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Int. J. Production Economics 87 (2004) 333–347
international journal of production economics
www.elsevier.com/locate/dsw

A framework for supply chain performance measurement

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Abstract

Supply chain management (SCM) has been a major component of competitive strategy to enhance organizational productivity and profitability. The literature on SCM that deals with strategies and technologies for effectively managing a supply chain is quite vast. In recent years, organizational performance measurement and metrics have received much attention from researchers and practitioners. The role of these measures and metrics in the success of an organization cannot be overstated because they affect strategic, tactical and operational planning and control. Performance measurement and metrics have an important role to play in setting objectives, evaluating performance, and determining future courses of actions. Performance measurement and metrics pertaining to SCM have not received adequate attention from researchers or practitioners. We developed a framework to promote a better understanding of the importance of SCM performance measurement and metrics. Using the current literature and the results of an empirical study of selected British companies, we developed the framework presented herein, in hopes that it would stimulate more interest in this important area.

Keywords: Supply chain; Performance measurements; Metrics; Empirical analysis; Framework

1. Introduction

By the late 1980s, outsourcing in US industries contributed to nearly 60% of the total product cost (Ballou, 1992). In the UK, a survey showed that 40% of the UK's gross domestic product was spent on distribution and logistics related activities (Department of Trade and Industry, UK, 1990). Such findings and developments present significant visible impact of distribution, purchasing, and supply management on company assets. Managers in many industries, especially those in manufacturing, are trying to better manage supply chains. Important techniques/methodologies like just-in-time (JIT), total quality management, lean production, computer generated enterprise resource planning schedule (ERP) and Kaizen have been embraced. The concept of supply chain management (SCM), according to Thomas and Griffin (1996) represents the most advanced state in the evolutionary development of purchasing, procurement and other supply chain activities. At the operational level, this brings together functions that are as old as commerce itself—seeking goods, buying them, storing them and distributing them. At the strategic level, SCM is a relatively new and rapidly expanding discipline that is transforming

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doi:10.1016/j.ijpe.2003.08.003

the way that manufacturing and non-manufacturing operations meet the needs of their customers.

Development of cross-functional teams aligns organisations with process oriented structure, which is much needed to realise a smooth flow of resources in a supply chain. As suggested by Trent and Monczka (1994), such teams promote improved supply chain effectiveness. They minimise or eliminate functional and departmental boundaries and overcome the drawbacks of specialisation, which according to Fawcett (1995), can distribute the knowledge of all value adding activities such that no one, including upper level managers, has complete control over the process. Such teams helped in the formation of modern supply chains by promoting greater integration of organisations with their suppliers and customers.

Supplier partnerships and strategic alliances refer to the co-operative and more exclusive relationships between organisations and their upstream suppliers and downstream customers. Today many firms have taken bold steps to break down both inter and intra firm barriers to form alliances, with the objective of reducing uncertainty and enhancing control of supply and distribution channels. Such alliances are usually created to increase the financial and operational performance of each channel member through reductions in total cost and inventories and increased sharing of information (Maloni and Benton, 1997). Rather than concerning themselves only with price, manufacturers are looking to suppliers to work co-operatively in providing improved service, technological innovation and product design. This development has produced a significant impact by expanding the scope of SCM through greater integration of suppliers with organisations.

The growth and development of SCM is not driven only by internal motives, but by a number of external factors such as increasing globalisation, reduced barriers to international trade, improvements in information availability, and environmental concerns. Furthermore, computer generated production schedules, increasing importance of controlling inventory, government regulations and actions such as the creation of a single European market, and the guidelines of GATT and WTO have provided the stimulus for development of and existing trends in SCM. Supply chain integration is needed to manage and control the flow in operating systems. Such flow control is associated with inventory control and activity system scheduling across the whole range of resource and time constraints. Supplementing this flow control, an operating system must try to meet the broad competitive and strategic objectives of quality, speed, dependability, flexibility and cost (Slack et al., 1995; Gunasekaran et al., 2001; De Toni and Tonchia, 2001). Control is also essential as both customer needs and supply chain performance might change with time.

To meet objectives, the output of the processes enabled by the supply chain must be measured and compared with a set of standards. In order to be controlled, the process parameter values need to be kept within a set limit and remain relatively constant. This will allow comparison of planned and actual parameter values, and once done, the parameter values can be influenced through certain reactive measures in order to improve the performance or re-align the monitored value to the defined value. For example, an analysis of the layout of facilities could reveal the cause of long distribution time, high transportation and movement costs and inventory accumulation. Using suitable approaches like re-engineering facilities, problems can be tackled and close monitoring and subsequent improvements can be possible from analysis of the new design. Thus, control of processes in a supply chain is crucial in improving performance and can be achieved, at least in part, through measurement. Well-defined and controlled processes are essential to better SCM.

There are number of conceptual frameworks and discussions on supply chain performance measurements in the literature; however, there is a lack of empirical analysis and case studies on performance metrics and measurements in a supply chain environment. We will discuss the background for the research, review the selected literature on supply chain performance metrics and measurements, develop a framework based on the literature and an empirical analysis, and finally, summarize the findings and conclusions.

2. Background for research

In this section, the literature is used in describing the general context within which measurement of supply chain performance is undertaken. The works of various authors are used in establishing the need for supply chain performance measurement and to describe in general terms how it should be addressed—emphasis is on measurement systems and approaches as opposed to specific measures.

The strategic, operational and tactical levels are the hierarchies in function, wherein policies and trade-offs can be distinguished and suitable control exerted (Ballou, 1992). According to Rushton and Oxley (1989), such a hierarchy is based on the time horizon for activities and the pertinence of decisions to and influence of different levels of management. The *strategic level* measures influence the top level management decisions, very often reflecting investigation of broad based policies, corporate financial plans, competitiveness and level of adherence to organisational goals. The *tactical level* deals with resource allocation and measuring performance against targets to be met in order to achieve results specified at the strategic level. Measurement of performance at this level provides valuable feedback on mid-level management decisions. *Operational level* measurements and metrics require accurate data and assess the results of decisions of low level managers. Supervisors and workers are to set operational objectives that, if met, will lead to the achievement of tactical objectives.

Many firms look to continuous improvement as a tool to enhance their core competitiveness using SCM. Many companies have not succeeded in maximizing their supply chain's potential because they have often failed to develop the performance measures and metrics needed to fully integrate their supply chain to maximize effectiveness and efficiency. Lee and Billington (1992) observed that the discrete sites in a supply chain do not maximize efficiency if each pursues goals independently. They point to incomplete performance measures existing among industries for assessment of the entire supply chain. Measurements should be understandable by all supply chain members and should offer minimum opportunity for manipulation (Schroeder et al., 1986). Performance studies and models should be created so that organisational goals and achievement of those goals can be measured, thus allowing the effectiveness of the strategy or techniques employed to be accessed.

Most companies realise the importance of financial and non-financial performance measures, however they have failed to represent them in a balanced framework. According to Kaplan and Norton (1992), while some companies and researchers have concentrated on financial performance measures, others have concentrated on operational measures. Such an inequality does not lead to metrics that can present a clear picture of organisational performance. For a balanced approach, Maskell (1991) suggests that companies should understand that, while financial performance measurements are important for strategic decisions and external reporting, day to day control of manufacturing and distribution operations is often handled better with non-financial measures. Another area where inequality persists is deciding upon the number of metrics to be used. Quite often companies have a large number of performance measures to which they continue to add based on suggestions from employees and consultants. They fail to realise that performance assessment can be better addressed using a trivial few—they are not really trivial, but instead are those few areas most critical to success.

The metrics that are used in performance measurement and improvement should be those that truly capture the essence of organizational performance. A measurement system should facilitate the assignment of metrics to where they would be most appropriate. For effective performance measurement and improvement, measurement goals must represent organisational goals and metrics selected should reflect a balance between financial and non-financial measures that can be related to strategic, tactical and operational levels of decision making and control.

3. Performance measurements and metrics in SCM

In this section, the literature on performance measurements and metrics in SCM is reviewed.

The metrics and measures are discussed in the context of the following supply chain activities/processes: (1) plan, (2) source, (3) make/assemble, and (4) delivery/customer (Stewart, 1995; Gunasekaran et al., 2001).

3.1. Metrics for order planning

3.1.1. The order entry method

This method determines the way and extent to which customer specifications are converted into information exchanged along the supply chain.

3.1.2. Order lead-time

The total order cycle time, called order to delivery cycle time, refers to the time elapsed in between the receipt of customer order until the delivery of finished goods to the customer. The reduction in order cycle time leads to reduction in supply chain response time, and as such is an important performance measure and source of competitive advantage (Christopher, 1992)—it directly interacts with customer service in determining competitiveness.

3.1.3. The customer order path

The path that an order traverses is another important measure whereby the time spent in different channels can be determined. By analyzing the customer order path, non-value adding activities can be identified so that suitable steps can be taken to eliminate them.

3.2. Evaluation of supply link

Traditionally supplier performance measures were based on price variation, rejects on receipt and on time delivery. For many years, the selection of suppliers and product choice were mainly based on price competition with less attention afforded to other criteria like quality, reliability, etc. More recently, the whole approach to evaluating suppliers has undergone drastic change.

Evaluation of suppliers: The evaluation of suppliers in the context of the supply chain (efficiency, flow, integration, responsiveness and customer satisfaction) involves measures important at the strategic, operational and tactical level.

Strategic level measures include lead time against industry norm, Quality level, Cost saving initiatives, and supplier pricing against market.

Tactical level measures include the efficiency of purchase order cycle time, booking in procedures, cash flow, quality assurance methodology and capacity flexibility.

Operational level measures include ability in day to day technical representation, adherence to developed schedule, ability to avoid complaints and achievement of defect free deliveries.

Purchasing and supply management must analyze on a periodic basis their supplier abilities to meet the firm's long-term needs. The areas that need particular attention include the supplier's general growth plans, future design capability in relevant areas, role of purchasing and supply management in the supplier's strategic planning, potential for future production capacity and financial ability to support such growth (Fisher, 1997). Supply chain partnership is a collaborative relationship between a buyer and seller which recognises some degree of interdependence and cooperation on a specific project or for a specific purchase agreement (Ellram, 1991; van Hoek, 2001). Such a partnership emphasises direct, long-term association, encouraging mutual planning and problem solving efforts (Maloni and Benton, 1997). Supplier partnerships have attracted the attention of practitioners and researchers (Macbeth and Ferguson, 1994; Ellram, 1991; Graham et al., 1994). All have contended that partnership formation is vital in supply chain operations and as such for efficient and effective sourcing. Partnership maintenance is no less important. Performance evaluation of buyers or suppliers is simply not enough—relationships must be evaluated.

The parameters that need to be considered in the evaluation of partnerships are the ones that promote and strengthen them. For example, the level of assistance in mutual problem solving is indicative of the strength of supplier partnerships. Partnership evaluation based on such criteria will result in win–win partnerships leading to more efficient and more thoroughly integrated supply chains.

3.3. Measures and metrics at production level

After the order is planned and goods sourced, the next step in to make/assemble products. This is the activity carried out by organisations that own production sites, and their performance has a major impact on product cost, quality, speed of delivery and delivery reliability, and flexibility (Mapes et al., 1997; Slack et al., 1995). As it is quite an important part of the supply chain, production needs to be measured and continuously improved. Suitable metrics for the production level are as follows:

Range of product and services: According to Mapes et al. (1997), a plant that manufactures a broad product range is likely to introduce new products more slowly than plants with a narrow product range. Plants that can manufacture a wide range of products are likely to perform less well in the areas of value added per employee, speed and delivery reliability. This clearly suggests that product range affects supply chain performance.

Capacity utilization: From the above assertion, it is clear that the role-played by capacity in determining the level of activities in a supply chain is quite important. According to Slack et al. (1995), of the many aspects of production performance, capacity utilization directly affects the speed of response to customer demand through its impact on flexibility, leadtime and deliverability.

Effectiveness of scheduling techniques: Scheduling refers to the time or date on or by which activities are to be undertaken. Such fixing determines the manner in which resources will flow in an operating system, the effectiveness of which has an important impact on production and thus supply chain performance. For example, scheduling techniques such as JIT, MRP and ERP have implications on purchasing, throughput time and batch size. In case of the supply chain, since scheduling depends heavily on customer demands and supplier performance, the scheduling tools should be viewed in that context (Little et al., 1995).

3.4. Evaluation of delivery link

The link in a supply chain that directly impacts customers is delivery. It is a primary determinant of customer satisfaction; hence, measuring and improving delivery is always desirable to increase competitiveness. Delivery by its very nature takes place in a dynamic and ever-changing environment, making the study and subsequent improvement of a distribution system difficult. It should be noted that it is not an easy matter to anticipate how changes to one of the major elements within a distribution structure will affect the system as a whole (Rushton and Oxley, 1989).

3.4.1. Measures for delivery performance evaluation

According to Stewart (1995), an increase in delivery performance is possible through a reduction in leadtime attributes. Another important aspect of delivery performance is on-time delivery. On-time delivery reflects whether perfect delivery has taken place or otherwise and is also a measure of customer service level. A similar concept, *on time order fill,* was used by Christopher (1992), describing it as a combination of delivery reliability and order completeness. Another aspect of delivery is the percentage of finished goods in transit, which if high signifies low inventory turns, leading to unnecessary increases in tied up capital. Various factors that can influence delivery speed include vehicle speed, driver reliability, frequency of delivery, and location of depots. An increase in efficiency in these areas can lead to a decrease in the inventory levels (Novich, 1990).

Number of faultless notes invoiced: An invoice shows the delivery date, time and condition under which goods were received. By comparing these with the previously made agreement, it can be determined whether perfect delivery has taken place or not, and areas of discrepancy can be identified so that improvements can be made.

Flexibility of delivery systems to meet particular customer needs: This refers to flexibility in meeting a particular customer delivery requirement at an

agreed place, agreed mode of delivery and with agreed upon customised packaging. This type of flexibility can influence the decision of customers to place orders, and thus can be regarded as important in enchanting and retaining customers (Novich, 1990).

3.4.2. Total distribution cost

Perhaps the most important research concerning logistics is going on in the area of design of efficient and cost effective distribution systems. For this, an understanding of total distribution cost is essential, so that proper trade-offs can be applied as a basis for planning and reassessment of distribution systems. The urgency of dealing with transportation cost was highlighted by Thomas and Griffin (1996), who argued that since transportation cost accounts for more than half of the total logistics cost, more active research is needed in the area. To deal with distribution costs, measuring individual cost elements together with their impact on customer service encourages trade-offs that lead to a more effective and efficient distribution system.

3.5. Measuring customer service and satisfaction

To a world class organisation, a happy and satisfied customer is of the utmost importance. In a modern supply chain customers can reside next door or across the globe, and in either case they must be well served. Without a contented customer, the supply chain strategy cannot be deemed effective. Lee and Billington (1992) and van Hoek et al. (2001) emphasised that to assess supply chain performance, supply chain metrics must centre on customer satisfaction.

3.5.1. Flexibility

Of the factors by which supply chains compete, flexibility can be rightly regarded as a critical one. Being flexible means having the capability to provide products/services that meet the individual demands of customers. Some flexibility measures include: (i) product development cycle time, (ii) machine/tool set up time, (iii) economies of scope (Christopher, 1992)—refers to the production of small quantities of wider range (e.g. JIT lot size)—and (iv) number of Inventory turns.

3.5.2. Customer query time

Customer query time relates to the time it takes for a firm to respond to a customer query with the required information. It is not unusual for a customer to enquire about the status of order, potential problems on stock availability, or delivery. A fast and accurate response to those requests is essential in keeping customers satisfied.

3.5.3. Post transaction measures of customer service

The function of a supply chain does not end when goods are provided to the customer. Post transaction activities play an important role in customer service and provide valuable feedback that can be used to further improve supply chain performance.

3.6. Supply chain and logistics cost

The efficiency of a supply chain can be assessed using the total logistics cost—a financial measure. It is necessary to assess the financial impact of broad level strategies and practices that contribute to the flow of products in a supply chain. Since logistics cut across functional boundaries, care must be taken to assess the impact of actions to influence costs in one area in terms of their impact on costs associated with other areas (Cavinato, 1992). For example, a change in capacity has a major effect on cost associated with inventory and order processing.

3.6.1. Cost associated with assets and return on investment

Supply chain assets include accounts receivable, plant, property and equipment, and inventories. With increasing inflation and decreased liquidity, pressure is on firms to improve the productivity of capital—to make the assets sweat. In this regard it is essential to determine how the cost associated with each asset, combined with its turnover, affects total cash flow time. One way to address this is by

expressing it as an average days required to turn cash invested in assets employed into cash collected from a customer (Stewart, 1995). Thus, total cash flow time can be regarded as a metric to determine the productivity of assets in a supply chain. Once the total cash flow time is determined, this can be readily combined with profit to provide insight into the rate of return on investment (ROI). This determines the performance by top management is terms of earnings on the total capital invested in a business.

With customer service requirements constantly increasing, effective management of inventory in the supply chain is crucial (Slack et al., 1995). In a supply chain, the total cost associated with inventory can be broken down into the following (Stewart, 1995; Christopher, 1992; Slack et al., 1995; Lee and Billington, 1992; Levy, 1997): Opportunity cost, consisting of warehousing, capital and storage; Cost associated with inventory at the incoming stock level and work in progress; Service costs, consisting of cost associated with stock management and insurance; Cost of finished goods including those in transit; Risk costs, consisting of cost associated with pilferage, deterioration, and damage; Cost associated with scrap and rework; and Cost associated with too little inventory accounting for lost sales/lost production.

3.6.2. *Information processing cost*

This includes costs such as those associated with order entry, order follow/updating, discounts, and invoicing. On the basis of survey results from various industries, Stewart (1995) identified information processing cost as the largest contributor to total logistics cost. The role of information technology is shifting from a general passive management enabler through databases, to a highly advanced process controller that can monitor activities and decide upon an appropriate route for information. Modern information technology, through its power to provide timely, accurate, and reliable information, has led to a greater integration of modern supply chains than possible by any other means (Naim, 1997; Benjamin and Wigand, 1995).

4. The research methodology

The framework presented by Gunasekaran et al. (2001) was used in developing a survey used to study performance measures and metrics used in a supply chain environment. A seven-page questionnaire[1] was developed for collecting data. The questionnaire was divided into four basic sections. They are as follows: plan (including strategy), source/supply (order), produce (make/assemble), and delivery (to customer). These four categories correspond to the four basic activities or processes in a supply chain—*plan–source–make/assemble–delivery*. The questionnaires were mailed with a cover letter and addressed to the CEO of each firm. Targeted recipients were instructed to complete the survey themselves or refer it to an appropriate person for the same. Participants were identified using the '*Kompass Register*' for UK industries (Volumes I and II) published by the Reed Business Information Ltd., West Sussex, UK. A total of 150 large companies were selected from a wide range of industry settings.

5. Empirical analysis

Of the 150 questionnaires mailed, 21 were completed and returned. A breakdown of the survey response is shown in Fig. 1. Nearly all the responses were received within 4 weeks of mailing. Twelve companies said that because of the larger number of such enquiries they were unable to reply. Ten companies returned the questionnaire stating that they were not suitable candidates for the survey because of changes in their operations. The response rate was only 14%, but we felt that it was adequate to assist us in developing our framework.

5.1. *Planning performance evaluation metrics*

This section deals with financial and non-financial strategic level performance measures. The importance of these parameters was established by calculating the mean of all responses and

[1] Available upon request from authors

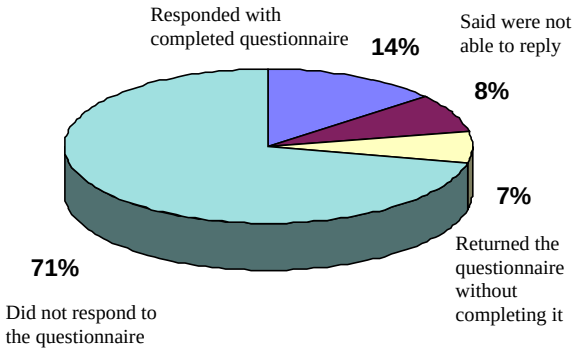

Fig. 1. Breakdown of response for the survey.

ranking them accordingly. The ranks were converted to relative percentages by dividing each rank, by the total of all ranks for the group of measures/metrics. This approach is similar to the method used in Pareto analysis wherein problem frequencies are converted to percentages to show relative importance. The percentages better highlight differences in the importance of performance measures in each group (we used this approach in analysing performance measures in all groups discussed herein). We further categorized the measures based on importance (highly important, moderately important and less important). The methodology employed for such was similar to the methodology used in ABC inventory (inventory item's annual cost is stated as a percent of total inventory costs) to prioritize inventory management decisions (item cost percentages sorted in descending order and grouped into A—most important, B—moderate importance, and C—less important based on their contribution to total costs). We used this approach in analysing performance measures in all groups discussed herein. Please note that categorizing a measure as less important does not mean it is unimportant, but rather it seems less important compared to others in the measurement group. We believe a similar approach could be used by managers in setting priorities in the development of a measurement system for supply chain performance. Our small sample size precluded the use of more powerful statistical techniques. We believe our approach is adequate for our use of the data in framework development. A more rigorous study to validate the framework should employ a better sample and more rigorous statistical techniques. The first set of measures (five non-financial and three financial) pertain to planning, but more specifically to strategic planning. Table 1 shows the measures and their relative importance as determined by our analysis of the survey data.

Table 1
Ratings strategic planning metrics

Assessment	Strategic performance metrics	Percentage importance
Highly important	Level of customer perceived value of product	16.42
Moderately important	Variances against budget	14.23
	Order lead time	13.50
	Information processing cost	12.68
	Net profit Vs productivity ratio	12.46
	Total cycle time	11.80
	Total cash flow time	10.27
Less important	Level of energy utilisation	8.64

The importance rating survey results show that the level of customer perceived value of product is of the utmost importance. It was deemed highly important which clearly reflects the perception of practitioners that customer satisfaction is paramount in importance in increasing competitiveness. The measures considered moderately important in descending order include variances against budget, order lead-time, information-processing cost, net profit vs. productivity ratio, total cycle time and total cash flow time. Variances against budget, information-processing cost and net profit vs. productivity are of course financial measures and reflect the importance of financial measures in strategic planning and control—financial stability is essential to organizational success. The other three moderately important measures were order lead time, total cycle time and total cash flow time. Their rating further highlights the importance of non-financial measures in strategic planning and control and to subsequent

Table 2
Importance of order planning metrics

Assessment	Metrics	Percentage importance
Highly important	Customer query time	19.11
Moderately important	Product development cycle time	17.37
Less important	Accuracy of forecasting	16.59
	Planning process cycle time	15.90
	Order entry methods	15.51
	Human resource productivity	15.51

organizational success. The only strategic planning measure deemed less important was level of energy utilisation which may suggest that it is not of strategic significance. That, of course, could vary from firm to firm, depending on energy cost as a percent of total manufacturing cost and on energy price levels relative to the prices of other manufacturing inputs.

The percentage importance (relative importance) of the strategic performance metrics clearly suggests that non-financial measures of performance are considered by practitioners to be important in assessing the competitiveness of an organization. This is not to say that financial measures are no longer important, but rather that non-financial measures are important and necessary in assessing a firm's ability to compete.

In Table 2, the order of priority for the order planning level metrics is presented. At the order planning level, customer query time was highly important, which would seem to emphasize the importance of customer service. Product development cycle time and forecasting were moderately important. These two factors relate to meeting customer needs and doing so in a timely fashion. Although there is no statistical evidence contained herein to prove such a link, common sense suggests a link between these and the perceived customer value of the product, rated number one among the strategy performance measures. The importance ratings of product development cycle time and forecasting measures suggests that they warrant monitoring by management and improvement effort. Cross-functional teams, rapid prototyping, and concurrent engineering involving suppliers would seem appropriate in efforts to improve product development cycle time. Many alternative techniques are available for forecasting. If forecasting accuracy is a concern, firms might examine the techniques employed with an eye toward improvement. Because the forecasts of all supply chain links can influence supply chain performance, a concerted effort by all should be made to assure accurate forecasts. This is emphasized by a survey participant (a machine tool manufacturer) who said that supply chain partners should *''Use better forecasting techniques to remove uncertainties in supply chain.''* Many understand the consequences of weak forecasting performance and recognize the need to measure and improve it.

By benchmarking their forecasting methods with those of the best, a better understanding the techniques might be gained and greater accuracy achieved. Also, by integrating production schedules with others in the supply chain, more accurate day to day demand forecast might be possible for all links in the supply chain. Planning process cycle time, order entry methods, and human resource productivity were the less important order planning measures. Planning process cycle time and order entry methods could be improved through reengineering efforts that include multiple links in the supply chain, because the actions of multiple participants interact to influence performance in these areas. Improvements in customer query time, product development cycle time and planning process cycle time might be brought about by greater human resource productivity, so although it was rated last in importance, human resource productivity should not be dismissed as unimportant. Improvement in order entry methods, customer query time, forecasting accuracy and customer query time might be brought about through the application of information technology to increase accuracy and expedite the flow of information throughout the supply chain. Process cycle time can be tackled by using techniques like single minute exchange of die and group technology, whereby similar facilities

for production will be grouped to reduce manufacturing lead-time.

5.2. Supply link evaluation metrics

Due to the growing importance outsourcing, whereby firms outsource a major part of their products, evaluation of supply link performance is very important in managing the supply chain for peak efficiency and effectiveness. In this section, the importance of performance measures/metrics in a supply chain link (includes purchasing and supplier management activities) are rated in importance. Based on the literature, six key performance indicators (KPI) pertaining to the supplier link were included in the survey and ranked by participants. These measures include: supplier delivery performance, lead-time against industry norm, supplier pricing against market, efficiency of purchase order cycle time, efficiency of cashflow method, and supply booking procedures. The main objective here is to identify the KPI in supply link performance evaluation. The KPI can be defined as the performance indicators that have significant impact on the overall performance of an organization in the areas of strategic, tactical and operational planning and control. The percentage importance ratings of the six measures are included in Table 3.

As can be seen in Table 3, supplier delivery performance emerged as the most important measure pertaining to the evaluation of supplier performance. It was the only highly important measure. One can see from the table that it is clearly set apart from the others by its percentage importance rating. The moderately important measures in descending order are supplier lead-time against industry norm, supplier pricing against market and efficiency of purchase order cycle time. The less important supplier measures were efficiency of cash flow method and supplier booking in procedures. Most notable about the supplier metrics is that firms regard the supplier's capability to reliably deliver goods in a timely fashion as more important than price. Price has increasing become an order qualifier rather than an order winner. Other aspects of supplier performance such as adherence to agreed upon schedules and terms of the order as well as prompt delivery of goods have become order winners. Firms would do well to not just use supplier metrics for selection of suppliers, but rather they should work closely with suppliers to see that they have in place within their organizations, measurement systems that will foster significant improvement in all of these areas. Such improvement contributes to the overall success of a supply chain.

Table 3
Importance of supplier metrics

Assessment	Metrics	Percentage importance
Highly important	Supplier delivery performance	23.20
Moderately important	Supplier lead-time against industry norm	19.69
	Supplier pricing against market	18.30
	Efficiency of purchase order cycle time	15.42
Less important	Efficiency of cash-flow method	12.38
	Supplier booking in procedures	11.01

5.3. Production performance evaluation metrics

In this section, supply chain production link metrics/measures are rated in importance. The literature provided the production link measures, and as with other metrics evaluated in this paper, the survey responses provided the basis for rating the importance of these measures. The performance measures for the production link included percentage of defects (a measure of product quality), cost per operation-hour, capacity utilization, range of product and services, and utilization of economic order quantity. Table 4 contains the measures and their percentage importance ratings. From the table one can see that the percentage of defects emerged to be the most important (24.27%), but two others, cost per operation hour and capacity utilization, were also highly important. The latter two are essentially measures of the

Table 4
Importance of production metrics

Assessment	Metrics	Percentage importance
Highly important	Percentage of defects	24.27
	Cost per operation hour	22.51
	Capacity utilization	21.61
Moderately important	Range of products and services	18.01
Less important	Utilization of economic order quantity	13.60

efficiency with which resources are used in manufacturing (produce/assemble), and good performance in these two areas translates into lower cost per unit to manufacture products/provide services. Efficiency of operations is important for all supply chain partners, if the elusive goal of supply chain optimization is to be achieved. Note that the percentage importance of each of these three clearly sets them apart from the moderately important and less important measures. We should caution that maximum efficiency of each partner in all areas might not be a desirable because tradeoffs are necessary in order to achieve a global optimum for the supply chain—local optimums in all parts do not necessarily lead to global optimization for a system.

The only measure rated moderately important was range of products and services. As noted in the literature, a broader range of products tends to result in fewer new products being introduced and a more narrow range is associated with greater product innovation. For this reason, the measure does seem worthy of the attention of managers, especially in making decisions about the breadth and depth of product lines. The least important measure in the production link measures was utilization of economic order quantity. It was the only measure rated less important. It may be that the participants, in assigning their ratings, regarded the use of EOQ as a means to an end rather than an end in and of itself. In short, quality and efficiency seem to be more important considerations in evaluating production performance.

5.4. Delivery performance evaluation metrics

After the orders are planned and goods sourced, produced and assembled, the remaining task is to deliver them to customer. Table 5 shows the order of importance of delivery performance measures. Quality of delivered goods is first in importance, followed by on time delivery of goods and flexibility of service systems to meet customer needs. These three measures are highly important. Note that there is very little difference in the rating of quality of delivered goods and on time deliver of goods. Here again, we believe that these three are related to the perceived customer value of the product, the top ranking strategic planning measure. Providing the customer with a quality product in a timely fashion, and maintaining customer satisfaction with a service system designed to flexibly respond to customer needs are key in producing value for the customer. The effectiveness of the enterprise distribution

Table 5
Importance of delivery performance measures

Assessment	Delivery performance metrics	Percentage rating
Highly important	Quality of delivered goods	12.34
	On time delivery of goods	12.20
	Flexibility of service systems to meet customer needs	11.43
Moderately important	Effectiveness of enterprise distribution planning schedule	10.31
	Effectiveness of delivery invoice methods	10.23
	Number of faultless delivery notes invoiced	10.05
	Percentage of urgent deliveries	9.32
	Information richness in carrying out delivery	8.76
Less important	Percentage of finished goods in transit	7.76
	Delivery reliability performance	7.70

planning schedule, effectiveness of delivery invoice methods, number of faultless delivery notes invoiced, percentage of urgent deliveries and information richness in carrying out the delivery are moderately important. According to the rating of measures, while unquestionably important, these measures are not as important as the quality of the delivered product and on time delivery. It would seem, at least on the surface that on time delivery would result from an effective enterprise distribution planning schedule, so it would probably be unwise to ignore the obvious importance of the enterprise distribution planning schedule—one is the means and the other the end.

In the survey, companies were asked to express their views on reducing the cost of a delivery system. Their responses tended to emphasize techniques like JIT and the application of automation alternatives to reduce costs. Trade-offs between centralisation of the distribution system and decentralisation of the system were mentioned as was third party logistics.

6. A framework for performance measurement in a supply chain

In this section, a framework for performance measures and metrics is presented (see Table 6), considering the four major supply chain activities/processes (plan, source, make/assemble, and deliver). These metrics were classified at strategic, tactical and operational to clarify the appropriate level of management authority and responsibility for performance. This framework is based in part of a theoretical framework discussed by Gunasekaran et al. (2001) and on the empirical analysis reported herein. Measures are grouped in cells at the intersection of the supply chain activity and planning level. For example, Supplier delivery performance can be found at the intersection of the Source activity and Tactical planning level indicating that it pertains to sourcing activities (source) and the tactical planning level. Supplier delivery performance would thus be a measure useful in analyzing the performance of mid-level managers as they undertake sourcing activities—mid-level managers who are generally the ones responsible for tactical decisions.

The items in each cell are listed in the order of importance based on percentage importance ratings. Those ratings can be seen in Tables 1–5. Readers can refer to those tables in order to more closely examine the importance ratings of individual measures/metrics. Some measures appear in more than one cell, indicating that measures may be appropriate at more than one management level. Measures used at different management levels will most assuredly require adjustment to tailor them to planning and control needs of the different levels. For example, appropriate measurement may require that data used by the lower level of management be aggregated in some form or fashion to make the data appropriate for the next higher level (convert data into information appropriate for the context). There is nothing novel about this approach, as it has been used for years in management planning and control systems.

The approach we used in organizing the measures for the framework could be used by organizations in development of a performance measurement program for SCM. Managers and/or consultants could identify measurements (we recommended many such measurements herein), rate their importance using the methodology we used for rating importance, and construct a matrix like our own to identify the supply chain activity/process to be measured, the measurement, and level of management to which the measure should be applied. More detail could be added to fix personal responsibility for measures with individual managers, or management positions.

Readers should keep in mind that this framework is based largely on metrics discussed in the literature. Individual firms will certainly have performance measurement needs that reflect the unique operations of their business and of course not all supply chains are identical. Thus other measures may be desirable and should be developed by firms and supply chain participants to reflect their unique needs. This framework should be regarded as a starting point for an assessment of the need for supply chain performance measurement. It is likewise important to understand

Table 6
Supply chain performance metrics framework

Supply chain activity/ process	Strategic	Tactical	Operational
Plan	Level of customer perceived value of product, Variances against budget, Order lead time, Information processing cost, Net profit Vs productivity ratio, Total cycle time, Total cash flow time, Product development cycle time	Customer query time, Product development cycle time, Accuracy of forecasting techniques, Planning process cycle time, Order entry methods, Human resource productivity	Order entry methods, Human resource productivity
Source		Supplier delivery performance, supplier leadtime against industry norm, supplier pricing against market, Efficiency of purchase order cycle time, Efficiency of cash flow method, Supplier booking in procedures	Efficiency of purchase order cycle time, Supplier pricing against market
Make/ Assemble	Range of products and services	Percentage of defects, Cost per operation hour, Capacity utilization, Utilization of economic order quantity	Percentage of Defects, Cost per operation hour, Human resource productivity index
Deliver	Flexibility of service system to meet customer needs, Effectiveness of enterprise distribution planning schedule	Flexibility of service system to meet customer needs, Effectiveness of enterprise distribution planning schedule, Effectiveness of delivery invoice methods, Percentage of finished goods in transit, Delivery reliability performance	Quality of delivered goods, On time delivery of goods, Effectiveness of delivery invoice methods, Number of faultless delivery notes invoiced, Percentage of urgent deliveries, Information richness in carrying out delivery, Delivery reliability performance

that the rated importance of metrics in this framework is based on a relatively small sample, and thus, care should be taken in generalizing results to all supply chains. The importance of individual metrics presented herein might not apply to all supply chains in all industries. Again, the framework is only a starting point. It is hoped that this framework will assist practitioners in their efforts to assess supply chain performance.

7. Conclusions

In our survey participants were asked whether their return on investment had increased to expected levels after implementing contemporary supply chain management (SCM) practices. The 76% affirmative response to that question clearly showed that effort focused on carefully managing supply chains produced financial benefits for participating firms. From a financial perspective alone, a proactive approach to SCM is advisable for firms wanting to enhance competitiveness. The SCM literature suggests that effective SCM help to win customers and improve customer service. Some 66% of the respondents in our survey noted the positive impact of SCM on market share, providing more evidence of the strategic importance of successful SCM. The potential benefits of SCM make it attractive, but

improved performance is not automatic. As with any other organisational undertaking, it must be done well to yield positive results. This is why we believe it is important to assess performance in SCM and the reason we developed the SCM performance measurement framework.

To bring about improved performance in a supply chain and move closer to attainment of the illusive goal of supply chain optimization, performance measurement and improvement studies must be done throughout the supply chain. All participants in the supply chain should be involved and committed to common goals, such as customer satisfaction throughout the supply chain and enhanced competitiveness. A performance measurement program for a supply chain should be complete—important aspects of performance in any link are not ignored—and they must be tailored to varying needs of participants. A good SCM program will bring about improved cross-functional and intra-organisational process planning and control and more complete supply chain integration. A supply chain wide performance measurement initiative would seem most appropriate. This is not to suggest that one party dictate measurement programs for all supply chain participants, but rather that all participants take part in developing a well planned, well coordinated, supply chain-wide performance measurement initiative to which all can and will be committed. A comprehensive control system will be necessary in order to assure effective and efficient performance measurement all along the supply chain, but it must not be done in such a way as to unduly limit the decision making authority of managers in participating organizations. Care must be exercised in developing such a system in order that it promotes mutually advantageous exchange among participants, so that relationships endure the test of time.

Additional research and practitioner-driven initiatives are needed in the area of SCM performance measurement. Creative efforts are needed to design new measures and new programs for assessing the performance of the supply chain as a whole as well as the performance of each organization that is a part of the supply chain. Organisation, suppliers and customers should come together to discuss how they will address the measurement and improvement of SCM performance. Industry consortiums, consultants, and researchers could be helpful in promoting SCM performance measurement generally, and in developing measures and measurement techniques specifically. They could play a significant role in helping firms address the present and future challenges of managing supply chains. Clearly tremendous opportunity exists to develop measures that facilitate progress and promote greater supply chain integration.

Acknowledgements

The authors gratefully acknowledge the constructive and helpful comments of two anonymous referees on the earlier version of the manuscript.

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