	MF1	Frequency of delivery/shipment	70	50
72	M, S	MF1	Frequency of MRP run	89	89
73	C, S	MF6	Frequency order cancellation[a]	95	95
74	C, D, M, S	MF6	Inventory accuracy[a]	100	100
75	M	MF6	Obsolete inventory (dead stock)[a]	95	95
76	M, S	MF3	Inventory days of supply[a]	100	100
77	M	MF2	Inventory level (scrap/wastage)[a]	60	60
78		Material flow	Inventory level (WIP)		
79		Material flow	Inventory level as incoming stocks		
80	M, S	MF3	Inventory turns (finished goods)[a]	93	93
81		Material Flow	Inventory turns (raw material)		
82	D, M, S	FF1	Inventory carrying cost[a]	64	48
83	M, S	MF4	Lead time, from order to delivery[a]	100	100
84	M, S	MF4	Lead time, prodn[a]	93	93
85		Material Flow	Manufacturer-customer disputes		
86	M	MF5	Master schedule stability[a]	88	88
87	M	MF6	Material stock outs (shortage)[a]	85	85
88		Material flow	No. cycle counts		
89		Material flow	Number of visit to vendor/customer		

(continued)

Table III.

SNo	Important for	Classification	Performance measure	Percentage considered important	Percentage using the measure
90	C, D, M	MF1	On-time shipment[a]	90	90
91	M, S	MF1	Order fill rate[a]	90	90
92	S	MF1	Order fulfillment lead time[a]	100	100
93		Material Flow	Order size constraints (lots size)		
94	D, M	MF6	Order track and trace performance	78	54
95	M, S	MF6	Part/finished goods in transit	88	88
96	C, D, S	MF6	Priority of critical part order allocation	80	77
97		Material Flow	Product environmental assessment		
98	S	MF1	Production capacity[a]	100	100
99	C, D, M	MF1	Quantity fill rate[a]	90	90
100	D, M, S	MF6	Response to urgent delivery/shipment	88	80
101	C, M, S	MF2	Rework upon delivery[a]	65	65
102	S, M	Sales & Ser. Flow	Satisfied-customer index (%)[a]	100	100
103	C, D	MF6	Service part aging	78	78
104	M, S	MF6	Service parts availability	86	86
105	D, M	MF1	Shipment accuracy[a]	84	75
106	S, D	MF1	Stock out[a]	90	90
107		Fund Flow	Supplier claim on order cancellation		
108	M, S	MF6	Vendor response time to quality failure[a]	82	78
109		Sales & Ser. flow	Flexibility making available product/service		
110	M	SSF1	Measuring customer perception of service[a]	68	68
111	M	SSF2	New customer order[a]	78	78
112	M	SSF2	New customer order backlog	70	70
113	M	SSF2	New customer order value	60	60
114	M	SSF3	Number of complaints[a]	84	84
115	M	SSF5	Order complete manufacture to customer receipt	82	67
116	M	SSF5	Order entry accuracy[a]	90	84
117	M	SSF5	Order entry method	70	70
118	M	SSF5	Order receipt to order entry complete	61	52
119	D, M	SSF5	Percent of customer sharing forecasts[a]	80	80
120	D, M	SSF1	Percent of products representing 80 percent of sales[a]	88	88

(continued)

SNo	Important for	Classification	Performance measure	Percentage considered important	Percentage using the measure
121	M	SSF2	Percent of sales from new products	75	75
122	D	SSF4	Pick list fill rate	59	59
123	D, M	SSF2	Repeat versus new customer sales	64	64
124	M	SSF1	Service level compared to competitors	69	62
125		Sales & Ser. flow	Customer receipt to installation complete		
126	M	SSF1	Customer retention[a]	80	75
127	M	SSF4	Damaged shipment[a]	86	86
128	M	SSF1	Customer rating (%)	79	79
129	M	SSF1	Customer lost (No/%)		
130		Sales & Ser. Flow	Customer order path		
131	C, D, M, S	IF1	Global visibility through near real time data	62	25
132	C, D, M, S	IF1	System response time	77	55
133	C, D, M, S	IF1	Data transmission speed[a]	77	56
134	C, D, M, S	IF1	Security of data/information[a]	85	37
135	C, D, M, S	IF1	Traffic by page and site (SRM/e-procurement)	52	31
136	C, D, M, S	IF2	Transaction error rate (number of transaction error rate)[a]	80	63
137	C, D, M, S	IF2	Easy tracking of goods movement (number of backlog tracking)	48	31
138	C, D, M, S	IF2	Gain control over payables process	40	20
139	C, D, M, S	IF2	User utilization[a]	80	60
140	M, S	IF4	Time taken to fix the interface troubleshooting link with ERP	44	27
141	M, S	IF4	Messaging-alert capabilities (response time to alarm trigger)[a]	79	70
142	M, S	IF4	Quick response to information updated via web application	64	56
143	C, D, M, S	IF5	Number of processes of invoice presentation	62	47
144	C, D, M, S	IF5	Collaboration dispute resolution cycle time[a]	48	40
145	C, D, M, S	IF5	Payment and reconciliation cycle time[a]	78	67
146	M, S	IF3	Reducing administration time (as per man-hour in purchasing activities) and cost[a]	59	33
147	M, S	IF3	Standardize number of procurement cycle exist for different supplier	67	43
148	M, S	IF3	Shortening the procurement cycle time[a]	65	49

(*continued*)

Table III.

Table III.

SNo	Important for	Classification	Performance measure	Percentage considered important	Percentage using the measure
149	M, S	IF3	Supplier-buyer response time in procurement operation[a]	44	32
150	C, D, M, S	IF4	Mail service reliability	90	75
151	C, D, M, S	IF5	Cycle time for purchasing process from requisition to receipt[a]	60	50
152	C, D, M, S	IF6	Document accuracy[a]	100	60
153	M, S	PRPF2	Level and degree of information sharing[a]	92	80
154	M, S	PRPF2	Supplier-manufacturer cost saving initiatives[a]	89	75
155	M, S	PRPF1	Cooperation leading to improved quality[a]	91	80
156	M, S	PRPF1	Response to quality problems[a]	87	87
157	M, S	PRPF2	The entity and stage at which a supplier should be involved	58	50
158	M, S	PRPF1	Extent of mutual assistance in problem solving efforts[a]	73	70
159	C, M, S	PRPF1	Interest in developing partnership (supplier-customer)[a]	80	60

Notes: [a]Performance measures selected by the managers of the company that participated in the case study; C – customer, D – distributor; M – manufacturer; S – supplier; PRPF1 – partner relationship process flow (supplier evaluation); PRPF2 – partner relationship process flow (sharing of information); FF1 – fund flow (inventory cost); FF2 – fund flow (profitability); FF3 – fund flow (payment terms); FF4 – fund flow (production cost); FF5 – fund flow (others); IPF1 – internal process flow (production schedule); IPF2 – internal process flow (flexibility and planning); IPF3 – internal process flow (productivity and quality); IPF4 – Internal process flow (order fulfillment); IPF5 – internal process flow (others); SSF1 – sales and service flow (customer satisfaction and retention); SSF2 – sales and service flow (new customer orders); SSF3 – sales and service flow (customer responsiveness); SSF4 – sales and service flow (delivery performance); SSF5 – sales and service flow (others); MF1 – material flow (order fulfillment and flexibility); MF2 – material flow (quality); MF3 – material flow (inventory); MF4 – material flow (internal time performance); MF5 – material flow (stability of schedule); MF6 – material flow (others); IF1 – information flow (web-enabled service); IF2 – information flow (web application); IF3 – information flow (efficiency improvement); IF4 – information flow (e-response); IF5 – information flow (invoice presentation and payment); IF6 – information flow (document management)

Table IV. CFA results for various metrics

SNo	Metric	Measure: Dixon *et al.*(1990)	Measure: Our research	CFA results
1	Partner relationship process flow	Not addressed	Supplier evaluation, sharing of information	RMSEA = 0.078; GFI = 0.96; RMR = 0.067; CFI = 0.96; Chisq/df = 1.73; df = 6; *p*-value = 0.06
2	Fund flow	Cost, profitability	Inventory cost, profitability, payment terms, production and shipment cost	RMSEA = 0.084; GFI = 0.90; RMR = 0.067; CFI = 0.91; Chisq/df = 1.83; df = 8; *p*-value = 0.00064
3	Internal process flow	Production level flexibility, order fulfillment, quality	Production schedule, flexibility and planning, productivity and quality, order fulfillment	RMSEA = 0.088; GFI = 0.90; RMR = 0.076; CFI = 0.90; Chisq/df = 2.32; df = 9; *p*-value = 0.0007
4	Sales and service flow	Delivery performance, customer responsiveness, customer satisfaction	Customer satisfaction and retention, new customer orders, customer responsiveness, delivery performance	RMSEA = 0.094; GFI = 0.90; RMR = 0.053; CFI = 0.92; Chisq/df = 2.98; df = 9; *p*-value = 0.008
5	Material flow	Inventory, Internal time performance	Order fulfillment and flexibility, quality (scrap), inventory, internal time performance, stability of schedule	RMSEA = 0.081; GFI = 0.91; RMR = 0.069; CFI = 0.93; Chisq/df = 1.77; df = 8; p-value = 0.0007
6	Information flow	Not specified	Web-enabled service, web application, efficiency improvement, e-response, invoice presentation and payment, document management	RMSEA = 0.091; GFI = 0.95; RMR = 0.058; CFI = 0.96; Chisq/df = 2.01; df = 9; *p*-value = 0.034

7. Results and discussions

According to Gunasekaran *et al.* (2004), the roles played by performance measures and metrics are critical to the success of an organization because they help in setting objectives, evaluate performance, and determine future courses of action. An important component in supply chain design and analysis is the establishment of appropriate performance measures (Beamon, 1998). According to Neely *et al.* (2005, p. 1,231), "performance measures need to be positioned in a strategic context as they influence what people do". The basic purpose of performance measures is to stimulate action and help managers make appropriate decisions. Therefore, the significance of appropriate measures and metrics to effectively manage supply chains cannot be overemphasized. However, Ketokivi and Schroeder (2004) warn that finding the appropriate "valid" performance measures can be difficult.

We started this paper with three intriguing questions:

(1) How many measures and metrics pertaining to measurement of supply chains exist?

(2) How many of these measure and metrics are being used by the mangers in the industry?

(3) How can a company identify the relevant measures and metrics to be used?

We addressed the first question by consolidating the measures and metrics from literature and from interviews/discussion with industry experts. A total 838 measures were identified and a database was created with proper classification. A classification scheme proposed by Dixon *et al.* (1990) was extended to include partner-relationship process flow and information flow to accommodate different measures and metrics. The databases and the classification scheme provided in this study can help managers identify the right performance measures for managing the supply chains in their organizations. The measures cover upstream and downstream supply chain elements and e-supply chains. A caveat at this point is that the performance measures are not stationary. They have to be reviewed continuously and should reflect the current strategies. Measures that are developed to address new issues in supply chains can be appended to the existing database.

We addressed the second question in two phases. In the first phase, the database with 838 measures was distributed to 26 practitioners/experts from the electronics industry. These experts selected 159 measures that they considered important and relevant for the electronics industry. A questionnaire with these 159 measures was sent to 300 electronics manufacturing companies. This validation procedure resulted in 135 measures that were in use in the industry. Malaysia, being one of the leading exporters of semiconductor devices, plays a very important role as a partner in the electronics supply chain. Our study revealed that the companies in this industry had implemented many supply chain initiatives and were in the process of implementing many more such as e-business initiatives.

We addressed the third question by conducting a case study in one of the largest multinational companies in the electronics industry. Managers are often overloaded with performance measures and metrics that are often not in line with companies' business strategies, budget policy, or even vision (Adams *et al.*, 1995; Eccles, 1991; Holmberg, 2000; Hausman, 2002). According to Hausman (2002), the supply chain performance measures of a company that are not in line with its supply chain

objectives are useless. The case study company was informed about the significance of supply chain objectives and the company was made to spell out the objectives explicitly. Then the managers of the company were given the database (with 135 measures) developed in this research and they used the database to pick the relevant measures and metrics that matched the objectives. Based on the request of the top management, we are in the process of implementing the database in the company.

Our study reveals that many performance measures have been developed so far. Can we say, therefore, that the development of performance measures should cease? We cannot make this conclusion because there are many underdeveloped areas of performance measures. These areas are:

- measures to track performance across supply chains and networks rather than within organizations (Kim, 2006; Neely, 2005);
- measures to handle intangible assets in addition to tangible assets for better internal management (Lev, 2004); and
- measures that can cope with the changes in organization, technology, and environment – measures that are dynamic and not static (Kennerley and Neely, 2003).

These areas pose major challenges to researchers and practitioners. Researchers need to address these areas immediately so that performance measurement as an area of research in general and specifically, in supply chains can progress further.

8. Conclusions and limitations

This paper has managed to consolidate the various performance measures that have already been developed by academicians and practitioners. For a typical manufacturing supply chain, the literature search and interviews with experts, consultants and practitioners have revealed that there are 838 measures and these measures have been classified under the following metrics: material flow, fund flow, internal process flow, sales and service flow, information flow, and partnership evaluation. Further analysis with these measures on Malaysian electronic manufacturing companies identified 159 "important" and "very important" measures and out of which 135 measures were in use. Based on CFA, these measures, under different metrics, were grouped according to the "underlying" dimensions. This paper lists the various sources that were used to collect all the performance measures and provides a list (database) of these measures with classification schemes for metrics and measures. We believe that this database can be a ready reference to academicians and practitioners that are involved in performance measurement research. We demonstrated the use of this database by conducting a case study with an electronics manufacturing company.

Our study has some limitations. This study considered only one manufacturing industry. Therefore, the database of measures is not exhaustive. The importance and usage of measures was studied using 150 companies that participated in the study. Therefore, generalization across the industry can be questionable. We believe that each industry can do its own exercise to identify the relevant measures and metrics from the "master list" database of 838 measures.

Lessons learnt

There are many lessons that have been learnt from this study:

- Many performance measures for the supply chain have already been developed by researchers and practitioners. But there are areas of performance measures in supply chains that are underdeveloped.
- The performance measures and metrics must reflect the supply chain objectives of the company. Different industries and different companies within an industry may use different performance measures.
- The performance measures used must reflect different elements of a supply chain such as suppliers, customers, and internal processes. Using too many measures may prove detrimental to a company.
- The management responsibility is enormous in implementing the relevant performance measures and metrics for supply chains.

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