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Performance measures and metrics in logistics and supply chain management: a review of recent literature (1995–2004) for research and applications

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Performance measures and metrics are essential for effectively managing logistics operations, particularly in a competitive global economy. The global economy is featured with global operations, outsourcing and supply chain and e-commerce. The real challenge for managers of this new enterprise environment is to develop suitable performance measures and metrics to make right decisions that would contribute to an improved organizational competitiveness. Now the question is whether traditional performance measures can be used and out of them which ones should be given priority for measuring the performance in a new enterprise environment. Some of the traditional measures and metrics may not be suitable for the new environment wherein many activities are not easily identifiable. Measuring intangibles and nonfinancial performance measures pose the greater challenge in the so-called knowledge economy. Nevertheless, measuring them is so critical for the successful operations of companies in this environment. Considering the importance of nonfinancial measures and intangibles, an attempt has been made in this paper to determine the key performance measures and metrics in supply chain and logistics operations. This is based on a literature survey and some of the reported case experiences. Suggestions for future research directions are also indicated.

Keywords: Performance measures; Metrics; Logistics; Supply chain

1. Introduction

Globalization of markets and operations has given a fresh impetus to the managers of twenty first century firms for developing new perspectives of various managerial functions that include marketing, design, engineering, production, finance, accounting and human resources. These new managerial perspectives require new tools in terms of suitable performance measures and metrics so that the resources available can be judiciously utilized for producing quality goods and services and in turn enhance the organizational competitiveness. Since the market and operations environments have changed over the years, now the question is whether the existing performance measures and metrics can be used or we have to come out with a new set of performance measures in addition to some of the existing ones. These could be used in the new enterprise environment that is characterized by supply chain and

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physically distributed global operations. In this paper, an attempt has been made to determine suitable performance measures for supply chain and logistics. It is hoped this research will generate further interest in the field of performance measures and metrics including cost management system for supply chain and logistics management together with e-commerce.

Business organizations are increasingly finding it necessary to be extremely flexible in responding to changes in the market environment. This is especially important when virtual organizations continue to emerge as the most important paradigm for improving organizational competitiveness. Researchers believe that tools for measuring an organization's need and ability to develop an agile business strategy within the context of a virtual organization (Weber 2002) are important. A trend both in practice and increasingly in the literature is the attention on performance measures and metrics (Kaplan and Norton 1997). In the past, various financial performance indicators were seen as relevant management information; today management needs additional performance indicators (van Donselaar *et al.* 1998).

A performance measurement system plays an important role in managing a business as it provides the information necessary for decision-making and actions. As per Kaplan (1990), ''No measures, no improvement,'' it is essential to measure the right things at the right time in a supply chain and virtual enterprise environments so that timely action can be taken. Performance measures and metrics are not just measuring the performance. They are also embedded with politics, emotions and several other behavioral issues. Good performance measures and metrics will facilitate a more open and transparent communication between people leading to a co-operative supported work and hence improved organizational performance.

The purpose of measuring organizational performance is to (a) identify success; (b) identify whether customer needs are met; (c) help the organization to understand its processes and to confirm what they know or reveal what they do not know; (d) identify where problems, bottlenecks, waste, etc. exist and where improvements are necessary; (e) ensure decisions are based on facts, not on supposition, emotion, faith or intuition; and (f) show if improvements planned actually happened (Parker 2000). Traditional business performance measures have been mostly financial – measuring rate of return on investment, cash flow and profit margins. However, conventional measures have the drawbacks of tending toward inward looking, fail to include intangibles and lagging indicators. This forced researchers and companies to revisit the performance measures and metrics in the new economic environment (Parker 2000).

Reviewing the literature suggests that there is a limited number of articles that deal with performance measures and metrics in a supply chain environment. However, Supply Chain Management (SCM) has been widely practiced by numerous companies in recent years and therefore; there is a need for more representative performance measures and metrics to reflect the performance of new environments. The objective of this paper is to determine performance of a Supply Chain (SC) system by using minimum number of measures (Key Performance Indicators) that provide reasonable accuracy with minimum cost. The organization of the paper is as follows: Section 2 reviews the basic concepts and definitions, performance measures and metrics in SC systems. The research objectives and details of methodology used are discussed in section 3. Section 4 provides a brief overview of the literature available on performance measures and metrics in SC systems. The results of the

analysis of literature review reported in section 4 are summarized in section 5. A summary of conclusions is presented in section 6.

2. Performance measures and metrics

Performance measurement can be defined as the process of quantifying the efficiency and effectiveness of an action. A performance measure is a set of metrics used to quantify the efficiency and/or effectiveness of an action (Neely *et al*. 1995). In logistics, performance measurement has been considered as one of the four key competencies, the other three are being positioning, integration, and agility to achieve world class performance (The Global Logistics Research Team at MSU 1995). A performance measurement system (PMS) should provide managers with sufficient information to address issues such as finance, customer internal processes and innovation and improvement (Kaplan and Norton 1997). Balanced score card (BSC) method has been popular in strategy formulation with clearly defined missions, targets, suitable performance measures and metrics.

The term ''metric'' refers to definition of the measure, how it will be calculated, who will be carrying out the calculation, and from where the data will be obtained (Neely *et al*. 1995). The main challenge is to identify the key performance measures for value-adding areas of an organization and then the factors that will affect the core business processes that create wealth to customers. Bagchi (1996) determined the metrics of a SC system to be used in comparing the competitiveness of selected companies. He placed each of the 28 metrics in one of the following four categories: time, quality, cost, and diagnostic measure. Though this approach is useful, a framework based on different levels of decision making (strategic, tactical and operational) would provide clearer idea on which measures/metrics should be used at different levels of an organization.

Typical problems in a PMS are summarized by Holmberg (2000) as organization's strategy and measurement system are not connected, a biased focus on financial metrics, and too many isolated and incompatible measures. This study focuses on the last problem and tries to minimize overlap and incompatibility by reducing the number of metrics used in a PMS. Major drawbacks of traditional PMSs are that they tend to be insular and inward looking and fail to include qualitative factors, and they are poor predictors of future performance (Parker 2000). Globerson (1985) suggests the performance criteria (PC) should: be based on company objectives, be comparable to other PC used by similar organizations, clearly define the purpose, define data collection and calculation methods, be ratio-based than absolute number, be under the control of the evaluated organizational unit, be determined through discussions with the parties involved, and be objective.

Maskell (1989) suggests seven principles of PMS design: (1) the PM should be directly related to firm's strategy; (2) nonfinancial measures should be adopted; (3) measures should vary between locations (departments or companies); (4) measures should change as circumstances do; (5) measures should be simple and easy to use; (6) measures should provide fast feedback; and (7) measures should stimulate continuous improvement. It is important to identify which performance measures

correlate to the success of a PMS the most. This may be determined by two independent evaluation of a particular SCM system: (a) performance measured by actual results; and (b) performance measured by a few pre-selected metrics.

There are several metrics in the literature and in business organizations recommended for use in measuring the performance of a SCM system (Gunasekaran *et al*. 2004, 2005, Folan and Browne 2005, Fynes *et al*. 2005). However, there are few attempts to determine the minimum number of metrics in measuring the performance of a SCM system. Therefore, a set of metrics, which consists of small number of items, has yet to be determined in order to measure a SCM system's performance with maximum effectiveness and minimum operating cost. Integration of research and practice has not been evident (McAdam and McCormack 2001). According to a recent study many PMSs are failing and about half of these systems are found to be too inwardly focusing (Howard *et al*. 2000).

Many researchers have proposed new performance measures and metrics considering the changes in markets and enterprise environments. However, there are some confusion surrounding those measures and metrics regarding their importance and specific areas of application in SCM systems. Basu (2001) suggests the use of new emerging metrics defined in five categories: external, consumer, value-based competition, network performance, and intellectual capital. Stewart (1995) claims that companies that have outperformed their competitors are found to be superior in four key operational areas: (1) delivery performance; (2) flexibility and responsiveness; (3) logistics costs; and (4) asset management. Spekman *et al*. (1998), based on a survey of 22 firms' SC systems, concluded that SC partners do not share a common vision of or react to the same set of metrics. They claim "buyers still view the cost savings aspects of SCMs as more important than the revenue enhancing benefits." Recently, many research papers that deal with performance measurement in a SC context (Van Hoek 1998) have appeared in the literature. However, most of them are prescriptive and not based on historical facts and their analysis and changing market and operations environments or well grounded empirical analysis. In addition, they lack a complete coverage of all the performance measures and metrics in new enterprise environments considering different levels of decision-making. An overview of PMSs in SCMs environments highlights the justification for the selection of suitable metrics based on the current and emerging new enterprise environments.

3. Research objectives and methodology

The purpose of this literature review paper has many folds: (i) understand the importance of PMs and metrics as a critical managerial challenge; (ii) understand the difference between traditional and new SC environments; (iii) analyze the differences in PMs and metrics in these environments; (iv) gain insights into various PMSs and their requirements to support the decision making process; (v) understand the requirements or characteristics of a good PMS; (vi) synthesize a PMS for new enterprise environments; (vii) classify the literature to gain detailed insights into the PMs and metrics of SC; (viii) determine key performance measures and metrics in

logistics and SC environments; and (ix) suggest some future research directions based on the gap between theory and practice.

This study attempts to provide an overview of most recent PMSs in logistics and SCM systems. It is also intended, to highlight the justification for the selection of appropriate metrics that would help managers with the right information at the right time in order to make decisions to enhance the organizational competitiveness. The research methodology is based on a review of recent publications on PMSs analysis of the current PMS with the aim of identifying the key measures, and the corresponding application areas in order to determine overlapping measures through a systematic elimination process. As a first step, for the selection of suitable performance measures and metrics, key business processes and value adding areas are examined and then parameters/variables that will affect these processes and areas are identified. Subsequently, the appropriate performance measures and metrics to evaluate the impact of those parameters/variables are then identified. The aim was not to come out with a long list of measures and metrics, but to present a list of key performance measures and metrics that are directly linked with organizational performance in a SCM system.

An effective PMS should be practical, easy to measure, reliable, comparable to other organizations' systems, and should have low operating costs. In addition, an effective PMS should provide feedback to focus on individual or team performances and data for correction and improvement (Dumond 1996). Overlap between the metrics in a PMS should be minimal in order to avoid double counting and unnecessary measurement costs. Methodology used in this study is based on the views of Dumond (1996) and Beamon (1999), that are, PMS should develop a reliable metrics to provide feedback on various performance areas by eliminating the overlapping (duplication) metrics and to include the most important metrics of logistics and supply chain management.

4. Classification and review of literature on PMSs in SC systems

Studies in recent years indicate that researchers have classified or categorized performance measures according to several different criteria (see table 1). In this section, the recent literature available† on performance measurement and metrics in SC systems has been reviewed. The literature has been classified and reviewed based on the following criteria: (i) balanced score card perspective; (ii) components of measures; (iii) location of measures in supply chain links; (iv) decision levels; (v) nature of measures; (vi) measurement base; and (vii) traditional vs. modern measures. The reason for this comprehensive classification of the literature on measures and metrics is to bring out pertinent facts and some insights into the measures and metrics for the new enterprise environments.

4.1 *Balance scorecard perspective*

Perhaps the best known PM framework is Kaplan and Norton's (1996) ''Balanced Scorecard (BSC)'' which is built around five perspectives: financial, customers,

†Only selected articles reviewed.

Table 1. Categories of performance measurement in logistics and SC systems.

Key references	Criteria	Details
Kaplan and Norton (1997)	Balanced score card perspective	• Financial • Internal process • Innovation and improvement • Customers
Beamon (1999)	Components of performance measures	• Time • Resource Utilization • Output • Flexibility
Gunasekaran *et al*. (2001)	Location of measures in supply chain links	• Planning and Product Design • Supplier • Production • Delivery • Customer
Gunasekaran *et al*. (2001)	Decision-making levels	• Strategic • Tactical • Operational
Financial base (De Toni and Tonchia 2001)	Nature of measures	• Financial • Non-financial
Gunasekaran *et al*. (2001)	Measurement base	• Quantitative • Non-quantitative
Bagchi (1996)	Traditional vs. modern measures	• Function-based • Value-based

internal processes, innovation and improvement, and employees. BSC method has been extensively used to develop a more realistic strategic plan incorporating the goals and initiatives to achieve the targets (Kaplan and Norton 1997).

Based on a survey conducted in 115 medium and large Italian manufacturing firms, De Toni and Tonchia (2001) present an analysis of PM systems and develop the dimensions and the actual state of these systems. The conclusion of this survey was that the majority of PMS are of the frustum type: the traditional cost performance is kept separate for the more innovative non-cost measures (time, quality, and flexibility).

Stewart (1995) states that integrating a SCM system requires changes in four areas: (1) policies, practice, and procedures; (2) organization; (3) structure; and (4) systems. Lawson (2002) attempts to determine the best operations strategies and their impact for the fast moving consumer goods sector by using the result of a survey on 71 companies. Plant *et al*. (2003) modified the BSC model to e-business. They claim their approach facilitates a better understanding of the customer perspective, which consequently benefits the process of selecting the goals and measures associated with the other three perspectives, improving the quality of the overall decision-making and managerial processes as a whole.

There are many other articles that deal with the application of BSC in manufacturing and services. However, the application of BSC in logistics and SCM has been limited. This offers a scope for further research; for example, researchers can come up with a supply chain balanced score-card (SCBSC).

4.2 *Components of performance measures*

Specific performance measures for evaluating logistics and supply chain have been called as components of performance measures and metrics. Beamon (1999) has focused on the major metrics such as time, resource utilization, output and flexibility to provide a context for developing more detailed performance measures and metrics in new enterprise environments. This group of measures can be defined considering the characteristics of supply chain. For example, resource utilization could be IT systems such as MRP or ERP to make available the right information at the right place for making more accurate decisions and in turn enhance the organizational performance and competitiveness. Moreover, flexibility has been included as the major metrics since the market and operations are characterized by agility of the market and customers in terms of their product/service requirements. Neely *et al.* (1995) provides categories of performance measures in recent literature, including time, quality, flexibility and cost. Weber (2002) proposes a model that provides means of measuring both the needs for agility and how agile an organization are by analyzing sources of variance in the SC systems.

Bagchi (1996) defined the metrics of a SC in four categories: time, quality, cost, efficiency and diagnostic measure and used them to compare the competitiveness of selected companies. Kaplan (1990) categorized PMs used by a large computer equipment supplier in 8 groups each with 3–8 measure. Researchers including Garvin (1987), Stalk (1988) and Schonberger (1990) have all pointed out that the generic terms quality, time, cost, and flexibility encompass several different measures (Neely *et al.* 1995). Globerson (1985) and Maskell (1989) offered guidelines to be used in selecting a preferred set of performance criteria.

Fitzgerald *et al.* (1991) suggest that there are two basic types of PMs in any organization: those that relate results (competitiveness and financial performance) and those that focus on the determinants of the results (quality, flexibility, resource utilization, and innovation). Van Landeghem and Persoons (2001) build a causal model relating the use of best practices to the resulting performance grouped under four objectives: flexibility, reaction time, quality and cost.

There are not many review articles on performance measures and metrics in logistics and supply chain. Beamon (1999) presents an overview and evaluation of the performance measures used in SC models and also presents a framework for the selection of PMSs for manufacturing SCs. Three types of PMs are identified as necessary components in any supply chain PMSs, viz., resources, output and flexibility. De Toni and Tonchia (2001) suggested that traditional models for PM should be separated from more innovative noncost measures such as the time, quality and flexibility.

Reviewing the sample literature on this classification, it can be concluded that more detailed metrics are needed to provide a right context for the new enterprise environment.

4.3 *Location of measures*

In order to develop a highly relevant performance measures and metrics, four phases of SC systems have been considered: (i) plan; (ii) source; (iii) make; and (iv) deliver. Whenever a measure or metric is developed, the issue of easy understanding and application should be considered. The location of measures along SC phases addresses these issues. Porter (1987) looked at the firm as a collection of key functional activities that would be identified as primary (inbound and outbound logistics, operations, marketing and sales and service) and support activities (such as infrastructure, HR, technology, and procurement). Bhatnagar and Sohal (2005) presented a framework incorporating qualitative factors (labor, infrastructure, business environment, political stability, proximity to markets, proximity to suppliers, key competitors' location, supply chain uncertainty, and manufacturing practices), and operational competitiveness of SC (quality, flexibility, inventory turnover and responsiveness).

Developing an integrated performance measurement system that would support an integrated supply chain development and operations is essential. The performance measures and metrics should facilitate the integration of various functional areas and also so called extended enterprises or partnering firms along the value chain. Bechtel and Jayaram (1997) state that measurements in a SC may use integrated measures that are cross-functional and can be applied to the entire SC system in order to avoid optimization at one point without considering potential effects at the other links of the SC. La Londe and Pohlen (1996) claimed that current PM systems such as total costs of ownership and profitability are focused at particular segments and are not intended to represent the whole SC system.

Lambert and Pohlen (2001) argue that many measures identified as SC metrics are actually measures of internal logistics operations as opposed to measures of SC system. They provide a framework focusing on the management of the interface between customer-relationship and supplier relationship management processes at each link in the SC. The translation of process improvements into supplier and customer profitability provides a method for developing metrics that identify opportunities for improved profitability and align objectives across all of the firms in the SC.

Prioritizing the measures and metrics in SCM is the key to the success by judiciously utilizing the available knowledge resources to stay focused on key performance measures and metrics. This would help management to easily understand and apply the metrics for improving the organizational performance. Lockamy and McCormack (2004) used the Supply-Chain Operations Reference (SCOR) model developed by the Supply Chain Council to identify suitable performance measures and metrics. Collaboration was found to be most important in the plan, source, make and deliver areas. Process measures, process credibility, process integration, and information technology were found to be the most critical in supporting the delivery planning decision area.

Phased SC approach for determining the key performance measures and metrics has been used to facilitate an easy understanding of the SCM and PMS.

4.4 *Decision levels in a SCM system*

The reason for studying the PMs and metrics at the strategic, tactical and operational levels is to make the right decisions so that they can support each other in achieving the overall goals and objectives of an organization. The success of strategy formulation depends upon the degree of alignment of strategies at different levels. Gunasekaran *et al.* (2001), based on literature survey, developed a framework for measuring the strategic, tactical, and operational performance in a SC system.

Stevens (1989) defines supply chain as "a system whose constituent parts include material suppliers, production facilities, distribution services and customers linked together via the feedforward flow of materials and the feedback flow of information." van Donselaar *et al.* (1998) attempted to identify the key factors (critical success factors = CFS) for transportation & distribution companies and developed three measures to determine the financial and operational success in SCM. They are: long-term financial performance, operational performance at company level, and operational performance at segment level.

In the most recent years, several research reports have been published on the PMs and metrics in e-commerce. However, this does not appear to meet the growing demand of the field both in theory and practice. Rudberg *et al.* (2002) claim that collaborating by using electronic marketplace facilitates, information sharing and it is less expensive and more flexible than EDI networks. Jutla *et al.* (2002) presents a conceptual model for the use by governments in creating and sustaining an appropriate climate that facilitate the national adaptation of eBusiness by Small and Medium Enterprises (SMEs). A survey of 175 managers regarding their PMS, indicated that the managers tend to agree strongly with the general statements about PMs and believe that PMs are supportive of the firm. However, they are negative about the detailed and complex measures (Reilly and Reilly 2001).

Researchers in recent years have questioned the traditional PMs for several reasons. Most common questions were: Strategy and measurements are not connected, a biased focus on financial metrics, too many isolated and incompatible measures and the problems in a SC system. Holmberg (2000) reports empirical evidence from a case study of a Swedish home furnishing business suggesting that a SC in firms cannot simply be characterized as either having adopted systems thinking or not. The author has presented a performance model, which can be used to reflect the systematic structure of an underlying supply chain and a potential integrator in SCM systems.

Some of the research articles either focused on process-based metrics or strategy-based measures. However, both are needed at different levels and they should support each other for achieving the goals at their own levels of decision-making. For example, Cooke (2003) introduces a balanced metrics that include process or strategic measures used to determine SC performance. He provided a new metric system based on four major objectives that include high reliability, high degree of flexibility and responsiveness, low costs, and high asset utilization. Stewart (1995) states that integrating a SCM system requires changes in four areas: (1) policies, practice, and procedures; (2) organization; (3) structure; and (4) systems.

Lawson (2002) attempts to determine the best operations strategies and their impact for the fast moving consumer goods sector by using the result of a survey on 71 companies. This paper attempts to highlight the PMs at strategic level as part of financial and nonfinancial measures along the four phases of the SC. Some of the metrics that could be used for planning phase are based on strategy-based PMs.

4.5 *Financial/nonfinancial performance measures*

Many companies fail to understand the importance of balanced approach to PM. While financial performance measures are important for strategic decisions, day-to-day control of manufacturing and distribution operations is better handled with nonfinancial measures (Maskell 1989).

Morita and Flynn (1997) described links between best practices and performance measurement. McIntyre *et al.* (1998) attempted to measure the environmental performance of an integrated supply chain at Xerox, UK and established a measure to predict future performance. They concluded that with the provision of an environmental performance metric, it is possible to optimize the environment against other SC metrics. Van Hoek (1998) developed a framework for measuring qualitative performance in SCs (Bechtel and Jayaram 1997). Said *et al.* (2003) examined the implications of nonfinancial PMs included in compensation contracts on current and future performance. Contextual and environmental factors and strategic plans vary across firms and in turn, adopting appropriate nonfinancial measures determine the performance consequences of such measures. Same study also concludes that firms that employ a combination of financial and nonfinancial PMs have significantly higher levels of returns on assets and market returns and the adoption of nonfinancial measures improves firms' current and future stock market performance.

The first step in improving a SC performance is to determine the appropriate performance measures and metrics considering the overall goals of the organization. For instance, Richardson (2000) proposed key success factors in SC PMs which include: identifying a compelling event to introduce the new PMs and metrics, choosing suppliers and customers with which to measure, ensuring that measurement is part of multifaceted business change, overcoming resistance to change, building a case for action, and using financial analysis tools. Scapens (1998) emphasized the significance of nonfinancial measures for improving operational PMs. Spekman *et al.* (1998) suggest that the full potential of cost reduction, benefits and revenue enhancing opportunities can be achieved by close collaborative linkages through the entire SC. They conclude that SC partners do not share a common vision or react to the same set of metrics. For example, buyers still view the cost savings aspects of SCM as more important than the revenue enhancing benefits. Basu (2001) suggests a six-stage process for the implementation of new PMs emerging as externally focused and adaptive for competing in a collaborative SCM system (Kaplan and Norton 1996).

Mattila *et al.* (2002) proposed a list of PMs for seasonal fashion product retailing industry. These include: service level, lost sales, product substitute percentage, gross margin, stock turnover, gross margin return on inventory and sell-through percentage. Bolstorff (2003) and Gunasekaran *et al.* (2001) proposed a list of PMs and metrics in SC systems and suggested that order fulfillment time, delivery performance and total SCM costs are the key PMs.

The basic question is where the financial and nonfinancial PMs would be suitable to evaluate the performance of a SC system. For example, strategic level PMs are mostly based on financial metrics. PMs at tactical level can be evaluated using both financial and nonfinancial indicators. Operational level performance evaluation is mostly based on nonfinancial indicators. However, we may not be able to generalize this perception and therefore, this choice should be based on individual organizational characteristics.

4.6 *Supply chain performance measurement bases*

There are two groups of major measurement bases: (i) quantitative and (ii) qualitative. The most pressing and challenging tasks for the managers are how to determine the key performance indicators based on organization's strategic goals and then how to measure and implement them. For example, if a company targets a low volume and high variety market, then the organization should use metrics for measuring the flexibility. There are different types of flexibility measures and some of them are based on volume, product, and delivery. On many instances, we need to translate the qualitative PMs into quantifiable measures. There is a strong correlation between qualitative and quantitative measures. Coordinating activities in a SC is difficult due to the complexity induced by the large number of related and inter-dependent activities. Understanding the inter-dependent and complex causal relationships is therefore crucial to the successful management of a SC system. Based on a case study of Swedish furniture company, Holmberg (2000) introduced a performance model that is used to reflect the systemic structure of an underlying SC and a potential integrator.

Poon and Lau (2000) have developed and successfully implemented three-layer "value challenge" approach to reduce costs in a particular company. Instead of trimming profit margins of the supplier side, they aimed to add value to SC activities such as quality, speed, response time etc. Fitzgerald *et al.* (1991) classify the types of PMs into: (i) those that relate results (competitiveness and financial performance); and (ii) those that focus on the determinants of the results (quality, flexibility, resource utilization, and innovation).

There are many articles published in the literature on qualitative-based PM in SC systems. For example, McAdam and McCormack (2001) developed a conceptual model of integrated business process by means of a qualitative study of the integration of SC. Researchers in 1990's began focusing on SCM as a whole and promoted customer satisfaction, collaboration of buyers and suppliers, information sharing (Kaplan and Norton 1996, Lee and Dale 1998, Christopher 1999). Van Hoek (1998) highlighted the importance of measuring intangibles in SCs (Bechtel and Jayaram 1997). Scapens (1998) explains the significance of innovative strategies and other nonfinancial measures such as teamwork and lead times on organizational performance. Basu (2001) points out that measuring external, consumer, value-based competition, network performance, and intellectual capital may lead to SC productivity.

Most PMSs concentrate on operational measures of the system; however, many of the manufacturing strategies are based on structural properties embodied in the system architecture, technology resources, and system control policies. Giachetti *et al.* (2003) presented a measurement framework to analyze measures of structural

properties of the enterprise system. The framework provides a mathematical foundation for formalizing our intuition of what constitutes a measure. It empowers system designers to better incorporate desirable structural properties to align system design with enterprise strategy.

There is a real challenge when it comes to quantifying various PMs in a SC system. For example, answering questions such as how to quantify delivery performance whether in terms of relative percentage or as an absolute number provide opportunities for future research.

4.7 *Traditional vs. modern measures*

One must recognize the fact that enterprise environment is different than what we have had about 15–20 years ago. Earlier, total absorption costing has been used wherein the overhead cost is allocated based on the labor hours. Nowadays the productivity depends on capital productivity and therefore machine hours should be used as a basis for allocating overhead costs. Later, activity-based costing has become popular in JIT and FMS environments. But in SC environments, because of outsourcing we may not be able to use Activity-Based Costing (ABC); instead one could use value-based costing and performance measurement system. Dumond (1996) developed a framework for Value-Based Management (VBM), which is an expansion of Porter's (1985) value-chain, and Houlihan's (1987) SCM revolves around the value chain (suppliers–procurement-manufacturing-delivery-customers). They studied the implementation of VBM approach to procurement in several companies and concluded that VBM approach requires changes in both organization and Human Resource Management (HRM).

Lambert and Cooper (2000) state that "one of the most significant paradigm shifts of modern business management is that individual organizations can no longer compete as solely autonomous entities, but rather as supply chains." Chan and Qi (2003a) have studied the feasibility of PMS for a SC based on process-based approach and measures. Process-based approach alone will not be appealing; as it will attempt to focus on improving functional areas without taking into account the organization's overall mission and objectives. However, they brought in system perspective integrated process-based PMs of a SC. It is not clear that this includes strategic performance measures. Chan and Qi (2003b) have extended their earlier approach and developed a Fuzzy Set Theory model to address the real situation on judgment and evaluation.

As said earlier, there is a need for more quantitative focused PMs. Both financial and nonfinancial PMs should be quantified using appropriate metrics. Relationship diagram would be useful for establishing a link between PMs and metrics and then finally the impact of such variables on the system performance. Lockamy (1998) provides a normative model based on six selected firms identified as "world class" for the development of quality-focused PM systems. This study claims that firms can no longer compete solely on the basis of price [cost], and must formulate new strategies defined by market-driven requirements. Bolstorff (2003) and Gunasekaran *et al.* (2004) proposed a list of performance measures and metrics in a SC environment. For example, order fulfillment lead-time, delivery performance and the total SCM cost are the key PMs.

Table 2. Classification of literature on performance measures and metrics.

Classification criteria	Publications
Balanced score card perspective	Kaplan (1990), Stewart (1995), Kaplan and Norton (1996, 1997), De Toni and Tonchia (2001), Lawson (2002), Plant *et al.* (2003)
Components of measures	Globerson (1985), Garvin (1987), Stalk (1988), Maskell (1989), Kaplan (1990), Schonberger (1990), Fitzgerald *et al.* (1991), Neely *et al.* (1995), Bagchi (1996), Spekman *et al.* (1998), Beamon (1999), McAdam and McCormack (2001), De Toni and Tonchia (2001), van Landegham and Persoons (2001), Weber (2002), Gunasekaran *et al.* (2005)
Location of measures in supply chain links	Porter (1987), Londe and Pohlen (1996), Jayaram (1997), Lockamy and McCormack (2004), Bhatnagar and Sohal (2005)
Decision levels	Stewart (1995), van Donsselaer *et al.* (1998), Holmberg (2000), Gunasekaran *et al.* (2001), Reilly and Reilly (2001), Jutla *et al.* (2002), Lawson (2002), Rudberg *et al.* (2002), Cooke (2003)
Nature of measures	Globerson (1985), Maskell (1989), Kaplan and Norton (1996), Morita and Flynn (1997), Bechtel and Jayaram (1997), Van Hoek (1998), Scapens (1998), Spekman *et al.* (1998), Richardson (2000), Basu (2001), Mattila *et al.* (2002), Bolstorff (2003), Gunasekaran *et al.* (2001, 2004), Said *et al.* (2003)
Measurement base	Maskell (1989), Fitzgerald *et al.* (1991), Neely *et al.* (1995), Kaplan and Norton (1996), Bechtel and Jayaram (1997), Lee and Dale (1998), Scapens (1998), Van Hoek (1998), Christopher (1999), Holmberg (2000), Poon and Lau (2000), Basu (2001), McAdam and McCormack (2001), Giachetti *et al.* (2003)
Traditional vs. modern measures	Collins *et al.* (1992), Dumond (1996), Skinner (1986), Lockamy (1998), Lambert and Cooper (2000), Basu (2001), Kehoe and Boughton (2001), Lundberg (2002), Rudberg *et al.* (2002), Bolstorff (2003), Chan and Qi (2003a, b), Gunasekaran *et al.* (2004), Gunasekaran *et al.* (2005)

Kehoe and Boughton (2001) compare traditional and IT based SCs in manufacturing organizations and investigates the role of Internet within the SC system by focusing on its impact on operations. Rudberg *et al.* (2002) defines electronic marketplace as a virtual marketplace on the Internet. They try to show how functionality of an electronic market place can facilitate collaborative SC system design based on five categories of collaborative processes: (1) demands; (2) supply; (3) promotion; (4) transportation; and (5) product development. The literature survey is summarized under each category in table 2.

5. Results of literature survey

Current literature indicates that clear and specific objectives and consistency (Nienstedt and Wintermantel 1988, Lock and Latham 1990) in measuring organizational performance are the key to the success. Traditional PMs like hours worked, purchasing price, efficiency, cost and time are being questioned as to their validity in today's value-based environment since these measures usually aims to minimize cost at the expense of total cost or value (Collins and Harris 1992). However, because of auditing and government requirements, it may not be feasible to totally eliminate some traditional measures (Skinner, 1986). Also, integration of research and practice in SCM has not been evident (McAdam and McCormack 2001).

The review of recently published (1995–2004) articles focusing on PMs in SCM systems revealed about 80–90 performance measures. After an alphabetical listing of all these measures, it is observed that while some measures are exactly the same, some others are practically the same with different titles. A further review of the remaining measures indicated significant overlap with others. There were 27 measures called "Key Performance Indicators (KPI)" after all repeats and overlapped measures are taken out†.

The following observations are based on the statistical analysis of the data presented in table 3 with key performance indicators for supply chain performance:

- Internal business process (50% of the KPI) and customers (50% of the KPI) play a significant role in SC environments. This implies that internal business process PMs have significant impact on the operational performance.
- The most widely used PM is financial performance (38% of the KPI). This indicates that we cannot ignore the fact that still cost plays a major role in a SC environment. However, nonfinancial performance measures are important for measuring the operational performance.
- Innovation and process improvement constitutes 27% of the KPI which is defined as one of the performance measures for SC systems. This may be an indication that most companies either do not measure or researchers have ignored these areas for measuring the performance. However, they may have significant impact on the overall performance.
- From the perspective of components of PMs: time and productivity (46% and 40% respectively of the KPIs) have significant weight in measuring the performance.
- Resource utilization and flexibility (35% and 27%, respectively of the KPIs) have not been measured considering the fact that they are intangibles and difficult to measure. However, they play a major role in effective management of SC systems.
- In the location of PMs along the supply chain; the performance of planning and product design, supplier, production and delivery constitutes 50%, 15%, 35% and 12% respectively of the KPIs. It is to be noted that measuring the performance related customer satisfaction (27% of the KPIs) has not been given due consideration in measuring the performance of SC.

†Intermediate results will be provided upon request.

Table 3. Metrics used to measure performance in SCM systems and their relations to categories and factors suggested by researchers.

	A				B				C					D			E		F		G			
Metrics	1	2	3	4	1	2	3	4	1	2	3	4	5	1	2	3	1	2	1	2	1	2	Total	Percentage
01 Accuracy of scheduling		X			X				X							X		X	X		X		7	32
05 Bid management cycle time		X			X				X					X				X	X		X		7	32
06 Capacity utilization		X	X			X					X				X	X		X	X		X		9	41
07 Compliance to regulations		X	X				X		X	X				X				X	X	X		X	10	45
08 Conformance to specifications		X		X			X			X	X					X		X	X			X	9	41
18 Delivery reliability		X		X	X		X						X			X		X	X			X	9	41
24 Forecasting accuracy				X	X		X		X						X	X		X	X			X	9	41
29 Inventory costs	X	X				X		X	X	X	X	X	X			X	X		X		X	X	14	63
33 Labor efficiency			X			X					X				X	X		X	X		X		8	36
35 Lead time for procurement				X	X					X					X			X	X		X		7	32
36 Lead time manufacturing		X		X	X						X				X	X		X	X		X		9	41
39 Obsolescence cost	X			X	X		X		X								X		X			X	8	32
44 Overhead cost	X	X			X	X			X		X					X	X		X			X	10	42
46 Perceived quality				X			X	X					X					X		X		X	7	32
47 Perceived value of product				X			X						X					X		X		X	6	27
50 Process cycle time		X			X			X	X		X	X			X	X		X	X		X		11	50
51 Product development time		X	X		X				X					X				X	X		X		8	36
54 Product/service variety	X		X	X			X	X	X					X				X		X		X	10	45
55 Production flexibility		X	X		X	X	X	X			X					X		X		X	X		11	50
62 Return on investment	X					X			X					X			X		X			X	7	32
63 Selling price	X			X		X	X						X	X			X		X			X	9	41
68 Stock out cost	X			X			X	X					X				X		X			X	8	32
71 Supply chain response time		X	X		X			X	X					X	X	X		X	X		X		11	50
76 Transportation cost	X					X						X			X	X	X		X			X	8	32
77 Value added	X			X		X					X		X		X	X	X		X			X	10	45
81 Warranty cost	X			X			X		X								X		X			X	7	32
Total	10	13	7	13	12	9	12	7	13	4	9	3	7	7	9	14	9	17	22	5	11	16		
Percentage	38	50	27	50	46	35	46	27	50	15	35	12	27	27	35	54	35	65	85	19	42	61		

A. Balance score perspectives: 1. Financial, 2. Internal process, 3. Innovation and improvement, 4. Customers. **B**. Components of performance measures: 1. Time, 2. Resource utilization, 3. Output, 4. Flexibility. **C**. Location of measures in supply chain links: 1. Planning and product design, 2. Supplier, 3. Production, 4. Delivery, 5. Customer. **D**. Decision level: 1. Strategic, 2. Tactical, 3. Operational. **E**. Financial base: 1. Financial, 2. Nonfinancial. **F**. Measurement base: 1. Quantitative, 2. Nonquantitative. **G**. Traditional vs. Modern: 1. Function based, 2. Value based.

- PM in operations (54%) has received significant attention from both researchers and practitioners. However, strategic and tactical level PMs need to be given further attention as they are significant (41% and 79% of the KPIs) considering their impact on SCM systems.
- Nonfinancial PMs received due attention in SC systems (65% of the KPIs). Financial PMs are only 35% of the KPI.
- Quantitative PMs received due attention (85% of the KPIs). Only 19% of the KPIs are non-quantitative measures.

The analysis indicates that majority PMs are function based (61% of the KPIs) instead of value-based (42% of the KPIs). Some of the missing and most critical PMs for the successful development and operations of SCs should include information productivity, cost of data processing and information, risk of not using an IT/IS system, and implications of outsourcing. The KPMs and metrics are then categorized according to SC phases and financial and nonfinancial bases (see table 4).

6. Managerial implications and applications of key performance measures

Having arrived at the key PMs and metrics in logistics and supply chain management, the challenge now is analyze the managerial issues in selecting and implementing them. In this section, we discuss some of the managerial issues that we have to address in applying the KPMs and metrics in logistics and supply chains.

- Determining the key measures and metrics (see 27 of them as presented in table 4) should be tailored to the individual organizations. Though one can select or determine which of those 27 measures should be used and at what levels of decision-making (tactical and operational). As noted earlier, the strategic level decisions are discussed throughout the paper which includes mostly the financial PMs (rate of return on investment, sales, profit, etc.) and some nonfinancial measures (such as image of the company, brand name, etc.).
- Most of the measures and metrics presented in table 4 cover the tactical and operational level performance in logistics and supply chain. Middle level and lower level managers should be responsible for applying the tactical and operational level PMs. Upper level managers are responsible for strategic performance management.
- While selecting the key PMs and metrics for a particular logistics and supply chain whether an organization is in manufacturing or service industry, attention should be given to the organizational goals and objectives, type of business, nature of the market, and technological competence. For example, automobile company's performance depends upon the forecasting accuracy (as a make-to-stock system) and this requires measuring the accuracy of forecasting. One of the forecasting accuracy measurements could be the inventory turnover.
- Data collection and analysis are a major task in monitoring the performance using the key measures and metrics in logistics and SC. It becomes more difficult when the operations are global and achieving parity among the data

Table 4. Key performance measures/metrics[a] in logistics and SC environment.

Phases in supply chain	Performance measures/metrics	
	Financial	Nonfinancial
Plan	Return on investment, selling price	Labor efficiency, perceived value of product, product development cycle time, bidding management cycle time, compliance to regulations, forecasting accuracy, perceived value of product, supply chain response time
Source	Scrap/obsolescence cost, inventory cost, selling price of goods and service	Labor efficiency, product development time, lead time for procurement including supplier development time, delivery reliability, product and service variety
Make	Scrap/obsolescence cost, overhead cost, inventory cost, selling price of goods/services, value added	Labor efficiency, Conformance to specifications, capacity utilization, lead-time for manufacturing, production flexibility, process cycle time, accuracy of scheduling, product and service variety, value added
Deliver	Overhead cost, value added, inventory cost, stock-out cost, transportation cost and warranty cost	Labor efficiency, Delivery reliability, perceived value of product, value added, product and service variety, perceived quality

[a]These performance measures and metrics are process-based measures, but strategy-based measures are discussed within the text of the manuscript.

collected and analyzed. This necessitates the need for computerized information systems such as enterprise resource planning system to efficiently collect the right data that will be useful for measuring the performance.

- There is a heavy influence of behavioral issues while establishing and implementing the key PMs and metrics. Cultural and political factors also play a significant role in determining the right PMs and metrics. These complexities can be overcome by the participation of the senior executives in determining the PMS by highlighting the overall organizational objectives and goals and the need for aligning targets at all levels.
- Key PMs and metrics (27 such metrics) will save time in collecting and analyzing the data and then translating them into useful information for decision-making. Auditing of such a system should be conducted regularly to make sure necessary data are collected and documented.

- In most companies, there is no shortage for performance measures and metrics, but the issue here is the determining the right performance measures and metrics for the given logistics and supply chain and then judiciously applying them in practice for a continuous improvement. Intangibles can be used at the higher level decision-making such as strategic level, but the tangibles can be used at the operational level decision-making. A mix of intangibles and tangibles can be used at the tactical level decision-making in logistics and supply chain. Financial level metrics can mostly be used at strategic level and nonfinancial measures at operational level. A combination of financial and nonfinancial metrics can be used at the tactical level.
- Key PMs and metrics should adopt a proactive approach rather than reactive approach. Information technology and systems can be employed for reducing the time-lag between measuring the performance and applying them for any corrective actions.
- Frequent meetings and transparent communication system such as web-based information systems will be helpful to overcome barriers that arise due to behavioral and political factors.
- The key PMs and metrics listed in table 4 can be applied for both manufacturing and services. However, when it comes to individual companies such as steel, transportation, and automobile, some additional measures may be required. For example, in transportation business, the utilization of transportation resources and customer service level could be the KPMs at tactical and operational levels. In automobile companies, the inventory turnover will be a KPM. Product variety will be the PM in fashion design industry. Similarly, one could determine suitable key PMs and metrics in logistics and SC across a range of industries.
- A simple PMS can be employed at lower level of an organization so that people can easily understand and follows them. At the higher level, the PMS can be comprehensive due to the strategic nature of the decisions. But the reporting structure should be simple at all levels of decision-making. IS plays a major role in facilitating the data collection and retrieval, and therefore, influencing the PMs and metrics used in logistics and SCs.
- Constant updating of such key PMs and metrics is a necessary condition for continuous improvement depending upon the evolution of the business. Most organizations assume that PMs are permanent once selected and agreed. Since competitive business strategy and technology change from time to time, the PMs and metrics in logistics and supply chain change accordingly. Also, it would be helpful if companies can organize their measures and metrics into ABC classification (strategic, tactical and operational).
- Considering the nature of the logistics and SC operations, the information productivity should be measured. The question is how we are going to measure it and who will be responsible for monitoring the performance. The top management should be responsible for strategic level decisions and their performance. The middle level managers are responsible for tactical level performance. The junior managers are responsible for operational level performance in a logistics and SC system. Frequent meetings on performance measures will be helpful in revising the measures considering the dynamics of businesses.

- We have three major types of production environments, viz. make-to-order, make-to-stock, and project SC systems. The key PMs and metrics will differ according to the nature of systems. For example, lead time should be a key performance measure in make-to-order system, but in the case of make-to-stock it should be inventory turnover.

7. Concluding remarks

As discussed earlier, PMs and metrics are essential for effectively managing SC operations, in particular in e-commerce and virtual enterprise environments. Traditional performance measures can be used for measuring performance in a SC or virtual enterprise environment. However, understanding the importance of nonfinancial measures and intangibles, a list of key performance indicators in a supply chain environment is identified. This list is based on the literature survey and some reported case experiences. We have reviewed the literature based on predetermined classification criteria that is again based on the scope of their research objectives. Some of the additional future research directions in the areas of PMs and metrics are recommended below:

- Validate the key PMs and metrics proposed in this paper with the help of case studies or empirical analyses.
- Develop more specific PMs and metrics for virtual enterprise and e-commerce environment.
- Determine KPMs and metrics that need to be considered while measuring the performance of supplier development or partnership formation?
- Develop suitable mathematical models in order to measure the performance of SC systems including virtual enterprise and e-commerce environments.

With the emergence of advanced information technologies, data warehousing and data mining techniques, it is relatively easy to handle large volumes of data for processing and generate relevant information for making more accurate and timely decisions. This does not mean to say that we can collect and have access to large volumes of data because of the technologies. Rather, it is to say to use the appropriate IT for collecting accurate and timely data and providing the right information to the right people for making right decisions. However, one has to determine the volume of data to be collected by focusing on only the key PMs and metrics that directly influence the organizational performance in terms of productivity and competitiveness.

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