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ACKNOWLEDGMENTS

Writing a doctoral thesis is a big challenge for every young researcher. It is, probably, the most important step to initiate a successful academic career. In the same time, it is a great responsibility that requires study, attention, patience, perseverance, and sometimes, a little bit of luck, especially when the doctoral candidate chooses to make an empirical research.

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INTRODUCTION – PERFORMANCE IN DOWNSTREAM SUPPLY CHAIN

Research Outline

The direct sales approach of Dell has been considered the best business model to sell products. Recently, Dell has announced that they will combine the direct model with indirect distribution channels to improve the performance of the core processes of their business. Also, for the first time, in the last decade, Dell has lost its supremacy as number one PCs manufacturer, HP becoming the number one seller. Continuous improvement on core processes as PLAN, SOURCE, MAKE, DELIVER in supply chain can be achieved if companies do measure systematically and continuously the performance on each of them. Reducing and even eliminating the negative effects of the phenomena as bullwhip in supply chain through coordination (channel alignment) and collaboration (information sharing, operational efficiency) among members are priorities for every key player involved in a decision process. Since bullwhip effect is a cause of human behavior within a given downstream supply chain, such questions can be raised: Does structure influence performance in supply chain? Could be avoided this effect reengineering the downstream structure? What type of downstream supply chain networks are and how can be selected the best network to achieve the best performance?

Downstream supply chain refers to the movement and storage activities required to transport a product from the supplier to a customer in the supply chain. It represents the ‘face of the company’ to customers with a strong bearing on customer satisfaction. Customers expect quality service defined as reliable product deliveries of the right amount, at the right time with no damage to product and at a low cost. The company, however, must balance customer satisfaction with the need for profitability. The balance of customer satisfaction is determined by the proper mix of downstream supply chain process strategies.

The process strategies can be figured in many ways using a complex distribution network of internal and external providers or they can be configured as a direct model, such as used by Dell.

The dilemma faced by companies concerns the choice of the best downstream supply chain that balances customer satisfaction and profitability. To solve this dilemma, companies need to have strategic supply chain planning tools to asses the performance along the supply chain.

The thesis, “Performance Metrics in Downstream Supply Chain”, has the roots in the ancient axiom ‘what it cannot be measured, it cannot be managed’. In a dynamic world economy, where the gap between leaders and followers is closing due to the rapid adaptation of the last category to the new changes on the markets, continuous improvement can be achieved by having a clear and broad picture of the performance of the supply chain, in upstream and downstream. The study proposes a mix of approaches to explain how companies can achieve higher performance within their downstream supply chains.

The thesis structure spans five chapters: chapter 1 – Performance in Downstream Supply Chain, chapter 2 - Supply Chain Performance Metrics: A Confluence of Foci and Methodology Maturation, chapter 3 – Research Methodology, chapter 4 – Does Structure Influence Performance in Downstream Supply Chain? – a normative approach, chapter 5 – Performance Metrics in Downstream Supply Chain – a descriptive approach.

Chapter one, Performance in Downstream Supply Chain, provides an insight about performance in supply chain and why ‘what it cannot be measured, it cannot be managed’. This principle, although simple, is not always applied. Enron, the biggest recent bankruptcy in the corporations’ history, represents the most relevant case of not doing so. Covering operational losses, especially in downstream, by financial speculations has been proven a disastrous strategy for medium and long term. Moreover, a research carried by Bain &

Company (2000) showed that more than 85% of senior executives said improving their supply chain performance is one of their top priorities, but fewer than 10% were adequately tracking that performance. And fewer still -7% - collected the information necessary to meaningfully measure their progress. The study, which polled 162 top managers with supply chain oversight, also found that the supply chain gap is set to widen: two-thirds of companies that said they are already ahead rate improvement of supply chain performance as a high or top priority; but just over a third of laggards said they will prioritize catching up.

Chapter two, Supply Chain Performance Metrics: A Confluence of Foci and Methodology Maturation, is an extensive meta-analysis carried with three scientific web engines (SCOPUS, Scholar Google, and ISI Web of Science). The present chapter serves as a review of the literature to explore the evolving nature of supply chain performance metrics. At its most general sense, this chapter begets the inquiry of what is occurring in the literature regarding supply chain performance metrics. I propose a review of scientific articles and books on supply chain performance metrics to determine the following exploratory issues: 1) is there a trending focus among studies from many measures to a reduced set of metrics? 2) If there is a trending focus to a reduced set of metrics, do these cover the tier one set of metrics as proposed in the SCOR model (i.e., delivery reliability, flexibility and responsiveness, cost, and assets)? And if the topics cover the tier one set of SCOR model tier one metrics, what other metrics are also included that diverge from the SCOR model? Finally, as an assessment of the maturity of the field of supply chain performance metrics, what is the nature of the methodologies being used in the literature? Is the field moving away from conceptual and theory articles and single case studies to larger sample size empirical studies? That is, what is the current state of research methodologies in the field?

Performance metrics topic in supply chain was identified by Johnson and Pyke (2000) as one of twelve main topics for supply chain management. A survey developed by ARC

Advisory Group (2005) with 130 logistics executives from 1000 Global companies revealed that supply chain metrics is the top priority for companies, obtaining an average of 2.97 points from a 4 points scale.

Chapter 3, Research Methodology, deals with the process of selecting research instrument, the survey process, the questionnaire development, the data collection process, and research techniques proposed in reaching the targets. A special attention has been granted to the nonresponse bias and low response rate.

Chapter 4, Does Structure Influence Performance in Downstream Supply Chain? A normative approach provides a normative model to select the best alternative in designing the downstream supply chain. The model makes an appeal to the utility theory under certitude, using a value function in the sense of Keeney and Raiffa (1976). An important help in creating this model is the empirical evidence about the existing networks in downstream supply chain and data collected regarding the value of the key performance metrics used as attributes in the value function. Also, the coefficients of importance for the attributes are established using the ranking made by the respondents in defining each SCOR dimension. This ranking gives an empirical validation of the importance priorities of performance metrics in the mind of the supply chain managers. The model uses the research of Dias (2000) by allowing the coefficients to fluctuate from 0 to 1 (total sum of the coefficients should be one) and proposes three types of computations in selecting the best design (computation of range of value for each alternative, computation of the highest difference of value for each ordered pair of alternatives, computation of the "maximum regret" associated with choosing each alternative).

Not just single decision makers can use the model, but also, it does allow taking group decisions, even in spatial distribution situation.

Chapter 5, Performance Metrics in Downstream Supply Chain – a descriptive approach, deals with the situations when the decision makers cannot have enough quantitative data about the existing networks to measure the performance. The causes are multiple and the most relevant is the lack of direct information from competitors within and across industries (key informants do not provide enough data about their supply chains and the data collection process is very difficult to do.). When such situations do occur, a decision maker can make an appeal to a different approach, a descriptive one – Analytic Hierarchy Process (AHP) (Saaty, 1980). The Analytic Hierarchy Process was created by Thomas Saaty and is a systematic procedure for representing the elements of any problem, hierarchically. The AHP includes procedures and principles used to synthesize the many judgments to derive priorities among criteria and subsequently for alternative solutions. This chapter provides a case study made with a decision maker in supply chain that agreed to evaluate the alternatives based on his judgments following the AHP methodology.

Each approach (normative and descriptive) has advantages and shortages. The thesis proposes a mix of these approaches and based on situation, a decision maker can select the method that fits best with the given situation.

The Conclusions chapter makes a review regarding the steps involved in carrying the research, the instruments, methods and techniques used, the models created to define the best network in downstream supply chain and when it does fit to use the models, as well further research to be developed.

Why to measure? There are some benefits? Keebler et al (1999) identified three main benefits in a survey carried in 1998 with supply chain manager from companies, members to CSCMP.

Reducing costs. A good measurement system can help companies to understand which customers are profitable and which not; which suppliers offer the lowest cost; which services really add value and which just add cost; which processes are fraught with excess hand-off, rework, and redundant activities.

Improving service level. Replacement of subjective, rating-bases customer satisfaction surveys with objective measurement programs, companies can get more accurate picture of how they serve the customers. The measurement system, as it is defined by Neely (1999) is the heart of the companies ability to attract and retain customers in the competition within their markets.

Generating healthy growth. Having a good understanding of supply chain costs and performance can help companies weed out unprofitable customers and spur profitable growth. Having information about their supply chains and competition's chain, companies can focus its resources and efforts towards the customers that really pay off

Over the modern history of measurement in supply chain, it can be identified some decades of importance: '60s with little measurement (retailers and consumers could not have access even to basic information about products and services), '70s as decade of accelerated competition and a start point to globalization (the major crisis of oil generated an increase of logistics costs that created a need for better system to control and measure in order to maintain the costs at a low level), '80s as a period of a better structure in defining measurement system (introducing UPC-Uniform Products Code-started to have a good impact of the way how the inventory systems measured their performance), '90s as a decade of technology revolution (years that the global competition generated the need for better and more accurate systems of measurement).

Choosing a measurement system is a extremely hard task and corporate governance vision should be in concordance with the vision of operational managers. More often, companies do fail to create good measurement systems, not of a lack of vision, in most of the cases because of a lack of concordance between these two levels in the organization structure.

The present research proposes as a measurement system the SCOR model, a standard that cross industries and created by Supply Chain Council. Implementing such system is beneficial for companies but to be successful, companies do have to create an implementation program that span important steps as educate for support, discover the opportunity, analyze, design, develop and implement. The value of such system is reflected in (Bolstorff and Rosenbaum, 2003):

- an average of 3 percent as a percentage to total sales operating income improvement for the initial SCOR project portfolio derived from cost reduction and service improvement
- two to six times return on investment within twelve months, often with cost neutral quick-hit projects underway on a six months time frame
- full leverage of capital investment in systems improving return on assets, for fixed-asset technology investments
- reduced information technology operating expenses through minimized customization and better use of standard system functions
- ongoing updates to a project portfolio, using continuous supply chain improvement to drive profit improvement at 1 percent to 1-to-3 percent per year.

In the following chapter, the SCOR model and a mix of performance metrics and best practices are exploited in order to explain performance in downstream supply chain.

Chapter 2 – Supply Chain Performance Metrics: A Confluence of Foci and Methodology Maturation (Literature Review)

Introduction

The ability to assess supply chain performance among and across interlinked organizations is an important factor of success for leading supply chains organizations and differentiates them from poorly performing supply chain members (Harrison and New, 2002). Supply chain management (SCM) is defined here as all of the linked individual organizations that, by direct or indirect means, lead to the delivery of a service or a good to a customer (Chopra and Meindl, 2004). The overall benefits of SCM lies in the creation of end-customer value provided through closer integration activities and communication with other member firms along the supply chain (Bowersox, Closs, and Stank, 2000). The benefits specifically consist of elimination of non-value added activities, decreased variance of orders, swifter product flows, and more efficient use of time and material and human resources and reduction of the bullwhip effect (Frohlich and Westbrook, 2001; Yu, Yan, and Cheng, 2001).

Supply chain performance assessment also provides firms with a clearer picture of processes along the supply chain (Croxton, Garcia-Datugue, Lambert, and Rogers, 2001). Strategic supply chain planning tools, of which the SCOR model is an archetypal exemplar, provide organizations with a standard framework to assess supply chain performance (Huang, Sheoran, and Wang, 2004). The SCOR model integrates well established business management and improvement practices, including a multi-tiered metric system to improve the plan, source, make, and deliver activities in a supply chain. The SCOR model metric system is considered a breakthrough given its standardized approach to assessment across organizations and industry types.

The top tier of the SCOR metric system evaluates the overall strategic organizational activities in a supply chain context. These top tier metric system elements consist of: delivery reliability, flexibility and responsiveness, cost, and assets. These metrics follow the standard proffered by Schneiderman (1996). The first criterion suggests that the number of metrics should be set at no more than five. The use of a large number of metrics diffuses the focus of the firm and creates noise that reduces prospects for improvement. More over, the use of metrics provides a system of hierarchy to create an order that places one metric above another such that they are not all equally important and tradeoff determinations can be made easier (Hausman, 2003).

The second criterion of a metrics system concerns the types of activities assessed by the system. The two general areas proposed by Schneiderman (1996) consist of 1) internal process and 2) external results performance. The SCOR model activities consisting of plan, source, make, and deliver fit these internal and external schemas well.

Metrics also provide a system wide cross-organizational view of supply chain performance in addition to company specific assessments (Lambert and Pohlen, 2001). The use of a supply chain metrics system leads to synergies of performance among supply chain members that facilitate the measure of *total supply chain performance* as opposed to isolated functional "silo" measures (Hausman, 2003).

I have purposely chosen performance metrics as the standard of evaluation as opposed to the terms 'performance measurement' and 'performance measure.' In Neely, Gregory, and Platts (2005), a reprint of the same study from 1995, the framework for a performance measurement system was provided. The timeliness and significance of this framework is fundamental to several fields of study and serves as a seminal study in the field of performance metrics. In an update to the 1995 study, Neely (2005) found that the field of performance measurement had become a broad framework covering disciplines as distant as management to medicine, providing, as Neely states, “little consensus about its theoretical foundations (p. 1267).” The term “performance measure” carries a connotational definition that is vague, historical, and diffused (Neely, 1999).

Schneiderman (1996) stated that measures and metrics differ in the following way: measures consist of the broad set of infinite forms of evaluating a firm’s process whereas metrics are a subset of the few measures actually useful to improve a company’s efforts. Metrics should be monotonic, that is, improvements in metrics must lead to improvement in shareholder wealth.

Recent studies demonstrate the evolution of the discipline away from supply chain performance measures toward supply chain performance metrics. Gunasekaran, Patel and Tirtiroglu (2001) discussed the problem of these terms in their study of the literature and stated,

> “Quite often, companies have a large number of performance measures to which they keep adding based on suggestions from employees and consultants, and fail to realize that performance measurement can be better addressed using a few good metrics (p. 72)”

More recently, Shepherd and Günter (2006) in a study of the literature found in a search of articles and book containing the key terms ‘supply chain management,’ with ‘performance’ or performance measurement’ 362 articles and books. In their framework, ‘measures’ served as a proxy for ‘metric.’ The list of articles and books was reduced to a set of 42 for consideration of only those that concentrated on “developing performance measurement systems and metrics for supply chains” and used an analytical framework provided by Neely et al., (1995). The Shepherd et al., (2006) study serves as the most current study of the literature and I propose building on their success and providing additional insight to the supply chain performance metric phenomena.

The present chapter serves as a review of the literature to explore the evolving nature of supply chain performance metrics. At its most general sense, this chapter begets the inquiry of what is occurring in the literature regarding supply chain performance metrics. I propose a review of scientific articles and books on supply chain performance metrics to determine the following exploratory issues: 1) is there a trending focus among studies from many measures to a reduced set of metrics? 2) If there is a trending focus to a reduced set of metrics, do these cover the tier one set of metrics as proposed in the SCOR model (i.e., delivery reliability, flexibility and responsiveness, cost, and assets)? And if the topics cover the tier one set of SCOR model tier one metrics, what other metrics are also included that diverge from the SCOR model? Finally, as an assessment of the maturity of the field of supply chain performance metrics, what is the nature of the methodologies being used in the literature? Is the field moving away from conceptual and theory articles and single case studies to larger sample size empirical studies? That is, what is the current state of research methodologies in the field?

In the subsequent sections I provide the methodological approach for the literature review, a classification of findings, and a discussion of results and direction for future research in the field of supply chain performance metric systems.

Methodological Approach

The body of literature was assembled from the results of an article search of the key words "supply chain performance metrics" and "performance metrics in a supply chain" in three web search engines. The search yielded 85 articles from Scholar Google™, 84 from Scopus™ and 44 from Web of Science℠. More than half of all articles appeared in all three engines. The timeline of articles ranged from 1991 to 2007.

The article search reflects a variety of schemes by discipline (i.e., business and economics theory), organizational levels (i.e., strategic, tactical and operational), perspectives of integration (i.e., plant, organization and supply chain), and empirical (i.e., survey and case designs) as well as model and simulation research designs (i.e., multiple criteria decision making as multiple attribute utility theory and analytical hierarchy process).

I propose an approach that differs than previous literature reviews by providing a classification focused on SCOR dimensions. In my findings, I emphasize the role of SCOR as convergent standard in measuring supply chain performance.

Classification of Findings

The classification method used in this study follows the basic premise that studies of organizational phenomena begin with observation of scattered knowledge and theory building supported by case studies and move toward more focused empirical surveys of larger populations (Meredith, 1998). This approach, not coincidentally, somewhat followed a chronological order. The classification categories are the following:

- conceptual articles
- modeling articles
- benchmarking articles
- case articles
- survey articles
- SCOR articles

I chose to provide a separate category for the SCOR model because of its importance for our study. In the evolutionary process of the supply chain construct, the SCOR model represents the latest thinking regarding supply chain metrics as seen in the published dates for these articles. In addition, the SCOR model is considered the latest standard of best practices for supply chain performance (need a reference). In the SCOR model category, a variety of research methodologies were identified, ranging from conceptual to survey articles.

Conceptual articles

Harrington, Lambert, and Christopher (1991) developed a methodology for measuring vendor performance using length of promised lead time, lead time variability, fill-rate, discrepancy rate, and total dollar purchases. They defined promised lead time as "the number of days from purchase order issuance until the promised lead time"; lead time variability as "the difference between the actual and promised lead time"; fill rate as "the percent of shipment received at the promised delivery date"; discrepancy rate as "units damaged, bad counts, and wrong product divided by total units shipped". Further, they configured a model to evaluate the vendor performance by using these metrics as criteria in a scoring model.

Mentzer and Konrad (1991) considered that the evaluation of performance is a vital managerial function. They made a discussion using an analysis of effectiveness and efficiency in five broad areas of logistics: transportation (to measure the transportation performance they used as measures labor, costs, equipment, energy, and transit time –each of them developed in a set of metrics) warehousing (labor, cost, time, utilization and administration), inventory control (labor, cost, equipment, and time, order processing (labor, cost, facility, equipment, and time), and logistics administration (labor, cost, time, and management).

Lee and Billington (1992) showed fourteen pitfalls that affect the efficiency and the effectiveness of a supply chain. Four of them addressed the problems linked with supply chain management (no supply chain metrics; inadequate definition of customer service; inaccurate delivery status data; inefficient information systems), another five pitfalls were related to operational problems (ignoring the impact of uncertainties; simplistic inventory stocking policies; discrimination against internal customers; poor coordination; incomplete shipment methods analysis) and the last pitfalls were strategic and design related (organizational barriers; product-process design without supply chain consideration; separation of supply chain design from operational decisions; incomplete supply chain). As we can see, it appeared a need to improve the supply chain performance by instituting performance metrics that should "take the supply chain perspective", with a regular check of overall performance, weekly or monthly.

Schneiderman (1996) made an extensive analysis of metrics for the order fulfillment process, presenting the difference between measures and metrics, the categories of metrics (results and process metrics), and prior to SCOR model, he made an important remark making an appeal to the Japanese conception that the focus should be on process, not on results (to have good results, the process should be efficient).

Beamon (1998) argued that a supply chain is comprised of two integrated processes: (1) the production planning and inventory control process that encompasses all the manufacturing and storage sub-processes and (2) the distribution and logistics process that determines how products are retrieved and transported from the warehouse to retailers. She identified four categories of models to design and analyze a supply chain (deterministic, stochastic, economic, and simulation model), showing that an important component in supply chain design and analysis is using appropriate performance measures. In another article (Beamon, 1999), same author presented a framework to measure performance in a supply chain from the perspective of resources, output, and flexibility. She included in resources: inventory levels, personnel requirements, equipment utilization, energy usage, and cost. Output measures referred to customer responsiveness, quality, and the quantity of final product. The flexibility was treated in terms of volume, delivery, mix and new product flexibility.

Van Hoek (1998) mitigated for a new measurement system to improve supply chain performance, with an accent on developing new benchmarks, pointing an important fact: "the position of players in the chain (supplier, manufacturer, whole-saler, service supplier) affects their contribution and relevant measures, the level of integration and the strategic approach may affect the relevance of measures".

Holmberg (2000) came with a systems perspective in measurement the supply chain performance, linking three key elements in a single system: a performance model based on balanced scorecard or SCOR, metrics and measurement methods.

Brewer and Speh (2000) used balanced scorecard (BSC) model developed by Kaplan and Norton (1992) to comply the supply chain goals as waste reduction by minimizing duplication, harmonizing operations and systems, and enhancing quality; time compression; flexible response; and unit cost reduction. Using balanced scorecard, they argued that the benefits of customers increase by improving product/service quality, timeliness, flexibility and value. Also, the financial benefits can be improved by gaining higher profit margin, revenue growth or higher return on assets. Applying BSC, the entire supply chain management suffers improvements in terms of product/process innovation, partnership management, information flow, threats/substitutes.

Lambert and Pohlen (2001) showed that many supply chain performance metrics used in most companies were nothing more than actually measures of internal logistics operations as opposed to measures of supply chain management. They considered that nonfinancial metrics must be developed for participating firms in a supply chain and tied to their financial performance. “The goal should not to be to identify specific metrics, but to provide the framework that allows management to develop the best metrics for their situation. To the extent that similar metrics are identified in different supply chain settings, it may be possible to conclude that standard metrics can be developed”.

Kleijnen and Smits (2001) proposed different approaches to treat performance metrics in supply chain. From economic theory perspective, performance can be measured in term of utility, used in most cases as a linear function of attributes, using kiviat graph that alternates good and bad attributes (e.g. fill-rate, stock, confirmed fill-rate, response delay) or the spider diagram. For business, they proposed a combination between balanced scorecard with simulation (spreadsheet simulation, system dynamics, discrete-event dynamic system, and business games).

Otto and Kotzab (2003) approached the supply chain performance metrics in a supply chain from six perspectives: the system dynamics –perspective, the operations research-perspective, logistics perspective, marketing, organization, and strategy. For each perspective, they identified standard problems, standard solutions, and performance metrics.

Chan and Qi (2003) used a process-based approach to measure the performance in a supply chain, decomposing the core business processes (suppliers, inbound logistics, core manufacturer, outbound logistics, marketing&sales, end customers) in sub-processes, and elementary activities of sub-processes. All the processes were decomposed into measurable elements, using a hierarchical structure. They introduced the term of performance on activity – POA, using a board of performance metrics as cost, time, capacity, capability, flexibility, productivity, utilization and outcome.

Hausman (2003) considered that supply chains need to perform on three key dimensions: service, assets, and speed. The service metrics should measure how well the customers are served (or not); assets metrics should capture the commercial value, primarily inventory and cash, and speed metrics should be time-related. An interesting point raised by the author is that the quality dimension should absent, because "in modern Supply Chain Management thinking, Quality is taken as given. The diagnosis and improvement of Quality involves factors which are quite separate from factors used to improve Supply Chain Management".

Melnyk, Stewart, and Swink (2004) argued that a metric is "a verifiable measure, stated in either quantitative or qualitative terms and defined with respect to a reference point, consistent with how the operations delivers value to its customers". They suggested that various metrics can be classified according to two primary attributes: metrics focus and metrics tense. Metrics focus pertains to the resource that is the focus of the metric (financial or operational). Metrics tense referrers the how the metrics are intended to be used (to judge outcome performance and to predict future performance).

Folan and Browne (2005) developed an performance measurement system in a supply chain based on BSC, proposing macro measures of performance as cost, time, quality, flexibility, precision, and innovation from different perspectives (internal, supplier, customer) applied to a first-tier supplier of chassis component products to leading automotive companies in the European automotive industry.

Shepherd and Gunter (2005) made a review about performance measurement in supply chain, using the web engines Web of Science, Google Scholar and PsychINFO and keywords as "supply chain management" linked with "performance" or "performance measurement". I limited the search to "performance metrics in a supply chain" or "supply chain performance metrics". Also, in developing our framework, we choose to differentiate metrics from measures, and we propose a new classification of found articles. They classified the metrics found in terms of SCOR processes on five measures: cost, time, quality, flexibility, and innovativeness.

Xia, Lee, Sing, and Zhengping (2005) treated the issue of performance metrics in a software focused supply chain on three dimensional performance measurements: resources, visibility and agility. They used for resources: total resource cost, distribution cost, inventory cost, cost of goods sold, and return on investment, but also measurements on activities and profitability such as total asset turnover, receivable turnover, net profit margin, net return on assets, gross return on assets or return on equity. Visibility is fundamental for keeping the promises "Whatever is promised must be delivered-without fail". For this, they identified seven activities must be integrated to keep visibility of whole supply chain (delivery capability, order management, inventory management, capacity management, and customer service). For agility measurement, were identified: order lead time, work force skill, time to re-configure supply chain when changes occur, number of products a supply chain can deliver to a customer with the customer satisfaction, number of organizational levels.

Also practitioners were preoccupied of performance metrics in a supply chain. AMR Research proposed a hierarchy of supply chain metrics “to bring order to the chaos” (Hofman, 2004) from ground level: correct to mid tier: diagnose and from here to top tier: assess. At the highest level – top tier, there are three key metrics: demand forecast accuracy defined as “the difference between forecasted and actual demand”, perfect order - “complete, accurate, on time, and in perfect condition”, and supply chain management costs - “total supply chain management operating costs”. Mid tier looks at cash-to-cash cycle time, defined as a composite between “ship to costumer deliver – time taken from shipment of finished goods to delivery at customer’s address”, “raw material receipt to payment – time from receipt of raw materials to payment”, “inventory days – average days of inventory on hand”, and “days sales outstanding – measurement of the average collection period from invoicing to cash receipt”. At the ground level, the detailed metrics reveals the root causes of high inventory, high cost or bad customer responsiveness.

In another research, McCrea (2006) presented the importance of performance metrics in a supply chain, with references from individual companies and making an appeal to a survey made by Abeerden Group (2005) with the scope to identify what supplier performance metrics do companies use, on the highest level was situated on-time delivery; meanwhile innovation was at the lowest level.

As part of the MIT project, Supply Chain 2020, Shen (2005) surveyed twenty-five (25) studies from both industry and academia to see the link between supply chain management practices and operational and financial performance. Each study’s credibility was quantified using a research quality index that assessed the strength of evidence supporting the causal link. He identified as financial performance metrics three categories: short-term financials, market share, and stock market. For operational performance metrics, the categories were: customer service, responsiveness, supply chain cost, asset utilization, product quality, and operational flexibility.

Benchmarking articles

Benchmarking supply chain processes can be done also using performance metrics. In a study applied to Australian companies, Gilmour (1999) developed a benchmark using measures based on a set of capabilities grouped in five categories: strategy and organization; planning; business process and information; product flow, and measurement: supplier performance. For all capabilities, the author proposed four levels and the respondents were asked to say at what level they thought they were and at what level they would be in two years' time. Respondents rated each of the capabilities elements at level one, two, three of four. Each level was scored one point. The findings revealed that some of the capabilities have higher importance for respondents, as process capabilities (e.g. customer connectivity or efficient distribution) followed then the technology capabilities and organization capabilities.

Landerghem and Persoons (2001) benchmarked the logistical operations using a causal model, the top objectives being flexibility, reaction time, quality, return on assets in a study applied to 22 companies. The study was performed through a list of questions probing the best practices, the value of the key metrics (SCOR and others), and benchmark data from customers. The answers were put in a computerized checklist format, grouped on eight domains: employees; planning and control; production and assembly; research and development; distribution; order handling; purchase and suppliers; market and client. This approach allowed companies to identify which best practices they did not used and how they could improve their overall performance, introducing three levels of benchmarks: the customer requirements, sector and world level benchmarks.

Simatupang and Sridharan (2004) conceptualized a benchmarking scheme that assisted the chain members to understand the links between supply chain performance metrics and possible enablers of performance improvement. They created the benchmark to compare the performance not only with the best-in-class practice, but also with the customer expectations in order to reinvent key levers used to enhance performance. Their approach was to propose a scheme to incorporate the collaborative performance system and collaborative enablers to reveal the interactions among performance metrics. The benchmark helped chain members to determine the level of performance they plan to achieve and to respond not only to the question “How do we compare to others?” but also “What areas need to be improved?”

Case articles

Kuo and Smits (2003) linked supply chain performance with IT performance, the aim of their study was to find factors that improve the performance of integrated supply chain, how IT architectures from a supply chain member influence other IT architectures from other supply chain members, how were linked business and IT architectures, together. The analyzed subject was an IT products company with operations in Asia and Europe. They found that there is no supply chain wide planning of IT infrastructure, and no IT driven strategy to improve supply chain performance and also not a common performance measure or a shared balanced scorecard. This study represented a source for one of the authors (Smits, Huvel, and Huisman, 2006) to analyze the supply chain performance using SCOR metrics for the same company and to verify if that integrated supply chain performance can improve substantially without the critical need of high levels of networkability of the organizations in the chain - “internal and external capability of organizations to collaborate with each other at the level of both business processes at the level of both business processes and underlying IT infrastructure”.

Lohman, Fortuin, and Wouters (2006) created an IT tool for a global clothing and sport accessory company, with the headquarter in Netherlands for European Operations. The performance metrics were developed on the following areas: customer, sustainability, financial, process improvement, product flow, and people. The proposed performance metrics system had a hierarchical structure, using a scorecard on three layers (top, mid and lowest) with the objective to improve the performance at the operational level.

Survey articles

Surveys were used to express supply chain performance metrics in different industrial sectors and geographical zones.

Gelders, Mannaerts, and Maes (1994) made a survey with 60 manufacturing companies in Belgium, with the aim to study the company strategy, performance measurement in manufacturing and improvement projects in manufacturing. Their research is valuable source for comparison over time in terms of performance metrics. Company strategy was treated in term of strategic dimensions (price, quality, availability, product characteristics). The main indicators used for performance measurement were: quality, volumes, manufacturing cost, inventory levels. The results in improvement programmes showed the following priorities for companies: improving process quality, reducing throughput time, increase process flexibility, reduce rework/scrap, and reduce raw material inventories.

In a survey of 22 extended supply chains from North America, South America, and Europe, Ramdas and Spekman (2000) focused in whether innovative-product supply chains differ in term of practices, thinking, and performance dimensions from functional-product supply chains. The performance variables used in the study were: inventory, time, order fulfillment, quality, customer focus, and customer satisfaction. The results showed that the fuctional-product and innovative-product supply chains differ significantly in practices used and thinking. High performers among innovative-product supply chains are more likely to engage in supply chain management to enhance revenues than are high performers among functional-product supply chains.

Harrison and New (2002) implemented a worldwide survey to study the relationship between corporate strategy, supply chain strategy, and supply chain performance management. On the section about supply chain performance metrics, the respondent companies used mostly to measure customer delivery performance, inventory turn, supplier delivery performance, meanwhile just 16% used as metrics telephone response time and 9% line item deletions. The survey permitted to the authors to classify the companies in: supply chain leaders, strong players, weak players, lagging players and non-players.

Bharadwaj (2004) proposed a cross-sectional survey to identify the decision for buying components in an electronics supply chain, using performance metrics as decision criteria: delivery fulfillment, product quality, service and price, each of these "key buying criteria" were developed in 10 items to evaluate the suppliers' performance. The respondents were asked to rank the decision criteria; quality and delivery fulfillment had the highest ranks. The results of the survey had important managerial implications also for the customer side, the suppliers' performance can affect the perceptions that customer can have about companies' products as well as the velocity with which products reach the market

Corsten and Felde (2005) looked to explore the performance effects of key-supplier collaboration in a study applied in 235 Swiss companies. They linked the relationship factors: trust, dependence and supplier collaboration with performance factors: innovation, purchasing cost reduction, and financial performance. The results revealed that collaboration, trust and dependence enhance the buyer's innovation level. Also, trust reduced the purchasing cost and collaboration improved financial outcomes of buyers. An interesting aspect was that the effect of collaboration on financial performance was stronger under conditions of low trust compared to high trust.

Modeling articles

I distinguished different modeling techniques, using operations research (as linear programming, mix-integer programming or goal programming), analytic hierarchy/network process –AHP/ANP, graph theory, artificial network, Petri net, etc.

Agarwal, Shankar, and Tiwari (2005) proposed an ANP-approach to select between a lean, agile or a leagile(“a combination of the lean and agile paradigms to best suit the need for responding to a volatile demand downstream yet providing level scheduling upstream from the market place”) supply chain as the best alternative. For this purpose, they used supply chain performance determinants (lead time, cost, quality, and service level), supply chain performance dimensions (market sensitiveness, process integration, information driver, flexibility), and supply chain performance enablers (for market sensitiveness: delivery speed, new product introduction, customer responsiveness; for process integration: collaboration across each partner’s core business process, company specific issues on demand side, company specific issues on supply side; for information driver: electronic data interchange, means of information, data accuracy; for flexibility: source flexibility, make flexibility, delivery flexibility) . The approach of ANP was based on three facts:(1) selecting a supply chain is a problem of multiple decision criteria; (2) many factors, enablers and criteria are interdependent on one another; and (3) some criteria, enablers and dimensions are subjective, so a complex weightage method is preferred than a simple one. The analysis revealed that when overall objective was to reduce lead time, desirability index was lower for lean supply chain than agile supply chain. When the objectives were to minimize cost and to improve quality, lean supply chain was preferred and when the objective was to improve service level, leagile supply chain took the first position.

Yang and Chen (2006) developed a model to evaluate suppliers based on a combination of qualitative and quantitative criteria, using analytic hierarchy process and grey relational analysis applied to evaluate the potential suppliers of printed circuit boards for a notebook computer firm. For qualitative criteria they used quality, finance, customer service, production capacity, design&technical capability, IT system and for quantitative criteria: turnover, cost, delivery, distance. The ultimate goal was to select the best supplier that can provide faster delivery, reduced cost, and improved quality to increase the corporate competitiveness.

Viswanadham and Raghavan (2000) investigated the performance metrics in a supply chain using stochastic generalized Petri nets (SGPN) in three production environments: Make-to-Stock, Make-to-Order, and Assemble-to-Order. They defined SGPN as “A GSPN is a 8-tuple (P, T, IN, OUT, INH, M_0, F, S) where P is a finite set of places; T is a finite set of transitions (P and T are disjoint); Transitions can be two types: immediate or exponential (timed), depending on whether they fire in zero time or random times; IN and OUT are the set of input and output functions that define directed arcs from places to transitions and vice versa; INH is the inhibitor function and defines the corresponding arcs (the presence of a token in the input places of these arcs will result in the transition being inhibited from firing); M_0 is the initial marking; F is a firing function associated with each exponential timed transition in each marking; S is a set, possible empty, of random switches associating probability distributions to subsets of conflicting immediate transitions.” The performance metrics problem was put in term of minimization of cost with a comparison of the make-to-stock and assemble-to-order policies in a supply chain and to locate the decoupling point in the supply chain (“a point in the supply chain until which sub-assemblies are made to forecast and beyond which products are built-to-order”).

Chiu and Liu (2004) used artificial neural approach to fulfill the customer requirements in an ATO environment. An artificial neural network (ANN) is “a network of interconnected computing network, which interact with one another via connection weights”.

The function of an ANN is to produce an output pattern when presented with an input pattern. The goal was to create an algorithm that allowed 100% order fulfillment in a short delivery lead time. In ANN, the players act like agents, the authors proposing four types of agents: supply agents, production agents, delivery agents, and customer agents, which collaborates each other to achieve a win-win situation.

Kainumaa and Tawarab (2006) proposed the multi-attribute utility theory to express performance in a supply chain. They used for a lean and "green" supply chain supply chain performance metrics as ROA (return on asset), customer satisfaction, and Life Cycle Assessment (LCA). The overall goal was to make a trade-off between minimizing environmental effects and maximizing the contribution. For this, the approach was to maximize a multi-attribute utility function of different type (risk neutral, risk adverse and risk prone).

SCOR articles

Although the literature on SCOR is not so developed, we identified articles from conceptual articles to simulation articles. Stewart (1995) presented the first framework about the processes encompassed in SCOR model – Plan, Source, Make, and Deliver. He considered the following keys areas to unlock supply chain excellence: (1) delivery performance; (2) flexibility and responsiveness; (3) logistics cost; (4) asset management. These areas have become key dimensions in SCOR model. The model is a product of the Supply-Chain Council (SCC) – organization founded in 1996 by Pittigilio Rabin Todd & McGrath (PRTM) and AMR Research. Stephens (2001) presented the evolution of the model that, initially, encompassed the processes presented by Stewart (1995) and starting with the forth version of the model, appeared also the Return process. The scope of SCOR model is to include all elements of demand satisfaction starting with the initial demand signal (order or forecast) and finishing with the signal of satisfying the demand (final invoice and payment). The author pointed "Plan activities balance resources and demand and provide integration between activities and organizations. Source activities are those that are associated with acquiring raw materials and source activities connect organizations with their suppliers. Deliver activities are those activities that are associated with the management of orders and the delivery of finished goods. Deliver activities connect an organization with its customers. Most organizations have Make activities that transform raw materials into finished goods but not always. Returns activities are those activities to return the raw materials to suppliers and the receipt of returns of finished good from customers."

Gunasekaran, Patel, and Tirtiroglu (2001) made a review of performance measures in a supply chain, considering that the performance must be measured at three levels (strategic, tactical and operational), using financial and nonfinancial metrics. The first two authors (Gunasekaran & Patel, 2004) proposed in another research a set of performance metrics for SCOR processes, applied to a set of British companies.

Another approach of SCOR model was to use modeling to optimize and improve the supply chain.

Huang (2005, 2007) proposed multiple criteria decision making to select suppliers and optimize the supply chain using AHP and Preemptive Goal Programming (PGP). He used as decision criteria the performance metrics from SCOR model, proposing also a simulation tool for SCOR in different production environments (To Stock or To Order).

Rabelo et al. (2006) used a hybrid simulation and AHP for SCOR model, as a combination of system dynamics and discrete-event simulation. The model consisted of three major units: strategic business unit one for manufacturing, strategic business two for service, and customer request for proposals and customer acquisition, loss, and recovery for customer relations management. The study proposed a stochastic approach with AHP, introducing the uncertainty in ranking the best alternative, with an interval of confidence of 95%.

Roder and Tibken (2005) created a model to evaluate different configurations of supply chain with different sets of parameters. The accent was on material and information flows, describing the production, inventory and transportation. They simulated different situations to control production and inventory levels.

A different modeling approach of SCOR was made by Khoo and Yin (2003) using graph theory. They created a graph-based virtual clustering to analyze the businesses processes of the SCOR model from customer orders to suppliers. The supply graph was able to represent multiple level assembly, various modes of transportation, a multiple split and merge of orders, alternative locations or manufacturing sites, cross boundary representation and other complex relationships.

IT tools were used by Tang et al. (2004) to simulate SCOR performance metrics. The methodology was based on three key analytical techniques: SWOT analysis, value-chain analysis, and the use of quality function deployment and four level of analysis: strategic, process focus, people and technology. Other simulation was proposed by Barnett and Miller (2000) from Gensym Corporation that developed a modeling tool, e-SCOR. The developed tool has an important advantage that it can be used for discrete event simulation for large-scale models, which incorporate large entities interacting in complex ways.

Also case study method has been used in expressing SCOR model by Burgers and Singh (2006) to see which factors determine the supply chain performance. Interviewing 31 key actors in the chain, they discovered social and political factors as corporate governance, infrastructure, operations knowledge, collaborative planning and architectural innovation which manifest an influence to supply chain performance.

In a survey of 90 firms and 523 individuals, from 11 industry sectors, Lockamy and McCormack (2004) tried to see which the most used practices from Plan, Source, Make, and Deliver decision areas are related to perceived supply chain performance. They showed that in the Plan area, the demand planning process has the strongest relationship to supply chain performance, followed by supply chain collaborative planning and operations strategy planning team. In the Source area the strongest relationship to performance has the supplier transactional collaboration, in Make area, the make planning process and in Deliver, the deliver process measures.

The literature review is summarized in the following table by author, methodology and SCOR model integration because of its importance for performance metrics research.

Analysis of findings

I take into consideration all the articles published between 1991 and 2006, containing the key words “performance metrics in a supply chain” and “supply chain performance metrics”. In the analysis, we make an appeal to three academic web engines: SCOPUS, Web of Science and, Scholar Google. I am conscious that I cannot cover the topic in an exhaustive manner, but I am consistent to the idea that I want to present a framework that brings the most relevant research on the topic. For this reason, I used these three world class tools, intense utilized in the academia.

All articles are classified after year of appearance in scientific publication (the official date), author(s), type of article, SCOR focus, and SCOR dimensions. We consider 1997 as the appearance year of SCOR model (Stephen, 2001). Hence, we separate the analysis in two sections: one that treats articles with at least one SCOR dimension (and at least one performance metric at level one) and the other one that treats articles with a clear mention of the focus on the SCOR model.

Table 1
Literature Review on Supply Chain Performance Metrics

Author(s)	*Methodology*	*SCOR Model Focus*	*SCOR DIMENSIONS*					*Other(s)*
			RE	*RS*	*FL*	*TC*	*AME*	
Harrington, T. C., & Lambert, D. M. (1991)	CA		✓	✓				✓
Mentzer, J. T. (1991)	CA			✓		✓		✓
Lee, H. L., & Billington, C. (1992)	CA		✓	✓	✓	✓		✓
Gelders, L., Mannaerts, P., & Maes, J. (1994)	SA		✓	✓	✓	✓		✓
Stewart, G. (1995)	SC		✓	✓	✓	✓	✓	
Schneiderman, A. M. (1996)	CA		✓	✓				✓
Schneiderman, A. M. (1996)	CA		✓	✓				✓
Beamon, B. M. (1998)	CA		✓	✓	✓	✓		✓
Van Hoek, R. I. (1998)	CA							✓
Beamon, B. M. (1999)	CA		✓	✓	✓	✓	✓	✓
Gilmour, P. (1999)	BA							✓
Barnett, M. W., & Miller, C. J. (2000)	SC	✓	✓	✓	✓	✓	✓	
Brewer, P. C., & Speh, T. W. (2000)	CA		✓	✓	✓	✓	✓	✓
Holmberg, S. (2000).	CA		✓	✓	✓	✓	✓	✓
Ramdas, K., & Spekman, R. E. (2000)	SA		✓	✓	✓	✓	✓	✓
Viswanadham, N., & Raghavan, N. R. S. (2000).	MA		✓	✓		✓		
Baiman, S., Fischer, P. E., & Rajan, M. V. (2001)	MA					✓		
Gunasekaran, A., Patel, C., & Tirtiroglu, E. (2001)	SC	✓	✓	✓	✓	✓	✓	✓
Lambert, D. M., & Pohlen, T. L. (2001)	CA		✓	✓	✓	✓	✓	✓
Stephens, S. (2001)	SC	✓	✓	✓	✓	✓	✓	
Van Landeghem, R., & Persoons, K. (2001)	BA/SC	✓	✓	✓	✓	✓	✓	
Harrison, A., & New, C. (2002)	SA		✓	✓		✓	✓	✓
Chan, F. T. S., & Qi, H. J. (2003)	CA		✓	✓	✓	✓	✓	✓
Hausman, W. H. (2003)	CA		✓	✓	✓	✓	✓	✓
Khoo, L. P., & Yin, X. F. (2003)	SC	✓	✓	✓	✓	✓	✓	
Kleijnen, J. P. C., & Smits, M. T. (2003)	CA		✓	✓				✓
Otto, A., & Kotzab, H. (2003)	CA		✓	✓	✓	✓		✓

Author(s)	***Methodology***	***SCOR Model Focus***	***SCOR DIMENSIONS***					***Other(s)***
			RE	*RS*	*FL*	*TC*	*AME*	
Smits, M., & Kuo, D. C. L. (2003)	CS		✓	✓		✓		
Bharadwaj, N. (2004)	SA		✓	✓	✓			✓
Chiu, M., & Lin, G. (2004)	MA			✓			✓	
Gunasekaran, A., Patel, C., & McGaughey, R. E. (2004)	SC	✓	✓	✓	✓	✓	✓	✓
Hofman, D. (2004)	CA		✓	✓		✓	✓	
Lockamy, A., & McCormack, K. (2004)	SC	✓	✓	✓	✓	✓	✓	
Lohman, C., Fortuin, L., & Wouters, M. (2004)	CS		✓	✓	✓	✓	✓	
Melnyk, S. A., Stewart, D. M., & Swink, M. (2004)	CA		✓	✓			✓	✓
Simatupang, T. M., & Sridharan, R. (2004)	BA		✓	✓	✓	✓	✓	
Tang, N. K. H., Benton, H., Love, D., Albores, P., Ball, P., MacBryde, J., et al. (2004)	SC	✓	✓	✓	✓	✓	✓	
Wang, G., Huang, S. H., & Dismukes, J. P. (2004)	SC	✓	✓	✓	✓	✓	✓	
Corsten, D., & Felde, J. (2005)	SA					✓		✓
Folan, P., & Browne, J. (2005)	CA		✓	✓	✓	✓	✓	✓
Huang, S. H., Sheoran, S. K., & Keskar, H. (2005).	SC	✓	✓	✓	✓	✓	✓	
Laura, X. X. X., William, L., Chai, L. S., & Li, Z. (2005)	CA		✓	✓	✓	✓	✓	
Rabelo, L., Eskandari, H., Shalan, T., & Helal, M. (2005)	SC	✓	✓	✓	✓	✓	✓	
Shen, T. (2005)	CA		✓	✓	✓	✓	✓	✓
Agarwal, A., Shankar, R., & Tiwari, M. K. (2006)	MA		✓	✓	✓	✓		
Burgess, K., & Singh, P. J. (2006)	SC	✓	✓	✓	✓	✓	✓	
Kainuma, Y., & Tawara, N. (2006)	MA			✓			✓	
McCrea, B. (2006)	CA		✓	✓				✓
Röder, A., & Tibken, B. (2006)	SC	✓	✓	✓	✓	✓	✓	

Author(s)	*Methodology*	*SCOR Model Focus*	*SCOR DIMENSIONS*					*Other(s)*
			RE	*RS*	*FL*	*TC*	*AME*	
Shepherd, C., & Günter, H. (2006)	CA		✓	✓	✓	✓		✓
Smits, M., van den Heuvel, W. J., & Huisman, W. (2006)	CS		✓	✓	✓	✓	✓	✓
Yang, C. C., & Chen, B. S. (2006)	MA		✓	✓	✓	✓	✓	✓
Huang, S. H., & Keskar, H. (2007)	SC	✓	✓	✓	✓	✓	✓	

Note. CA-Conceptual Article; BA-Benchmarking Article; CS-Case Article; SA-Survey Article; MA-Modeling Article; SC-SCOR Article; RE-Reliability; RS-Responsiveness; FL-Flexibility; TC-Total Cost; AME-Asset Management Efficiency.

Section one – SCOR Dimensions

I identified fifty-two (52) articles that claim the use of performance metrics as major way to carry the research on performance in supply chain. The articles vary from conceptual to survey articles. It is worthy to note that researchers focused primary on conceptual aspects of performance metrics topic (42.3%), followed by SCOR approach (25%), empirical research in form of surveys (11.5%), and much less on modeling and case studies (5.8% each one) (see table 2). In the same time, it can observed an increase in number of articles starting with 2000, with a peak in 2004 (10 articles), correlated with an increase of interest in using SCOR model (4 articles). The SCOR dimensions are presented in all articles, the lowest percentage is represented by supply chain asset management efficiency (63.5%), and meanwhile the supply chain responsiveness has highest presence (92.3%).

Section two-focus on SCOR Model

In 1995, Stewart advocated the idea that supply chain performance should be discussed in term of delivery performance, flexibility, responsiveness, logistics cost, asset management but, it took five years since we had identified the first article with a clear mention of using SCOR model. This modest start is probably due to the fact that SCOR is a product of the practitioner companies and perhaps in this way, we can explain the lack of response from academia. After 2000, the number of articles has increased, arriving at a peak of four articles in 2004 (see table 2). In the same time, I have to state that, even though authors did not specify in an explicit manner use of SCOR, they have focused on SCOR dimensions and at least one dimension has appeared in all the analyzed articles (table 3).

Table 2
Classification of Articles

Type		Year														Total
		1991	1992	1994	1995	1996	1998	1999	2000	2001	2002	2003	2004	2005	2006	
BA	Count							1		1			1			3
	% of Total							1.9%		1.9%			1.9%			5.8%
CA	Count	2	1			2	2	1	2	1		4	2	3	2	22
	% of Total	3.8%	1.9%			3.8%	3.8%	1.9%	3.8%	1.9%		7.7%	3.8%	5.8%	3.8%	42.3%
CS	Count											1	1		1	3
	% of Total											1.9%	1.9%		1.9%	5.8%
MA	Count								1	1			1		3	6
	% of Total								1.9%	1.9%			1.9%		5.8%	11.5%
SA	Count			1					1		1		1	1		5
	% of Total			1.9%					1.9%		1.9%		1.9%	1.9%		9.6%
SC	Count				1				1	2		1	4	2	2	13
	% of Total				1.9%				1.9%	3.8%		1.9%	7.7%	3.8%	3.8%	25.0%

Table 3
SCOR Dimensions Frequency in Articles

SCOR DIMENSION	Frequency	Percent
Supply Chain Delivery Reliability	45	86.5
Supply Chain Responsiveness	48	92.3
Supply Chain Flexibility	35	67.3
Supply Chain Cost	40	76.9
Supply Chain Asset Management Efficiency	33	63.5

Chapter Summary

In this chapter, I made a clear distinction between ‘performance measures’ and ‘performance metrics’- considered as a subset of the first ones - and mitigate for a better focus on a small number of metrics, preferable those than can span all the supply chain and can be a source of benchmarking criteria against the supply chain members and other supply chains from same industry sector and other industry.

I supported this clear separation between two notions by providing a survey of literature on supply chain performance metrics topic. Schneiderman (1996) provided the first point in constructing my theory, stating that metrics should not exceed more than five to assure a better focus on performance and should be separated in two categories: process and results metrics. It might be correlated this major finding with the framework of Stewart (1995) that stated that performance in supply chain should be done by analyzing four major supply chain processes: PLAN, SOURCE, MAKE, and DELIVER. The foundation of Supply Chain Council in 1996 with the main goal to define a reference tool to assess performance in supply chain, independent by the type of companies and supply chains has been in agreement with the research of Lambert and Pohlen (2001) that claimed an enlargement in using performance metrics from organizational level to supply chain level and a strong tie between financial and nonfinancial metrics. Based on a literature survey, Gunasekaran (2001) made a differentiation of metrics in financial and nonfinancial metrics, indicating three levels where performance should be measured (strategic, tactical and operational).

I proposed a classification of findings, orienting our efforts to identify if researchers have used SCOR dimensions as ways to measure performance in supply chain. The results show a clear orientation to conceptual work that makes us to affirm that the topic of performance metrics is still a "work in progress", but in the same time, a strong orientation to use SCOR as a reference model in measuring supply chain performance. I found that even though focusing on SCOR methodology is not revealed explicitly, at least one dimension (and at least one SCOR metric at level one) is used in all articles.

Still, I found that there is a lack of response from academia in using SCOR as a major way to define performance in a supply chain. First article that claimed a clear mention on

SCOR model focus has appeared after five years from the first statement of SCOR dimensions and three years later after the first version of SCOR.

The big percentage (42.9%) of conceptual papers can clearly induce the idea that performance in supply chain represents a continuous ferment for supply chain researchers and practitioners. The range of approaches presented in this chapter helps to create a figure about the variety of methods that can be used to analyze the topic. The finding of a quarter of articles that focuses on SCOR can express the optimism in a maturation of SCOR as a major tool to define performance in supply chain.

CHAPTER 3 – RESEARCH METHODOLOGY

This chapter describes the research methodology used in the study. The chapter narrative discusses the population characteristics, sample size, research instrument, procedures, measures, and data analysis tools used.

Population characteristics

In the study, I operated with World Class Manufacturers (WCM) from different industrial sectors such as machinery manufacturing; computer and electronic product manufacturing; electrical equipment, appliance, and component manufacturing; transportation equipment manufacturing. The companies were selected based on a list provided by Council of Supply Chain Management Professionals (CSCMP) that contained name, surname, and email address.

Research Instrument

The main research instrument to collect data for the study was a questionnaire implemented using websurvey administration software (http://www.surveymonkey.com). Logistics and supply chain managers were invited to participate to the study by email. The email was a standardized invitation to research study, with a name and surname personalization.

Those participants, who gave the consent to participate to survey, received by email the informed consent, contact information for the researchers, and the link to the study website (Appendix A).

The informed consent has explained that their responses will be anonymous and confidential. The informed consent also has explained their voluntary participation in the study and their possibility to withdraw from the study at any time prior to submitting their completed survey. Since there was no identifying information on the surveys, participants were unable to withdraw their survey after submission. To further protect participants' confidentiality, the survey website was encrypted.

(Grosh and Munoz, 1996; Van Selm and Jankowski, 2006) proposed a set of criteria to be followed in a successful survey: questionnaire development, sampling, field operations, data management, and dissemination discussion.

Questionnaire development

In developing the questionnaire, I looked to the following steps: content, process of questionnaire development, and format.

Content

The content of the questionnaire should be in perfect correspondence with the proposed analytical objectives. (Iarrossi, 2006) pointed: "A question is relevant if the information generated is appropriate for the purpose of the study. The objective of the question defines the information that is needed and models the words to be used."

Process of questionnaire development

Major issues in the development of the questionnaire are the people involved (the analysts, the policymakers and the data producers), the iterations, quality control and field test of the questionnaire (a pilot phase to pretest the questionnaire). (Grosh and Munoz, 1996) considered that "the field test is one of the most critical steps of survey preparation. Its goal is to ensure that the questionnaires are capable of collecting the information they are supposed to collect". The adequacy of the questionnaire can be checked at three levels: questionnaire as whole, at the level of individual modules and at the level of individual questions.

I tested the quality of the questionnaire with a pre sample formed by academic professionals, members of Institutional Review Board (IRB) of Our Lady of the Lake University (OLLU), giving the approval to develop the research on behalf of OLLU.

The second pretest was represented by the academic affairs office of CSCMP that consented to provide the list with email addresses of the executives with key responsibilities in logistics and supply chain management, members of the Council. The objective of this step was to minimize the errors in designing the questionnaire. I checked the relevance of the questions, the question types, wording, sequence, length and layout. Concerns about confidentiality and anonymity have been expressed. To ensure a high degree of security, the web survey administration software was selected by using an encryption protocol – Secure Sockets Layer (SSL).

Format

The questionnaire format is important because an impropriate one can affect the quality of responses. Major issues are: units of observation, identifiers and layout.

Study population is represented by companies that are affiliates to CSCMP and develop manufacturing activities in industrial sectors such as machinery manufacturing; computer and electronic product manufacturing; electrical equipment, appliance, and component manufacturing; and transportation equipment manufacturing. Units of observation are individuals (one per company) that have executive positions from senior manager to president in logistics planning, logistics management, traffic/transportation management, warehouse operations/management, material handling operations, inventory planning, production, internal consulting or corporate research, international planning, purchasing.

Dillman (1999) proposed a set of 11 principles in designing a respondent-friendly questionnaire that can be broken down into many aspects, ranging form decisions on what information should appear on each screen to what programming tools are used to present it. Individual decisions must be made about each component of the screen, ranging from line length to where the response boxes are placed.

In another research, Couper, Traugott, and Lamias (2001) found mixed results about the impact of the questionnaire design on completion response rate. They tested what kind of impact would have on completion rate using or not a progress indicator, using one single item versus multiple items screens, using radio buttons versus entry boxes.

In the study, each survey object was uniquely identified by page number and question number. To ease the filling process, the respondents could visualize the degree of survey completion. Questions that were considered generators of extremely important data for the study purpose were marked with an asterisk (*). In order to obtain these data, the respondents, that did not fill the core questions, received a warning text written in red after each question before to go to the next page. This restriction represented a potential driver for drop-outs because the respondents could not skip the page without filling these questions.

The questionnaire comprised three main sections: Company Profile, Network Design, and Performance Metrics. Each section was developed on a Web page.

Section one-Company Profile provided the demographic information about surveyed companies and individuals. Sections two-Network Design allowed to identify the network designs in downstream supply chain. Section three – Performance Metrics was split in two subsections: first one to define the SCOR dimensions, and second one, to see if the companies do measure systematically the performance and the level of competition within their markets.

Company Profile

In this section, I collected demographic data about companies and individuals as units of observation. Respondents were asked to provide data about age, gender, education, job title, principal manufacturing activity, years in business, number of employees at respondent location, manufacturing capability system.

Network Design

The purpose of this section was to see how companies deliver the products on their downstream supply chains. I considered the manufacturer, the intermediary distribution (distributors and retailers) and third party logistics (3PL) as downstream supply chain echelons. Data about sales approach, distribution system, transportation mode, and network configuration were collected.

Performance Metrics

This section was split in two subsections. First one comprised scales of importance based on seven points Likert scales from not important (1) to very important (7). Each SCOR dimension (Reliability, Responsiveness, Flexibility, Supply chain cost, Supply chain assets management efficiency) comprised a set of items – combinations between metrics and best practices.

Second one collected data about order cycle process from order receive until to order deliver, leadtime, delivery system, logistics cost, transportation cost, holding cost, on-time delivery, order fillrate, order accuracy, perfect delivery rate, and degree of competition within their markets.

Sampling

Major issues in sampling are sampling and non sampling errors, sample size and confidence interval.

Two types of errors affect the quality of any survey: non observation and measurement errors.

Groves (1987) showed that in a survey could appear errors due to nonobservation (noncoverage, nonresponse, and sampling). Coverage error refers to the discrepancy between sample survey results and the results of a full enumeration of the population under study that arises because some members of the population are not covered by the sampling frame. Nonresponse errors include all discrepancies between the population characteristics and those estimated from a sample survey that arise because some members of the sample were not measured in the survey. Sampling errors are discrepancies between population characteristics and those estimated from a sample survey that arise because some members of the population were deliberately excluded from the survey measurement through selection of a subset. All three of these errors arise because some part of the population was not measured. There are four potential sources of errors of observation or measurement errors: (1) the interviewer, (2) the respondent, (3) the questionnaire, and (4) the mode of interview (Groves, 1987).

Berenson, Levine, and Krehbiel (2004) showed the types of samples: probability samples (simple random sample, systematic sample, stratified sample, cluster sample) and nonprobability samples (judgments sample, quota sample, chunk sample, and convenience sample).

In the study, I used a convenient sample, based on a list provided by CSCMP. This type of sample increases the nonobservation errors. Surveying business is a difficult task, facing challenges different from those for any other type of survey. These potential difficulties may help explain why a review of 183 business surveys (in selected business journals published since 1990) revealed an average response rate of 21% (Dillman, 2007; Paxson, 1992). The coverage errors are high when the population is formed by business organizations. Costs of surveying companies amplify the errors. The observation units are highly non respondents and incentives to increase the likelihood of a positive feedback cannot be created. However, coverage errors are mainly addressed by efforts to reduce them, not to measure them (Groves, 1987). In doing so, I chose to have a convenient sample and a small reference population (companies that have membership to CSCMP). Previous research in SCM using Likert scales (Sakakibara, Flynn, and Schroeder, 1993, Flynn, 1994, Lockamy and McCormack, 2004) was based on convenient sample with multiple respondents per company. In my study, a common method bias can occur (Tan, 2002) since the respondent was one per company. Using a single informant without collecting and cross-validating responses from a second informant from the same company can increase the measurement error. High costs of surveying multiple informants from the same company made that this research to use data from a single informant per company while attempting to minimize the extent of common method variance by surveying senior executive with key responsibilities focused on downstream supply chain.

Another effort to reduce non response rate was to follow the Dillman's email methodology (1998) that proposed mixed mode to deliver the questionnaire to respondents and multiple contacts. In his research, four treatment groups have been studied. The overall response rate for the study was 55.1 percent. The response rate for the control group (group 1), which received a standard mail approach, was 57.5%. Group 2, which received all e-mail contacts when possible, had a response rate of 58 percent. A chi-square test revealed no significant difference between these two response rates ($p = .924$). The response rate for group 3, which received the paper prenotice, was 48.2 percent. This was significantly lower than both groups 1 and 2, ($p = .048/.038$). Group 4, which received a paper reminder, had a response rate of 54.4 percent, which, although lower, was not significantly different than groups 1 and 2, ($p = .507/.448$). Finally, a response rate of 58.6 percent was achieved for the set of individuals who received a paper survey on their request or because they were unreachable by e-mail. This was not significantly different from the response rate for the "all paper" group 1 ($p = .877$), indicating that the availability of such individuals did not differ from the rest of the population as represented by group 1. Further, the survey comprised in multiple waves as prenotice, letter and survey, thank you/reminder, replacement survey. Mixed mode and multiple contacts were reported by Schaefer (1998) as a way to increase the respondents' motivation because people may appreciate being able to choose their response mode. Smith (1997) had a 5.3% higher response rate with e-mail when using multiple contacts. Kittleson (1997) noted that the second follow-up e-mail doubled the response rate but the third or fourth e-mails had only marginal effects. A research made by Armstrong and Overton (1977) about the impact of the nonresponse bias on mail survey demonstrated that applying extrapolation methods, some improvements could be obtained.

Extrapolation methods are based on the assumption that subjects who respond less readily are more like nonrespondents. “Less readily” has been defined as answering later, or as requiring more prodding to answer. The most common type of extrapolation is carried over successive waves of a questionnaire. “Wave” refers to the response generated by a stimulus, e.g., a follow-up postcard. Persons who respond in later waves are assumed to have responded because of the increased stimulus and are expected to be similar to nonrespondents.

Vehovar et al (2001) showed that in a web survey, only the informed units receive the email message and only the aware units can decide whether to participate in the survey or not. The aware units form the base for the calculation of cooperation rates – ‘the percentage of respondents among eligible and contacted sample units.’ Among the aware units, only the clickers actually click on the website location. And still not all the clickers proceed to fill the questions. The people who decide to take the initial step are called starting units, grouped in two category: partial respondents (people who start answering to the questions but then abandon the survey prematurely) and complete respondents. Partial response is defined as the percentage of partial respondents among all respondents, known also as attrition rate (Kehoe and Pitkow, 1996), failure rate (Jeavons and Bayer, 1997) or drop off rate (Kottler, 1997).

The response rate vary according to the respondents’ characteristics as social-demographics, psychological predisposition, survey experience, interest in the survey topic, and other attitudes (Batagelj andVehovar, 1999).

Cook et al (2000) provided a meta-analysis of response rates in web or internet-based survey. Their results suggested that the number of contacts, personalized contacts, and precontacts were the factors most associated with higher response rates in the web studies analyzed. The search for Web surveys to incorporate in the meta-analysis was far-reaching and included use of several search engines and the examination of studies that themselves were also only reported on the Web. Nevertheless, it must be acknowledged that only a limited number of such studies has been reported to date.

In the study, for the first wave, the total started survey was 42 and total completed survey was 26, with a completion rate of 61.9 % (see table 1). Low response rates alone do not necessarily suggest bias. According to Krosnick (1999) and Dillman (1991), when respondent characteristics are representative of nonrespondents, low rates of return are not biasing. Yet estimating nonresponse is a challenge given that, in most cases, the identity of nonrespondents is unknown (Dey, 1997). Though limited demographic information is sometimes available, these data may not reveal the uniqueness of nonrespondents in terms of their attitudes or how they would have responded to survey items (Sax, Gilmart, and Bryant, 2003).

Couper (2000) showed that potential factors for low response rate in web survey could be the fact that there are not clear techniques that might increase the response rate, technical difficulties and privacy and/or confidentiality concerns. Some organizations keep records of all incoming and outgoing messages, and if the topic of the survey is particularly sensitive, this may discourage employees from completing company-related surveys at the office.

Table 4
Response rate per survey section

Survey Section	**Number of questions/section**	***Response Rate per question***	
		Min	***Max***
Company Profile	**8**	**42**	**42**
Network Design	**4**	**17**	**31**
Performance Metrics (1)	**5**	**30**	**30**
Performance Metrics (2)	**11**	**26**	**26**

Field operations and Data Management

I carried the pilot survey at the OLLU main site with academic professionals, members of IRB. Their suggestions were collected and the first revision of the questionnaire was performed. The second pretest of the questionnaire was made via email with the academic affairs office of CSCMP. Their concerns about security of the survey were solved using data encryption. The collecting process was made by a web survey administration software and the identity of the respondents could not be revealed at any time of the survey. Further, the collected data were downloaded in an EXCEL file format and imported in SPSS, version 14.

Metrics

In the study, I use metrics and best practices to explain each SCOR dimension (attribute). SCOR is a standard reference model created by Supply Chain Council in 1997, now at version 8 (SCC). The model itself contains several sections and is organized around the five primary management processes of Plan, Source, Make, Deliver, and Return. The model can be used to describe supply chains that are very simple or very complex using a common set of definitions. As a result, disparate industries can be linked to describe the depth and breadth of virtually any supply chain. SCOR can describe and provide a basis for supply chain improvement for global projects as well as site-specific projects. SCOR model has five performance dimensions: Delivery Reliability, Responsiveness, Flexibility, Supply Chain Cost and Supply Chain Assets Management Efficiency (see table 5). The model contains at least three levels, at the first level being identified performance metrics that are standard for all types of supply chains.

Table 5
SCOR Performance Dimensions (Attributes) and Level 1 Metrics

Performance Attribute	*Performance Attribute Definition*	*Level 1 Metric*
Delivery reliability	The performance of the supply chain in delivering: the correct product, to the correct place, at the correct time, in the correct condition and packaging, in the correct quantity, with the correct documentation, to the correct customer.	Delivery performance Perfect order fulfillment Line item fill rate
Responsiveness	The velocity at which a supply chain provides products to the customer.	Order fulfillment lead time Supply chain response time
Flexibility	The agility of a supply chain in responding to marketplace changes to gain or maintain competitive advantage	Supply chain response Time Production flexibility
Supply chain cost	The cost associated with operating the supply chain	Cost of goods SGA costs Warranty/returns processing costs Total supply chain cost
Supply chain asset management efficiency	The effectiveness of an organization in managing assets to support demand satisfaction. This includes the management of all assets: fixed and working capital.	Cash-to-cash cycle time Inventory days of supply asset turns

Delivery Reliability dimension defined as 'the performance of the supply chain in delivering: the correct product, to the correct place, at the correct time, in the correct quantity, with the correct documentation, to the correct customer' is explained by a set of five items that comprises SCOR metrics at level 1 (delivery performance, fill rate, perfect order fulfillment) and best practices (table 6).

Table 6
SCOR Delivery reliability

A. Delivery reliability
A1.The ability to meet promised delivery date defined as on-time and in full shipments *(delivery performance)DRA1*
A2.The accuracy in filling order *(perfect order fulfillment) DRA2*
A3.Order cycle consistency such that there is a minimal variance in promised versus actual delivery
A4.Fill rate on base line/in stock items (% of order included in initial shipment) *(line item fill rate)DRA4*
A5.Completeness of order (% of line items eventually shipped complete)

Responsiveness – the velocity at which a supply chain provides products to the customer – is explained by a combination of SCOR metrics at level1 (order fulfillment lead time, supply chain response time) and best practices, totalizing four items (table 7).

Table 7
SCOR Responsiveness

B. Responsiveness
B1. Length of promised order cycle (lead) times (from order submission to delivery) *(order fulfillment lead time)REB1*
B2. Length of time to answer to distribution partners/customers' queries
B3. Length of time to process a received order
B4. Length of time to produce and ship a received order *(supply chain response time)REB4*

Flexibility dimension is defined as 'the agility of a supply chain in responding to marketplace changes to gain and maintain competitive advantage' and is explained by four items, including production flexibility as performance metric (table 8).

Table 8
SCOR Flexibility

C. Flexibility
C1. The ability of manufacturer to identify and supply high volume product as part of "quick ship" program
C2. The ability of manufacturer to automatically back orders base line/in stock items ordered under "quick ship" programs
C3. The ability of manufacturer to meet specific and/or unique customer service and delivery needs of individual customers
C4. The ability of manufacturer to plan, source, make and deliver an unplanned increase or decrease in orders without cost penalty
(production flexibility)FLC4

Supply chain cost, defined as 'the costs associated with operating the supply chain' has as performance metrics costs of goods, sales, general, and administration costs, warranty/returns processing costs, and total supply chain management costs (table 9).

Table 9
SCOR supply chain cost

D. Supply chain cost
D1. Cost for order management (such as purchase order, expediting, etc.)
D2. Cost of goods (such as direct cost of material and labor)
(cost of goods)SCD2
D3. Cost of sales, contract administration, engineering, and lab support of products
(SGA costs)SCD3
D4. Cost of carrying inventory (such as trucking, warehouse, retail)
D5. Cost of transportation
D6. Cost of warranty/returns processing
(warranty/returns processing costs)SCD6
D7. Total supply chain management cost
(total supply chain cost)SCD7

Supply chain asset management efficiency comprises cash-to-cash cycle time, inventory days of supply, and asset turns, among other four performance metrics (table 7).

Table 10
SCOR Supply chain asset management efficiency

E. Supply chain asset management efficiency
E1. Cash-to-Cash cycle time
(cash-to-cash cycle time)AME1
E2. Inventory days of supply
(inventory days of supply)AME2
E3. Asset Turns
(asset turns)AME3
E4. Gross Margin
E5. Operating Income
E6. Return on Assets
E7. Earnings per share

Respondents were asked to grade the importance of the items from each dimension on Likert scales from 1-not important to 7-very important. Research of Miller (1956) demonstrated the people greater accuracy in providing data on a small set of items regarding the same topic. He proposed a 'magical number' of seven items as a boundary and his empirical research demonstrated the human limits in keeping in mind a larger set of items for a specific topic. The research can be used as a further step to provide motivation for the research of Schneiderman (1996) that mitigated for a small set of core performance metrics and not more than five. The magical number can be used also as motivation for the ratio scale of judgments developed by Saaty (1980) to make comparison between alternatives. Choosing a small scale to rank the importance of the dimension items seems to be appropriate in research where the purpose is to obtain a higher homogeneity in answers. Still, the controversy between a continuous scale and a Likert scale has not yet a clear answer concerning the scale choice capability to provide the highest degree of efficiency in measurement. Russell and Bobko (1992) proved that use of relatively coarse Likert scales to measure fine dependent responses causes information loss that, although varying widely across subjects, greatly reduces the probability of detecting true interaction effects.

Research methods

Data collected from the survey are used to construct two models of decision making with the purpose to assist the supply chain managers in taking better, faster and cheaper decisions in selecting the network configuration in downstream supply chain. Data collection process benefits are twofold. Respondents provided information about core performance metrics that allowed constructing a normative model, based on the multiple attribute utility theory (MAUT) under certitude, in the sense of Keeney and Raiffa (1976). The model allows decision makers to use scaling constants as variables and three computations in selecting best alternative. Also, the scales section from the survey provided data about how managers prioritized the importance of performance metrics. The second model is in contrast with the normative model and does allow some inconsistency in the decision maker's judgment. Decision making theory supports three types of approaches: normative (how should people take decisions), descriptive (how people take decisions), and prescriptive (how to do to take good decisions (Bell and Raiffa, 1993). A normative approach is appropriate when decision maker can have access to quantitative data from competitors supply chains. But, this approach is difficult to do because the process of data collection is costly and time consuming, doubled by the refuse of competition to share sensitive data. A solution for these inconveniences can be a descriptive model based on the judgments of the decision makers, developed on a cardinal scale of importance. The Analytic Hierarchy Process can be used as a second solution in selecting best alternatives. The great controversy of AHP is that it takes the world as it is and it does allows inconsistency in judgments that generated critics (Dyer, 1990), considering the results arbitrary.

Both approaches are complementary and are appropriate to be used according to the situation. A decision maker can choose to make a mix of these approaches and compare the results of the approaches.

Chapter Summary

This chapter outlines the research methodology and the research process and instrument developed.

The survey is made up of three sections, which include a section on individual and organizational demographic data, the network designs, and a section of performance metrics, including a subsection that explain the SCOR dimensions as well a subsection that collects data about core performance metrics, and the degree of competition of companies within their markets. All of the metrics were selected based on their high levels of validity and reliability, as provided by support documentation. Moreover, performance in downstream supply chain is expressed in two very different methods: one normative based on quantitative data provided by the respondents, and one descriptive. People do mistakes and in situation of lack of information, policy makers can take decision based on their judgments, using a descriptive approach.

CHAPTER 4 – DOES STRUCTURE INFLUENCE PERFORMANCE IN DOWNSTREAM SUPPLY CHAIN?[1]

Introduction

Human behavior plays an important role in bullwhip effect, defined as an increase of fluctuations in demand as it moves up the supply chain from retailers to wholesalers to manufacturers to suppliers. Research of Forrester (1958) and Sterman (1989) showed that members' perceptions about inventory and demand information, and mistrust in downstream supply chain generate this negative phenomenon.

The bullwhip effect distorts demand information and the supply chain members have a very different estimate of what demand looks like. The effect of the lack of coordination creates increase in variability of performance metrics in the downstream supply chain.(see table1).

Lee et al. (1992) has identified solutions to avoid bullwhip effect as information sharing, channel alignment, and operational efficiency.

Table 11
Impact of Bullwhip Effect on Downstream Supply Chain Performance

Performance Metrics	**Impact of Bullwhip effect**
Manufacturing cost	Increases
Inventory cost	Increases
Replenishment leadtime	Increases
Transportation cost	Increases
Shipping and receiving cost	Increases
Level of product availability	Decreases
Profitability	Decreases

Note: Adapted from Chopra (2003)

Since bullwhip effect is a cause of human behavior within a given downstream supply chain, such questions can be raised: Does structure influence performance in supply chain? Could be avoided this effect reengineering the downstream structure? What type of

[1] I express my gratitude to dr Luis Dias, professor at Coimbra University, Faculty of Economics, Portugal, for providing me the VIP software and for his valuable advices.

downstream supply chain networks are and how can be selected the best network to achieve best performance?

Downstream supply chain refers to the movement and storage activities required to transport a product from the supplier to a customer in the supply chain (Chopra 2003). The process strategies can be figured in many ways using a complex distribution network of internal and external providers or they can be configured as a direct model, such as used by Dell. It has succeeded to eliminate important downstream echelons as distributors and retailers, improving the visibility by creating a direct link with the end-customers. Recently, Dell has announced that they will renounce to use exclusively their famous direct sales approach and they will start to use retailers for some PC models.

The dilemma faced by companies concerns the choice of the best downstream supply chain that balances customer satisfaction and profitability. To solve this dilemma, companies need to have strategic supply chain planning tools to asses the performance along the supply chain.

One example is provided by SCOR model developed by Supply Chain Council in 1996, to integrate business management and improvement practices, including a multi-tiered metric system to improve the plan, source, make, and deliver activities in supply chain.

My study uses SCOR metrics and best practices in selecting the best alternative in downstream supply chain. It can serve as a tool for supply chain managers to plan supply chain networks based on a set of metrics and best practices to obtain a superior performance, continuous improvement and avoid negative phenomena as bullwhip effect.

The chapter is organized as follows. In section one, I identify the relevant performance metrics and best practices in downstream supply chain based on the first wave of a survey carried in June 2007 with 30 top executives from World Class Manufacturers. In section two, I propose a tool to define the best network alternative in downstream supply chain, based on

Multiple Attribute Utility Theory (MAUT), creating a value function with scalable importance criteria coefficients. I express the value function using min-max criteria and three computations: (1) computation of a range of values for each network design alternative; (2) computation of the highest difference for each pair of alternatives, and (3) computation of the maximum regret associated with each alternative.

Decision Making: normative, descriptive and prescriptive approaches

Bell and Raiffa (1988) proposed a trichotomy of approaches in decision making, moving out from the well known dichotomy (normative and descriptive). Normative approach refers to logically consistent decision procedures and how people *should decide*. Descriptive approach shows how people make and how *people decide*. A prescriptive approach provide us knowledge how *to help people* to make good decisions and how to train people *to make better* decisions.

Normative approach supposes that the decision makers are rational and make optimal decisions, being conscious by the consequences of their actions. Normative theory proposes quantitative tools in two environments: certitude and incertitude. Decisions makers use the utility as measure of their satisfaction, with the purpose of maximization in Pareto optimal conditions. Normative theory has its roots in the seminal research of von Neumann and Morgenstern (1947) for expected utility under risk. The principle of transitivity gives consistency in decision making (let suppose that we have three alternatives A, B, and C. If A is better than B, and B better than C, then A is better than C.). Also the consistency is given by the independence of irrelevant alternatives (if a person wants to visit USA or Mexico and evaluates the alternatives based on a set of attributes, he can select the best alternative. If he chooses USA and it does appear Canada with the same attributes value, the third alternative is irrelevant since the tourist wanted to select between USA and Mexico). The normative models are universal and they should apply to all decision makers who want to behave rationally. The descriptive models are general and they should apply to a wide range of decision makers facing similar decision problems. The prescriptive models tend to particular, suitable for a specific situation. The differences among approaches can be seen in table 2.

Table 12
Differences among approaches

Approach	Characteristics	Process to obtain the model
Normative	Exogenous rationality, ideal economic behavior	To postulate
Descriptive	Exogenous rationality, empirical behavior models	To observe
Prescriptive	Endogenous rationality, coherence	To unveil

Note. Adapted from Dias (2004).

The work of Keeney and Raiffa (1976) enlarged the normative vision, creating the preferences representation function and defined as value function using multiple attributes. The attributes should be complete (they should cover the most part of the problem), operational (the attributes must be meaningful to the decision maker, so that he can understand the implications of the alternatives), decomposable (a problem should be broken down into parts of smaller dimensionality), nonredundant, and in minimum size (attributes should be in smaller number to avoid the risk of excluding important concerns by dividing the attributes). Any problem of multiple attributes utility theory (MAUT) supposes the following steps:

1. statement of problem (defining the goal)
2. identification of alternatives
3. selection of relevant attributes
4. construction of value function
5. selection of best choice

In selecting the best performance metrics, I followed the definition of Neely, Gregory and Platts (2005) of performance measure as “a metric used to quantify the efficiency and/or effectiveness of an action”. Since a decision model to be effective requires a small number of alternatives (in the case of a large set of alternatives, a selection process based on ranking should be applied) and a small set of criteria (in the case of a large set of criteria, the problem risks to have suboptimal solutions or solutions that are not in the optimality range. A decomposition process should be applied.), I considered a set of performance metrics that are monotonic and improvement in metrics must lead to improvement in shareholder wealth (Schneiderman, 1996).

Performance metrics topic in supply chain was identified by Johnson and Pyke (2000) as one of twelve main topics for supply chain management. A survey developed by ARC Advisory Group (2005) with 130 logistics executives from 1000 Global companies revealed that supply chain metrics is the top priority for companies, obtaining an average of 2.97 points from a 4 points scale.

Still, a research carried by Bain & Company (2000) showed that more than 85% of senior executives said improving their supply chain performance is one of their top priorities, but fewer than 10% were adequately tracking that performance. And fewer still -7% - collected the information necessary to meaningfully measure their progress. The study, which polled 162 top managers with supply chain oversight, also found that the supply chain gap is set to widen: two-thirds of companies that said they are already ahead rate improvement of supply chain performance as a high or top priority; but just over a third of laggards said they will prioritize catching up.

In the following section I present the performance metrics to express performance in downstream supply chain based on the first wave of a survey carried in June 2007 with 30 top executives from World Class Manufacturers. The purpose of the survey was to identify which are the most important items that explain the SCOR dimensions (Delivery reliability, Flexibility and Responsiveness, Supply chain cost, Supply chain assets management efficiency), but also to define the network designs in downstream supply chain.

Criteria and subcriteria based on performance metrics and best practices in downstream supply chain

Stewart (1995) presented the first framework about the processes encompassed in SCOR model-Plan, Source, Make, and Deliver. He considered four key areas to unlock supply chain excellence: (1) delivery performance; (2) flexibility and responsiveness; (3) logistics cost; (4) asset management. These areas have become key dimensions in SCOR model. The model is a product of the Supply Chain-Council (SCC)-organization founded in 1996 by Pittigilio Rabin Todd & McGrath (PRTM) and AMR Research. Starting with the fifth version, the model has encompassed also the Return process. Stephens (2001) pointed: "Plan activities balance resources and demand and provide integration between activities and organizations. Source activities are those that are associated with acquiring raw materials and source activities connect organizations with their suppliers. Deliver activities are those activities that are associated with the management of orders and the delivery of finished goods. Deliver activities connect an organization with its customers. Most organizations have Make activities that transform raw materials into finished goods but not always. Returns activities are those activities to return the raw materials to suppliers and the receipt of returns of finished good from customers."

In order to identify the most significant performance metrics and best practices that express the SCOR dimensions, I surveyed 30 top executives from world class companies in different industrial sectors such as machinery manufacturing; computer and electronic product manufacturing; electrical equipment, appliance, and component manufacturing; and transportation equipment manufacturing. The executives had key responsibilities in logistics planning, logistics management, traffic/transportation management, warehouse operations/management, material handling operations, inventory planning, production, internal consulting or corporate research, international planning, purchasing. The individuals had positions from senior manager to president. A personalized email invitation and web survey instrument were used as questionnaire carrying ways. Questionnaire has comprised three sections: Company Profile, Network Design, and Performance Metrics. Section one-Company Profile provided demographic information about surveyed company and individuals. Sections two-Network Design allowed identifying the network designs in downstream supply chain. Section three – Performance Metrics was split in two subsections: first one to define the SCOR dimensions, and second one, to see if the companies measure systematically the performance and the level of competition within their markets.

Network Design

The purpose of this section is to see how companies deliver the products on their downstream supply chains. Chopra (2003) identified six network designs: manufacturer storage with direct shipping, manufacturer storage with direct shipping and in-transit merge, distributor storage with package carrier delivery, distributor storage with last mile delivery, manufacturer/distributor storage with costumer pickup, retail storage with customer pickup. The purpose of his research was to present the performance of each of them based on two factor categories: cost factor (inventory, transportation, facilities and handling, information), and service factor (response time, product variety, product availability, customer experience, order visibility, returnability).

In the my study, respondents were asked to provide information about company's approach to sale (direct sales, intermediary distribution, or both), transportation mode (proprietary fleet, third party logistics or both), number of nodes covered in downstream supply chain.

. I consider the manufacturer, the intermediary distribution (distributors and retailers) and third party logistics as downstream supply chain echelons.

Based on these echelons, I have found seven network configurations, presented in table 13.

Table 13
Network Configurations in Downstream Supply Chain

No.	***Network Configuration***	Description
1.	**DS-3PL-B2B**	Manufacturer sells products using a direct sales approach and third party logistics. The customer is a business company.
2.	**DS-3PL-B2C**	Manufacturer sells products using a direct sales approach and third party logistics to end-customers.
3.	**DS-OF-3PL-B2B**	Manufacturer sells products using a direct sale approach, own fleet and third party logistics. The customer is a business company.
4.	**ID-3PL-B2B**	Manufacturer sells products using an intermediary distribution approach and third party logistics. The customer is a business company.
5.	**DS-ID-3PL-B2B**	Manufacturer sells products using both sales approaches, direct sales and intermediary distribution, and third party logistics. The customer is a business company.
6.	**DS-ID-3PL-B2C**	Manufacturer sells products using both sales approaches, direct sales and intermediary distribution, own fleet, and third party logistics to end-customers.
7.	**DS-ID-OF-3PL-B2C**	Manufacturer sells products using both sales approaches, direct sales and intermediary distribution, own fleet and third party logistics to end-customers.

Note. DS – Direct sales approach, ID-intermediary distribution, 3PL-third party logistics, OF-own fleet, B2B-business-to-business, B2C-business-to-consumer.

The combinations of main echelons in downstream supply chain can lead also to other types of network designs, but for the study, I used only the configurations identified by respondents. As I emphasized in chapter 3, the response rate can affect, sometimes dramatically, the validity of the number of network designs. To reduce this bias, I chose companies from a determined set of industries as a point of interest. The main purpose of the study is to show different solutions for multiple situations that could face a decision maker. The methodology proposed can be replicated for a wider set of network designs, but it is recommendable for a larger set of alternatives to decompose the problem by creating smaller subsets of alternatives, using clustering technique.

Performance Metrics

Van Landeghem and Persoons (2001) created a causal model for logistics audit, to explain the performance in the management of the supply chain. They linked key metrics

(SCOR and others) with best practices and top objectives as flexibility, reaction time, quality and return on assets in eight domains of an enterprise: employees; planning and control; production and assembly; research and development; distribution; order handling; purchase and suppliers; market and clients.

In order to explain each dimension of SCOR model, I developed seven points Likert scales, and the respondents were asked to rate from one to seven the degree of importance of performance metrics and best practices.

According to Tam and Tummala (2001) just the relevant criteria should be kept to explain the performance in supply chain. Relevant criteria were considered those that had a mean value greater than a cut-off value on their Likert scale, from 1-not important to 3-very important. In our model, we keep all the items that had a mean value greater than 5-important on the Likert scale. As a result, the items "the ability to automatically back order base line/in stock items under 'quick ship' mode" (mean: 4.93)-Flexibility dimension and "cost of warranty/return processing" (mean: 4.10)-Supply chain cost dimension have been deleted (see chapter 5).

The model

In this section, I present a model of Multiple Attribute Utility Theory (MAUT) in the sense of Keeney and Raiffa (1976) that defined a preference representation function as a value function.

In the model, I consider the value function to represent the best downstream supply chain network design under certainty, using a set of attributes as decision criteria.

Selecting the best downstream supply chain network is a case for MAUT. Previous research of Viswanadham and Raghavan (2000), Agarwal, Shankar, and Tiwari (2005), Yang and Chen (2006) provided different approaches of modeling supply chain networks. The main shortage is that at a strategic level, decisions makers need to have a broad vision about their supply chain. An optimization model using linear programming or mix integer programming, in deterministic and stochastic environment, provides solution (optimal or a heuristic one) using just one performance metric and the others as constraints. A linear programming model uses a performance metric as objective function (most known: optimization of strategic network design by minimizing the cost, maximizing the flow or finding the shortest path from manufacturer to end-customer).

MAUT provides a better vision for the whole supply chain and gives a solution when decision makers want to use more decision criteria to select an alternative.

Research Methodology

Dias and Climaco (2000) showed that when the number of alternatives is relative small (in our case, seven alternatives) a good approach in selecting the best alternative from the set is pairwise comparisons. Also, decision makers can be in situations when the data available are not enough to provide a precise value for the importance of each performance metric. The solution is to use a linear program to scale the coefficients of importance of each metric according to the judgment of decision maker or based on hard data (strategic planning from the company governance) or soft data (empirical evidence). For the following model, I propose that the importance coefficients to be ranked by the respondents involved in the first wave of the survey. In section three of the survey, Performance Metrics, respondents ranked each item from the SCOR construction, using a scale of importance of seven points (by convention, a Likert scale) from one –non important to seven-very important. The methodology proposed requires an algorithm with the following steps:

Step1

Identifying the relevant performance metrics to be used as attributes in the model. The proposed metrics are perfect order defined as perfect deliveries per total deliveries (DRA2) (in percents), delivery performance defined as orders delivered on-time per total orders

(DRA1) (in percents), order fillrate defined as orders filled complete per total orders (DRA4) (in percents), total supply chain cost defined as supply chain IT plus finance and planning plus inventory carrying plus material acquisition plus order management costs plus return management costs (SCD7) (in percents), supply chain leadtime as the time from order receipt to order deliver to the customer (REB1) and, order accuracy as error-free orders per total orders (DRA3) (in percents).

Step 2

Establishing the importance priorities based on the respondents' ratings. Based on Keeney and Raiffa (1976), I normalize the mean of the items ratings (1-worst case, 7-best case – see table 14). As result, perfect order>delivery performance>order fillrate>total supply chain cost>leadtime>order accuracy. The sum of the scaling weights is equal with one. The scaling weights represented by importance of items flow freely from zero to one.

Table 14
Descriptive Statistics of Items Importance

	N	Minimum	Maximum	Mean	Std. Deviation
DRA1	30	4	7	6.63	.76
DRA2	30	5	7	6.80	.48
DRA4	30	4	7	6.43	.77
DRA3	30	5	7	6.13	.78
REB1	30	4	7	6.17	.83
SCD7	30	4	7	6.27	.87
Valid N (listwise)	30				

Step 3

Model assumptions

I consider a set of alternatives A represented by the seven supply chain configurations (DS-3PL-B2B; DS-3PL-B2C; DS-OF-3PL-B2B; ID-3PL-B2B; DS-ID-3PL-B2B; DS-ID-3PL-B2C; DS-ID-OF-3PL-B2C) and a set of criteria C represented by SCOR performance metrics (perfect order, delivery performance, order fillrate, total supply chain cost, leadtime, order accuracy) and a set of acceptable combinations of values for the criteria weights (scaling weights).

The model assumptions are summarized here:

A - set of alternatives, we consider m alternatives, $a_1, \ldots, a_m$,

C - set of criteria, we consider n criteria,

w_j*-criteria weight (scaling constant) associated with* $v_j(\cdot)$,

W - set of acceptable combinations of values for the criteria weights at a given stage of the decision aid process

(each combination is represented as a vector $w \in W$*. All the elements of the set satisfy the constraints*

$w_j \geq 0$ *and* $\sum_{j=1}^{n} w_j = 1$.

Step 4

Constructing the value function as:

$$V(a_i, w) = \sum_{j=1}^{n} w_j v_j(a_i), \text{ where } w = (w_1, \ldots, w_n) \text{ is an element of the set } W.$$

The value function is an additive linear function that expresses the value of each alternatives based on a sum of the criteria values (normalized) multiplied with the scaling weights.

Step 5

The data obtained from the survey are normalized an *m x n* pairwise confrontation table is analyzed, that is represented as $M = (m_{ij})$. (See figure 1.)

Figure 1
Normalization mxn pairwise confrontation table

Data | Bounds | Constraints

Criteria:	TOTAL_SUPPLY_(	DELIVERY_PERFC	ORDER_FILLRATE	ORDER ACCURAC	PERFECT_ORDER	LEADTIME
Importance:						
DS-3PL-B2B	0.29	0.92	0.7	0.88	0.88	0.95
DS-3PL-B2C	0.83	0.88	0.92	0.91	1	0.72
DS-OF-3PL-B2B	0.92	0.53	0.55	0.65	0.56	0.92
ID-3PL-B2B	1	1	1	1	1	1
DS-ID-3PL-B2B	0.94	0	0.2	0.96	0.82	0.97
DS-ID-3PL-B2C	0.76	0.83	0.78	0.44	0	0.9
DS-ID-OF-3PL-B2C	0	0.19	0	0	0.45	0

Keeney and Raiffa (1976) proposed that the value of the worst level of attributes to be fixed at zero and the best level of attributes to be fixed at one. The reason of doing so can be explained by the different measure units in that are expressed the performance metrics. The normalization process is based on max-min principles based on the objective attribute. Leadtime and total supply chain cost are minimized, meanwhile perfect order, delivery performance, order fillrate, and order accuracy are maximized.

The min-max principles are expressed by the following formulas:

$$\min(v_j(a_i)) = \frac{v_j - v_{j\min}}{v_{j\min} - v_{j\max}}$$

respectively,

$$\max(v_j(a_i)) = \frac{v_{\max j} - v_j}{v_{j\max} - v_{j\min}}$$

Step 6

Computations

The model proposes three types of computations (Dias, 2000): (1) computation of a range of values for each network design alternative; (2) computation of the highest difference for each pair of alternatives, and (3) computation of the maximum regret associated with each alternative. Each computation is realized by comparing each alternative value with another one, pairing them.

- Computation of range of value for each alternative a_i: the minimum value of a_i given W can be computed by solving a linear program (LP) with the scaling weights $W=(w_1,w_2,\ldots,w_n)$ as variables; or the maximum value of a_i given W can be computed by solving another LP. The LP helps to choose the best value for any scaling weight, situated on the interval [0, 1].

- Computation of the highest difference of value for each ordered pair of alternatives: given an ordered pair of alternatives $(a_i,a_j) \in A^2$ and W, an LP may be solved to find the maximum possible advantage of the first alternative over the second one. If the maximum difference is negative or null

$$m_{ij} = \max\{V(a_i, w) - V(a_j, w) : w \in W \}$$

then

$$V(a_i, w) \geq V(a_j, w) \forall w \in W$$

If the maximum difference does not exceed a tolerance parameter ε, then

$$V(a_i, w) \geq V(a_j, w) - \varepsilon, \forall w \in W$$

- Computation of the "maximum regret" associated with choosing each alternative: give an alternative $a_i \in A$, the set $A\backslash\{a_i\}$, and W, this amounts to find the maximum difference of value by which ai can lose to another alternative in $A\backslash\{a_i\}$. The scaling weights $w= (w_1,w_2,\ldots,w_n)$ are considered as variables (rather than being fixed) to allow the regret to be as high as possible given A and w.

$$\text{Regret}_{\max}(a_i) = \max_{w \in W}\{\max_{j=1,..,m}\{V(a_j,w) - V(a_i,w): w \in W\}\}$$

If $\text{Regret}_{\max}(\text{a}_\text{i}) = 0$ then we can say that the alternative a_i *is optimal.*

If $\text{Regret}_{\max}(\text{a}_\text{i}) \leq \varepsilon$ then we can say that the alternative a_i *is "quasi-optimal", with tolerance ε.*

Discussion of findings

Maximum regret computation does allow to decision makers to see how much they loose if they select a certain alternative respecting others. Even in the situation when the decision maker cannot provide a fix value for weights, he/she has two options:

1. scaling weights from zero to one based on his judgments, ratings each criteria.

2. scaling weights from zero to one based on empirical evidence (e.g. case studies, previous research, survey), using ratings made by multiple respondents with key responsibilities in the study area.

Maximum regret is defined as the maximum disadvantage of an alternative when compared with another. This disadvantage can be seen as a lost opportunity in not selecting another alternative. The method permits two kind of computations: when there is an alternative that dominates absolutely any other alternatives (absolute dominant) and a computation when there is an alternative that dominates (but not in all criteria) other alternatives, imposing an tolerance parameter. In the study the network configuration 'ID-3PL-B2B' is the best structure (0-the lowest disadvantage), being absolute dominant respecting other five network configuration and dominant respecting one configuration (see figure 2). Alternative 'DS-3PL-B2C' is just dominated by 'ID-3PL-B2B' because has the same maximum value (1) as the best alternative for any given scaling coefficient, but the minimum value is inferior to the minimum value of the best alternative (0.87 respecting 1).

In the case of close values, the decision maker can eliminate the absolute dominated alternatives and imposes a tolerance performance (around 10%) and can recalculate the value functions.

Figure 2
Maximum regret of the downstream supply chain network configurations

Summary | Range | Confrontation | Max Regret

Alternative	Value	Min Value	Max Value	Max Regret	Dominated?
DS-3PL-B2B		0.698	0.9	0.302	YES (Abs)
DS-3PL-B2C		0.87	1	0.13	YES
DS-OF-3PL-B2B		0.545	0.696	0.455	YES (Abs)
ID-3PL-B2B		1	1	0	
DS-ID-3PL-B2B		0.34	0.82	0.66	YES (Abs)
DS-ID-3PL-B2C		0	0.654	1	YES (Abs)
DS-ID-OF-3PL-B2C		0.107	0.45	0.893	YES (Abs)

The minimum and maximum value computations of the alternatives provide the best alternative. An alternative to be "best-in-class" should fulfill the following principle: the minimum value of the corresponding function has to have higher value than the maximum value of any other network configuration (see figure 2).

In the study, the highest number of minimum value is given by the alternative 'ID-3PL-B2B' (1) and the smallest number is given by the alternative 'DS-ID-3PL-B2C' (0).

The confrontation table provides the highest difference of value for each ordered pair of alternatives: given an ordered pair of alternatives *(a_i,a_j)*, it can be computed the highest differences between alternatives to express the advantage of one against another one. The computation supposes to use a linear program for scaling weights and keeps the highest difference for any given weights. The red negative cells express the dominance of column alternative against the row alternative (e.g. 'DS-3PL-B2B' is better than 'DS-OF-3PL-B2B' by 0. 052). The alternative 'ID-3PL-B2B' has the best value also in this computation (from 0.13 to 1).

Figure 3
Confrontation table results for the downstream supply chain network configurations

Summary | Range | Confrontation | Max Regret

	DS-3PL-B2B	DS-3PL-B2C	DS-OF-3PL-B2B	ID-3PL-B2B	DS-ID-3PL-B2B	DS-ID-3PL-B2C	DS-ID-OF-3PL-B2C
DS-3PL-B2B		-0.04	0.355	-0.1	0.493	0.88	0.663
DS-3PL-B2C	0.21		0.44	0	0.593	1	0.77
DS-OF-3PL-B2B	-0.052	-0.174		-0.304	0.207	0.56	0.582
ID-3PL-B2B	0.302	0.13	0.455		0.66	1	0.893
DS-ID-3PL-B2B	-0.06	-0.18	0.26	-0.18		0.82	0.542
DS-ID-3PL-B2C	-0.094	-0.216	-0.01	-0.346	0.197		0.526
DS-ID-OF-3PL-B2C	-0.43	-0.55	-0.11	-0.55	-0.09	0.45	
Max Regret:	0.302	0.13	0.455	0	0.66	1	0.893

An interesting finding is that the alternative 'DS-ID-OF-3PL-B2C' has the worst values. Still, this network design is wide used and it can be found in almost all industries and manufacturing capabilities (to order, to stock or mixed). At the beginning of the chapter, I emphasized the importance of bullwhip phenomena and its effects on supply chain performance. A long supply chain with multiple echelons is difficult to manage. These findings consolidate the idea behind bullwhip – ***as much does increase the number***

***of echelons, as much does increase the difficulty to manage it.* Companies that have chosen to use this network configuration should improve their performance by a continuous screening process on core performance metrics. An extension of the model will be to provide a benchmark for companies in same industries and cross industries.**

Another extension could be a model with multiple decision makers, even spatially distributed. The main problem of multiple decision makers is given by the difficulty to reach an agreement among them (a solution could be the geometric mean of the decision makers' preferences.).

Chapter summary

In this chapter, I present a multiple attribute utility theory model that can be used for the decision makers in supply chain to select the best downstream supply chain network configuration. The problem of selecting the best choice from a set of network designs can be approached using multiple criteria decision aid tools when the data collection process is available and reliable. The main advantages of this method are the avoidance of the issue of rank preservation and rank reversal when an alternative is added/deleted, and the selection of the best alternative is based on a combination between data and judgments (the respondents from the first wave of the survey were asked to rank the importance of the performance metrics on a seven points Likert scale). The main potential deficiencies of the method could be in the situation when the decision makers could not have access to data (to expensive or impossible to collect the data regarding the specific issue) and it uses just tangible criteria (quantitative criteria). When it does appear at least one of the two situations, an alternative approach of Analytic Hierarchy Process (AHP) could be explored (chapter 5).

CHAPTER 5 - PERFORMANCE METRICS IN DOWNSTREAM SUPPLY CHAIN – A DESCRIPTIVE APPROACH

Introduction

Performance in supply chain was approached using different methodologies, from theoretical concepts to empirical studies (Glaser and Cirtita, 2007). The present study proposes an approach of performance in downstream supply chain, with the goal to select the best network structure, based on Analytic Hierarchy Process (AHP), a pairwise judgments comparisons method.

The Analytic Hierarchy Process was created by Thomas Saaty (1977, 2006) and is a systematic procedure for representing the elements of any problem, hierarchically. The AHP 'includes procedures and principles used to synthesize the many judgments to derive priorities among criteria and subsequently for alternative solutions'.

This method has proven its success being used in a large activity sectors from economics and planning to consulting (Zahedi, 1986). Vaidya and Kumar (2006) presented a framework of AHP applications in areas as personal, social, manufacturer sector, political, engineering, education, government, sports, etc.

In spite of the great success of the method, researchers debated some potential deficiencies of the AHP, especially about rank reversal and arbitrary rankings (Belton and Gears, 1983). Dyer (1990) has considered the AHP being "flawed as procedure for raking alternatives in that the rankings produced by this procedure are arbitrary". The problem of rank preservation and rank reversal when another alternative is added/deleted still remains an unsolved issue in the AHP, being the major criticism of the utilitarians that consider the issue as a violation of rationality.

The AHP can be used as a performance measurement instrument by incorporating into the hierarchy assessment criteria with which to compare the actual performance of a system with its desired performance. Research in supply chain performance using AHP methodology has been made mostly on upstream part of supply chain in supplier selection issue.

Ghodsypour and O'Brien (1998) created a model of supplier selection by including tangible and intangible factors. AHP and linear programming are used to choose best suppliers and the optimum order quantities among them such that the total value of purchasing becomes maximum.

Wang, Huang and Dismukes (2004) proposed an integrated AHP and preemptive goal programming (PGP) methodology. While the AHP process matched product characteristics with supplier characteristics to qualitatively determined supply chain strategy, PGP mathematically determined the optimal order quantity from the chosen suppliers. Huang (2004, 2007) treated the issue of performance in supply chain proposing different methodologies based on SCOR model and AHP to select best supplier.

AHP methodology[2]

Any AHP model requires the following steps (Saaty, 1991):

1. Define the studied problem by establishing at the very top level the goal (e.g. choose the best network design in downstream supply chain)
2. Structure the hierarchy from the top (objectives) through the intermediate levels (criteria and subcriteria) to the lowest level (set of alternatives)
3. Construct a set of pairwise comparison matrices for each of the low levels-one matrix for each element in the level immediately above. Every lower level element affects every upper level element. Elements in the lower level are compared to each order on their effect on the governing element above. The comparisons are put in the judgments matrix, each judgment being expressed as an integer. The judgments are made based on the fundamental nine ratio scale (see table 1).

[2] Special thanks to dr Thomas Saaty and dr Garuti for the valuable insights offered.

4. There are n(n-1)/2 judgments required to develop each comparison matrix.
5. After pairwise comparisons, a consistency index is calculated using the eigenvalue. The consistency index is tested using the departure of λ_{max} from n compared with corresponding mean value for random entries yielding the consistency ratio C.R.
6. Steps 3, 4 and 5 are performed for all the levels and clusters in the hierarchy.
7. The hierarchical synthesis is used to weight the eigenvectors by the weight of the criteria and the sum is taken over all weighted eigenvector entries corresponding to those in the next lower level of the hierarchy.
8. The consistency of the entire hierarchy is found by multiplying each consistency index by the priority of the corresponding criterion and adding them together. The result is divided by the same type of expression using the random consistency index corresponding to the dimensions of each matrix weighted by the priorities as before. The consistency ratio C.R. should be about 10% or less to be acceptable.

Table 15
AHP fundamental ratio scale

Intensity of importance	***Definition***	Explanation
1	Equal importance	Two activities contribute equally to the objective
2	Weak	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation

Note. From Fundamentals of Analytic Hierarchy Process (p. 73), by T. Saaty, 2004, Pittsburgh: RWS Pubications.

Discussion of methodology

"The AHP is flawed as a procedure for ranking alternatives in that the rankings produced by this procedure are arbitrary. This flaw can be corrected, but not by moving away from traditional methods of analysis. The key to the proper use of the AHP relies on its synthesis with the concepts of multiattribute utility theory (Dyer 1990, p 249)."

These phrases belong to prof. Dyer that kept the attention of the academic world by showing potential shortages of the AHP methodology. The debate of ranking reversal and rank preservation has the roots in the utility theory that states if one is given a set of independent alternatives, a set of attributes of given weights, independent from the alternatives, and if the weights of the alternatives depend only on the criteria, then **the rank of the alternatives may change only if the weights of the criteria are changed, or if on introducing or deleting alternatives new criteria are introduced or old ones deleted.** Unfortunately, the traditional utility does not give a solution for hierarchical decision problems, ranking criteria based on interval is not a valid option. The solution proposed by Saaty to use a fundamental ratio scale as a major mean of comparing two homogeneous objects represents an alternative that can control the potential inconsistencies of people's judgments. The AHP is a measurement method based on judgments and potential errors can appear. To control the inconsistencies, Saaty proposed using eigenvector and eigenvalues to normalize the priorities in judgments. Also, the inconsistency is supported by the real life when people do not behave rationally and they make decisions without respecting normative approach. A potential advantage over the traditional utility theory in the sense of von Neumann and Morgenstern (1944) is represented by the fact the decision makers can arrive to outcomes using their preferences and not utility functions. People do have preferences and not utility functions. The complex mechanism of utility theory does help to explain phenomena and understand behaviors but does not help always the policy makers to take a decision in real time. Still, the MAUT does provide a good solution in certain environments and conditions. Rejection of a method by favoring another is risky and counterproductive. Academics and practitioners gave the validity proof for both methods. Saaty (1994) showed that more 1,000 papers, books, reports, and dissertations were written on the subject of AHP.

The present study presents both methods, explaining when each method does fit to be applied.

The AHP is based on three principles: decomposition, comparative judgments, and synthesis of priorities.

The decomposition principle is applied by structuring a simple problem with elements in a level independent from those in succeeding levels.

The principal of comparative judgments is applied to construct pairwise comparisons of the relative importance of elements in some given level with respect to a shared criterion or property in the level above. This builds a reciprocal paired comparison matrix and its corresponding principal eigenvector.

The principal of synthesizing priorities refers to the fact that the AHP priorities are synthesized from the second level down by multiplying local priorities by the priority of their corresponding criterion in the level above, and adding for each element in a level according to the criteria it affects.

Principal Eigenvector and Eigenvalues

The third principle of AHP brings in discussion the synthesis of priorities. A hierarchy multi-criteria decision problem requires hierarchic decomposition that generates local and global priorities. From the set of pairwise comparison matrices, it is generated a set of local priorities which express the relative impact of the set of elements on an element in the level immediately above. It can be found the relative strength, value, worth, desirability, or probability of each of items being compared by "solving" the matrices, each of which has reciprocal properties. That creates the need of computation of a set of eigenvectors for each matrix and then normalization to unity the result in order to get the vectors of priorities.

One method of computation of eigenvector is using the geometric mean by multiplying the elements in each row and taking their nth root where n is the number of elements. Then normalize to unity the column of numbers thus obtained by dividing each entry by the sum of all entries. Alternatively, normalize the elements in each column of the matrix and then average each row.

Below, I will consider a case with a set A of four elements A= (A_1, A_2, A_3, A_4) and a set of judgments W= (w_1, w_2, w_3, w_4).

I have

	A_1	A_2	A_3	A_4
A_1	$\frac{w_1}{w_1}$	$\frac{w_1}{w_2}$	$\frac{w_1}{w_3}$	$\frac{w_1}{w_4}$
A_2	$\frac{w_2}{w_1}$	$\frac{w_2}{w_2}$	$\frac{w_2}{w_3}$	$\frac{w_2}{w_4}$
A_3	$\frac{w_3}{w_1}$	$\frac{w_3}{w_2}$	$\frac{w_3}{w_3}$	$\frac{w_3}{w_4}$
A_4	$\frac{w_4}{w_1}$	$\frac{w_4}{w_2}$	$\frac{w_4}{w_3}$	$\frac{w_4}{w_4}$

If $\frac{w_1}{w_1}$ x $\frac{w_1}{w_2}$ x $\frac{w_1}{w_3}$ x $\frac{w_1}{w_4}$ are multiplied out and then the 4th root taken, an estimate of the first component of the principal eigenvector has been developed from this row, and so on.

The eigenvector component row 1 = $\sqrt[4]{\frac{w_1}{w_1} x \frac{w_1}{w_2} x \frac{w_1}{w_3} x \frac{w_1}{w_4}}$

Once the n eigenvector components have been developed for all the rows, it becomes necessary to normalize them to do further computation.

The matrix

Compute estimates of the eigenvector components from the rows

Normalize the result to get the estimate of vector of priorities

$$
\begin{array}{c|cccc}
 & A_1 & A_2 & A_3 & A_4 \\
\hline
A_1 & \frac{w_1}{w_1} & \frac{w_1}{w_2} & \frac{w_1}{w_3} & \frac{w_1}{w_4} \\
A_2 & \frac{w_2}{w_1} & \frac{w_2}{w_2} & \frac{w_2}{w_3} & \frac{w_2}{w_4} \\
A_3 & \frac{w_3}{w_1} & \frac{w_3}{w_2} & \frac{w_3}{w_3} & \frac{w_3}{w_4} \\
A_4 & \frac{w_4}{w_1} & \frac{w_4}{w_2} & \frac{w_4}{w_3} & \frac{w_4}{w_4}
\end{array}
$$

$$\sqrt[4]{\frac{w_1}{w_1} x \frac{w_1}{w_2} x \frac{w_1}{w_3} x \frac{w_1}{w_4}} = a$$

$+$

$$\sqrt[4]{\frac{w_2}{w_1} x \frac{w_2}{w_2} x \frac{w_2}{w_3} x \frac{w_2}{w_4}} = b$$

$+$

$$\sqrt[4]{\frac{w_3}{w_1} x \frac{w_3}{w_2} x \frac{w_3}{w_3} x \frac{w_3}{w_4}} = c$$

$+$

$$\sqrt[4]{\frac{w_4}{w_1} x \frac{w_4}{w_2} x \frac{w_4}{w_3} x \frac{w_4}{w_4}} = d$$

$\overline{}$

Total

Add the column and normalize

$$\frac{a}{Total} = x_1 \qquad \frac{b}{Total} = x_2 \qquad \frac{c}{Total} = x_3 \qquad \frac{d}{Total} = x_4$$

The last step is represented by the multiplication of the matrix by the vector of priorities. The first element of a row is multiplied by the first element of the column of xs; and so on. Then, it is obtained one number, Y, for that row as follows:

$$
\begin{bmatrix}
\frac{w_1}{w_1} & \frac{w_1}{w_2} & \frac{w_1}{w_3} & \frac{w_1}{w_4} \\
\frac{w_2}{w_1} & \frac{w_2}{w_2} & \frac{w_2}{w_3} & \frac{w_2}{w_4} \\
\frac{w_3}{w_1} & \frac{w_3}{w_2} & \frac{w_3}{w_3} & \frac{w_3}{w_4} \\
\frac{w_4}{w_1} & \frac{w_4}{w_2} & \frac{w_4}{w_3} & \frac{w_4}{w_4}
\end{bmatrix}
\begin{vmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{vmatrix}
=
\begin{array}{l}
\frac{w_1}{w_1} x_1 + \frac{w_1}{w_2} x_2 + \frac{w_1}{w_3} x_3 + \frac{w_1}{w_4} x_4 = Y_1 \\
\frac{w_2}{w_1} x_1 + \frac{w_2}{w_2} x_2 + \frac{w_2}{w_3} x_3 + \frac{w_2}{w_4} x_4 = Y_2 \\
\frac{w_3}{w_1} x_1 + \frac{w_3}{w_2} x_2 + \frac{w_3}{w_3} x_3 + \frac{w_3}{w_4} x_4 = Y_3 \\
\frac{w_4}{w_1} x_1 + \frac{w_4}{w_2} x_2 + \frac{w_4}{w_3} x_3 + \frac{w_4}{w_4} x_4 = Y_4
\end{array}
$$

The model

In constructing the model, I used the Liberatore's (1995) five-point rating scale of Superior (S), Excellent (E), Good (G), Acceptable (A), Fair (F) and determined the pairwise comparison judgment matrix. According to Liberatore (1995), I assume the difference in relative importance between two adjacent scales with respect to a particular scale is constant at 2 times.

Table 16
Pairwise comparison judgment matrix for five-point rating scale.

	S	E	G	A	F
S	1	3	5	7	9
E	1/3	1	3	5	7
G	1/5	1/3	1	3	5
A	1/7	1/5	1/3	1	3
F	1/9	1/7	1/5	1/3	1

Application of the AHP model to select the best alternative in Downstream Supply Chain

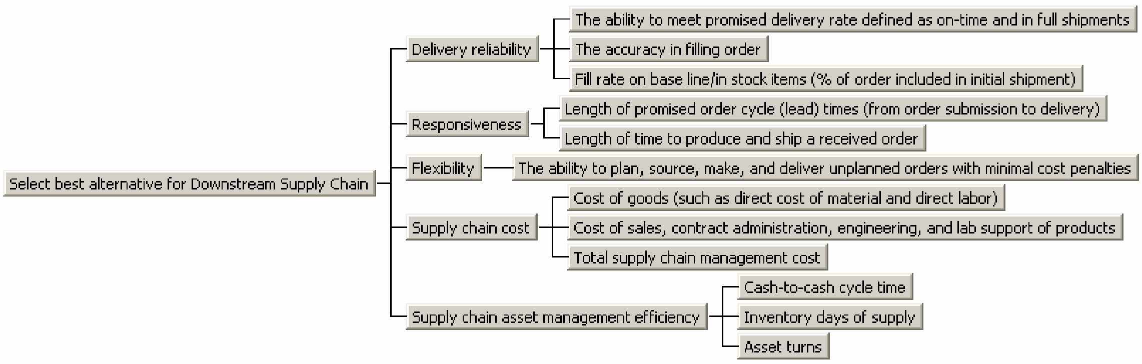
A decision maker from a world manufacturing company, with responsibilities in logistics and supply chain management, was involved in selecting the downstream supply chain network.

Develop the hierarchy

Structure the hierarchy from the top (objectives) through the intermediate levels (criteria and subcriteria) to the lowest level (set of alternatives) (see figure 4).

As I emphasized in the precedent sections, selecting the best alternative for downstream supply chain can be represented as a hierarchy decisions problem. Using multiple criteria, the decision maker can have a balanced approach. When the decision maker doesn’t have enough quantitative information from primary sources (e.g. empirical evidence, hard data), he or she can use the judgments in prioritizing the criteria according the goal. In the model, the policy maker has a hierarchy with four levels: top level – the goal: Select the best alternative for downstream supply chain, the second level – the main criteria (Delivery reliability, Responsiveness, Flexibility, Supply chain cost, Supply chain asset management efficiency), the third level – the subcriteria corresponding to each SCOR dimension, and the bottom level – the alternatives identified.

Figure 4
The hierarchy of goal, attributes and alternatives



Pairwise Comparison Matrix

Construct a set of pairwise comparison matrices for each of the low levels-one matrix for each element in the level immediately above. Every lower level element affects every upper level element. Elements in the lower level are compared to each order on their effect on the governing element above. The comparisons are put in the judgments matrix, each judgment being expressed as an integer. The judgments are made based on the fundamental nine ratio scale (see table15).

I consider the square matrix of elements:

$$\begin{pmatrix} a_{11} & a_{12} & a_{13}\dots & a_{1n} \\ a_{21} & a_{22} & a_{23}\dots & a_{2n} \\ a_{11} & a_{11} & a_{33}\dots & a_{3n} \\ & & & \vdots \\ a_{n1} & a_{n2} & a_{n3} & a_{nn} \end{pmatrix}$$

-reciprocal properties- $a_{ji} = \dfrac{1}{a_{ij}}$

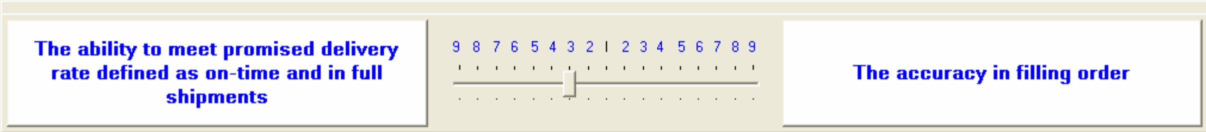
Let be $A_1, A_2, A_3,.., A_n$ - n set of elements and $w_1, w_2, w_3,..., w_n$ their correspondent weights. I compare the corresponding weights of each element with the weight of every other element in the set with the respect of the property or the goal that they have in common. The comparison of weights can be represented as follows (see figure5).

Figure 5
Comparison of weights

	A_1	A_2	A_3	. . .	A_n
A_1	$\frac{w_1}{w_1}$	$\frac{w_1}{w_2}$	$\frac{w_1}{w_3}$	. . .	$\frac{w_1}{w_n}$
A_2	$\frac{w_2}{w_1}$	$\frac{w_2}{w_2}$	$\frac{w_2}{w_3}$	. . .	$\frac{w_2}{w_n}$
A_3	$\frac{w_3}{w_1}$	$\frac{w_3}{w_2}$	$\frac{w_3}{w_3}$	. . .	$\frac{w_3}{w_n}$
⋮	⋮	⋮	⋮		⋮
A_n	$\frac{w_n}{w_1}$	$\frac{w_n}{w_2}$	$\frac{w_n}{w_3}$		$\frac{w_n}{w_n}$

There are n(n-1)/2 judgments required to develop each comparison matrix (figure 6 and 7). In some cases can be just n(n-1) judgments. Using Expert Choice software, the decision maker can visualize in a simple manner the process of taking decisions. In the following example, the policy maker compares the subcriteria among them according to corresponding criteria. The decision maker considers that "the ability to meet promised delivery rate defined as on-time and in full shipments" is three times more important than "the accuracy in filling order" with respect to "delivery reliability" and two times more important than "fill rate on base line/in stock items" with respect to "delivery reliability". The inconsistency in the decision maker judgments is 0.02, which is lower than maximum acceptance inconsistency of 0.10.

Figure 6
Judgments representation



Compare the relative importance with respect to: Delivery reliability

	The ability	The accura	Fill rate on
The ability to meet promised delivery rate defined as on-time and in full shipments		3.0	2.0
The accuracy in filling order			1.0
Fill rate on base line/in stock items (% of order included in initial shipment)		Incon: 0.02	

For level 2 (criteria) and level 3 (subcriteria), an important step in the model is represented by the calculation of local and global priorities. For example, for delivery reliability criterion, the local priority for “the ability to meet promised delivery rate defined as on-time and in full shipments” has a local priority of 0.550 and a global priority of 0.069 (the sum of local priorities is equal with unity).

Figure 7
Calculation of local and global priorities

Level 2	Alts	Prty
The ability to meet promised delivery rate defined as on-time and in full shipments (L: .550 G: .069)	DS+3PL+B2B	.053
	DS+3PL+B2C	.107
	DS+OF+3PL+B2B	.053
	ID+3PL+B2B	.211
	DS+ID+3PL+B2B	.026
	DS+ID+3PL+B2C	.014
	DS+ID+OF+3PL+B2B	.014
	DS+ID+OF+3PL+B2C	.026
The accuracy in filling order (L: .210 G: .026)	DS+3PL+B2B	.080
	DS+3PL+B2C	.020
	DS+OF+3PL+B2B	.020
	ID+3PL+B2B	.080
	DS+ID+3PL+B2B	.010
	DS+ID+3PL+B2C	.005
	DS+ID+OF+3PL+B2B	.005
	DS+ID+OF+3PL+B2C	.010
Fill rate on base line/in stock items (% of order included in initial shipment) (L: .240 G: .030)	DS+3PL+B2B	.092
	DS+3PL+B2C	.023
	DS+OF+3PL+B2B	.023
	ID+3PL+B2B	.092
	DS+ID+3PL+B2B	.011
	DS+ID+3PL+B2C	.006
	DS+ID+OF+3PL+B2B	.006
	DS+ID+OF+3PL+B2C	.011

Synthesization and Consistency

Steps:

1. Sum the values in each column of the pairwise comparison matrix.

2. Divide each element in the pairwise comparison matrix by its column total; the resulting matrix is referred to as the normalized pairwise comparison matrix.
3. Compute the average of the elements in each row of the normalized pairwise comparison matrix; these averages provide the priorities for the criteria.

After pairwise comparisons, a consistency index is calculated using the eigenvalue. The consistency of the pairwise judgments provided by the decision makers is a key step. Ex. If criterion A is 2 times better than criterion B, and criterion B is 3 times better than criterion C, than according to the preferences transitivity, criterion A is 6 times better than criterion.

Steps:

1. Multiple each value in the first column of the pairwise comparison matrix by the priority of the first item; continues the process for all columns of the pairwise comparison matrix. Sum the values across the rows to obtain a vector of values- “weighted sum.”
2. Divide the elements of the weighted sum vector from step 1 by corresponding priority for each criterion.
3. Compute the average of the values found in step 2 – eigenvalue $\lambda_{\max}$.
4. Compute the consistency index (CI) as follows:

$$CI = \frac{\lambda_{\max} - n}{n-1}$$

5. The consistency index is tested using the departure of $\lambda_{\max}$ from n compared with corresponding mean value for random entries yielding the consistency ratio C.R.

$$CR = \frac{CI}{RI}$$

where RI is the consistency index of a randomly generated pairwise comparison matrix. The value of RI depends on the number of items being compared and is given as follows (Table 17):

Table 17
Consistency index of a randomly generated pairwise comparison matrix

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

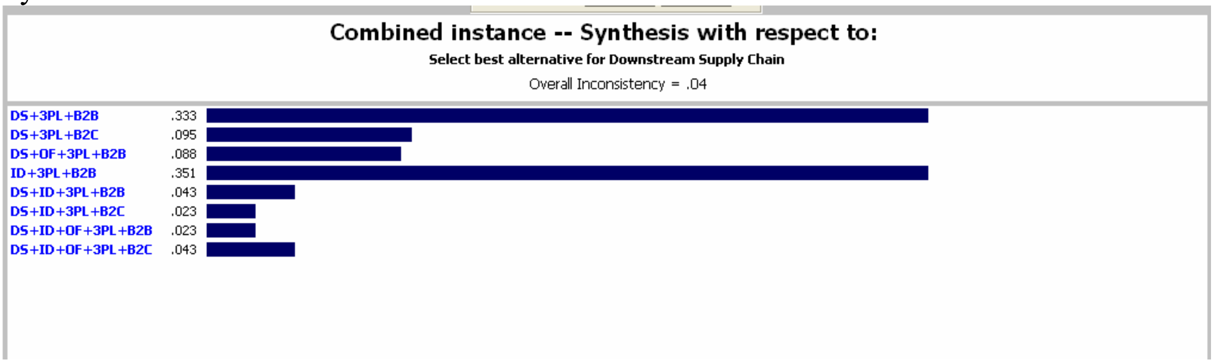
The hierarchical synthesis is used to weight the eigenvectors by the weight of the criteria and the sum is taken over all weighted eigenvector entries corresponding to those in the next lower level of the hierarchy.

The consistency of the entire hierarchy is found by multiplying each consistency index by the priority of the corresponding criterion and adding them together. The result is divided by the same type of expression using the random consistency index corresponding to the dimensions of each matrix weighted by the priorities as before. The consistency ratio C.R. should be about 10% or less to be acceptable.

Results

In this case, the alternative 'ID+3PL+B2B' is the best and coincides with the MAUT model developed in the chapter 4. This finding leads to the conclusion that our decision maker is consistent in judgments, but also even in the situations when he/she cannot have reliable information; the decision maker is capable to estimate the best alternative using AHP (figure 8). The alternative 'ID+3PL+B2B' has the highest value of 0.351, followed by the alternative 'DS+3PL+B2B' (0.333) and the worst alternatives are 'DS+ID+3PL+B2C' and 'DS+ID+OF+3PL+B2B' (0.023). The overall consistency is 0.04, lower than 0.10.

Figure 8
Synthesis of the results obtained



Discussion of the model

As the MAUT model presented in the previous chapter, AHP has advantages and some potential deficiencies. AHP does allow to decision makers to incorporate tangible and intangible criteria, especially for the situation when the primary data aren't available. Also it facilitates participation. Decision makers can participate and reach consensus by aggregating their priorities using geometric mean method (GMM) and the weighted arithmetic mean method (WAMM) (Bolloju, 2001). The method, simple and intuitive, but respecting the mathematical rigor, integrates subjective judgments with numerical data and can replace the lack of data, especially for sensitive data as it is the case of the study.

Still, the model presented could be the subject of rank preservation and rank reversal issue (Belton and Gears, 1983; Dyer, 1990) and of the inconsistency of judgments.

Chapter summary

In this chapter, I treated the situation when decision maker does not have access to primary data to select the best alternative in downstream supply chain. The Analytic Hierarchy Process created by Saaty represents an alternative to the traditional utility theory (with the case of Multiple Utility Theory presented in the precedent chapter). The AHP is a cardinal measurement method based on judgments of policy makers. Methodology poses a fundamental ratio scale of nine values (from one to nine) of importance to compare homogeneous items respecting to the goal. When the number of alternatives is relatively small, AHP can give good results. It does contain a set of requirements and potential deficiencies (consistency of judgments, independence of irrelevant alternatives to prevent rank reversal). For this reason, decision makers can choose the best method that fits with their situations.

CONCLUSIONS

“Supply chain? Gotta have one. It’s the all rage,” said one mid-sized manufacturing company owner recently. When he was pushed to explain his statement, it became clear that some of his thinking was solid, but other parts lacked substance. He concluded by saying, “I want my people to get one for me (Cavinato 2000, p 60).”

The purpose of this research is to define the networks types in downstream supply chain and assist the decision makers in selecting the best network to meet the customer requirements and the need for a higher profitability. Questions as “Does structure influence performance in supply chain? Could be avoided the negative effects in supply chain by reengineering the downstream structure? What type of downstream supply chain networks are and how can be selected the best network to achieve best performance?” receive an answer by carrying this research.

The study starts from the ancient axiom “what it cannot be measured, it cannot be managed.” To meet a superior customer service level and high profitability, companies can use a mix of strategies and methods in a variety of networks, from a direct model to a complex distribution network. One of the strategies used by companies to achieve superior performance is represented by SCOR model, a standard across industries. In the study, I used this standard to measure the performance of the downstream supply chain networks, based on a survey carried with 30 senior executives from world class manufacturing companies, from different industrial sectors such as machinery manufacturing; computer and electronic product manufacturing; electrical equipment, appliance, and component manufacturing; and transportation equipment manufacturing. The executives had key responsibilities in logistics planning, logistics management, traffic/transportation management, warehouse operations/management, material handling operations, inventory planning, production, internal consulting or corporate research, international planning, purchasing. The individuals had positions from senior manager to president.

The survey instrument was represented by a questionnaire implemented using a web software with encryption functionalities. The questionnaire has consisted in three sections: Company Profile, Network Design, and Performance Metrics. Each section was developed on a Web page.

Section one-Company Profile provided the demographic information about surveyed companies and individuals. Sections two-Network Design allowed to identify the network designs in downstream supply chain. Section three – Performance Metrics was split in two subsections: first one to define the SCOR dimensions, and second one, to see if the companies do measure systematically the performance and the level of competition within their markets.

The respondents provided information about type of networks in downstream supply chain based on the following echelons: manufacturer, third party logistics, distributor, retailer, and customer. Core performance metrics allowed constructing a normative model, based on the multiple attribute utility theory (MAUT) under certitude, in the sense of Keeney and Raiffa (1976). The model allows decision makers to use scaling constants as variables and three computations in selecting best alternative. Also, the scales section from the survey provided data about how managers prioritized the importance of performance metrics. The second model is in contrast with the normative model and does allow some inconsistency in the decision maker's judgment. Decision making theory supports three types of approaches: normative (how should people take decisions), descriptive (how people take decisions), and prescriptive (how to do to take good decisions (Bell and Raiffa, 1993). A normative approach is appropriate when decision maker can have access to quantitative data from competitors supply chains. But, this approach is difficult to do because the process of data collection is costly and time consuming, doubled by the refuse of competition to share sensitive data. A solution for these inconveniences can be a descriptive model based on the judgments of the decision makers, developed on a cardinal scale of importance. The Analytic Hierarchy Process can be used as a second solution in selecting best alternatives.

Each model reflects situations in which can be the decision makers. When such situations do occur, the policy makers need to have an decision support system that allows to fundament his/her action road. When access to primary data is granted, a MAUT approach is recommended. Still, MAUT presents a shortage in not incorporating the intangible criteria (qualitative). Also, traditional utility theory excludes an irrational behavior from the part of decision makers. This exclusion is not supported by real life. There are situations when decision makers act irrationally based on their judgments given by their preferences. Moreover, people have preferences and not utility functions and not always they have access to information in real time. AHP can replace these situations using the judgments of the decision makers. Still, AHP is recommended to be applied with caution. Decision makers should have knowledge and experience enough to use this method. A misleading approach in methodology can generate the rank reversal when an alternative is added/deleted and inconsistencies in judgments. Both methods require a small set of alternatives and homogeneous one. In case of a large set of alternatives and criteria the decomposition principle should be applied (already applied for the AHP in the case of criteria).

Further research

The study uses data from 30 top executives, data collected from the first wave of a survey carried with world class manufacturing companies from different industrial sectors. The study identifies a set of seven network configurations in downstream supply chain. This research does not exclude other combinations of the main of categories of echelons (manufacturer, third party logistics, distributor, retailer, and customer) but for the purpose of the study, it remains at the configurations validated by the empirical evidence. Both models developed uses just one decision maker and not provide solutions for multiple decision makers, even spatially distributed. The literature review provided in chapter two does lead to a formulation of a research hypothesis of maturation of SCOR model. This hypothesis can be exploited for a future study.

Also, a larger data set can provide the statistical validation for the metrics and best practices to explain the performance in downstream supply chain. A Cronbach Alpha methodology and a factor analysis could be exploited to extend the results of the study.

REFERENCES

Agarwal, A., Shankar, R., & Tiwari, M. K. (2006). Modeling the metrics of lean, agile and leagile supply chain: An ANP-based approach. *European Journal of Operational Research, 173*(1), 211-225.

Armstrong, J. (1997). Estimating Nonresponse Bias in Mail Surveys. *Journal of Marketing Research*, 396-402.

Baiman, S., Fischer, P. E., & Rajan, M. V. (2001). Performance measurement and design in supply chains. *Management Science, 47*(1), 173-188.

Barnett, M. W., & Miller, C. J. (2000). Analysis of the virtual enterprise using distributed supply chain modeling and simulation: an application of e-SCOR. *Proceedings of the 32nd conference on Winter simulation*, 352-355.

Basu, A. & Siems, T. (November, 2004). The Impact of E-Business Technologies on Supply Chain Operations: A Macroeconomic Perspective, Federal Reserve Bank of Dallas, Working Paper 0404.

Beamon, B. M. (1998). Supply chain design and analysis:: Models and methods. *International Journal of Production Economics, 55*(3), 281-294.

Beamon, B. M. (1999). Measuring supply chain performance. *International Journal of Operations and Production Management, 19*(3), 275-292.

Bharadwaj, N. (2004). Investigating the decision criteria used in electronic components procurement. *Industrial Marketing Management, 33*(4), 317-323.

Bowersox, D., & Closs, D., & Stank, T, (2000). Ten mega-trends that will revolutionize supply chain logistics. *Journal of Business Logistics, 21*(2), pp. 1-16

Brewer, P. C., & Speh, T. W. (2000). Using the balanced scorecard to measure supply chain performance. *Journal of Business Logistics, 21*(1), 75-93.

Burgess, K., & Singh, P. J. (2006). A proposed integrated framework for analysing supply chains. *Supply Chain Management: An International Journal, 11*(4), 337-344.

Chan, F. T. S., & Qi, H. J. (2003). Feasibility of performance measurement system for supply chain: A process-based approach and measures. *Integrated Manufacturing Systems, 14*(3), 179-190.

Chiu, M., & Lin, G. (2004). Collaborative supply chain planning using the artificial neural network approach Matthew Chiu, Grier Lin The Authors. *Journal of Manufacturing Technology Management, 15*(8), 787-796.

Chopra, S. (2003). Designing the distribution network in a supply chain. *Transportation Research Part E, 39*(2), 123-140.

Chopra, S. & Meindl, P. (2004). *Supply Chain Management: Strategy, Planning and Execution 2nd Ed*. New Jersey: Pearson.

Couper, M. P. (2000). Web Surveys. *Public Opinion Quarterly, 64*(4), 464-494.

Couper, M. P., Traugott, M. W., & Lamias, M. J. (2001). Web Survey Design and Administration*. *Public Opinion Quarterly, 65*(2), 230-253.

Corsten, D., & Felde, J. (2005). Exploring the performance effects of key-supplier collaboration: An empirical investigation into Swiss buyer-supplier relationships. *International Journal of Physical Distribution & Logistics Management, 35*(6), 445-461.

Croxton, K., Garcia-Dastugue, S., Lambert, D. & Rogers, D. (2001). The supply chain management processes. *The International Journal of Logistics Management, 12*(2), pp. 13-36.

Dey, E. L. (1997). Working with Low Survey Response Rates: The Efficacy of Weighting Adjustments. *Research in Higher Education, 38*(2), 215-227.

Dias, L. C., & Climaco, J. N. (2000). Additive aggregation with variable interdependent parameters: the VIP analysis software. *Journal of the Operational Research Society, 51*(9), 1070-1082.

Dillman, D. A. (1991). The Design and Administration of Mail Surveys. *Annual Review of Sociology, 17*(1), 225-249.

Dillman, D. A. (2007). *Mail and Internet Surveys: The Tailored Design, —2007 Update*: New York: John Wiley. New York: John Wiley and Sons, Inc.

Dillman, D. A., Tortora, R. D., & Bowker, D. (1998). *Principles for Constructing Web Surveys*.

Dillman, D. A., Tortora, R. D., & Bowker, D. (1999). *Principles for constructing web surveys 1998. Pullman, Washington: Washington State University; 1999*: SESRC Technical Report 98-50.

Flynn, B. B., Schroeder, R. G., & Sakakibara, S. (1994). A framework for quality management research and an associated measurement instrument. *Journal of Operations Management, 11*(4), 339-366.

Folan, P., & Browne, J. (2005). A review of performance measurement: Towards performance management. *Computers in Industry, 56*(7), 663-680.

Forrester, J. W. (1958). Industrial Dynamics: A Major Breakthrough for Decision Makers. *Harvard Business Review*, *36*(4), 37-66.

Frohlich, M. T.; & Westbrook, R. (2001). Arcs of integration: an international study of supply chain strategies. *Journal of Operations Management 19*(2), 185–200.

Gelders, L., Mannaerts, P., & Maes, J. (1994). Manufacturing strategy, performance indicators and improvement programmes. *International Journal of Production Research, 32*(4), 797-805.

Gilmour, P. (1999). Benchmarking supply chain operations. *International Journal of Physical Distribution & Logistics Management, 29*(4).

Glaser-Segura, D., Cirtita, H. (2007). Supply Chain Performance Metrics: A Confluence of Foci and Methodology Maturation. *Forthcoming*

Grosh, M. E., & Muñoz, J. (1996). *A Manual for Planning and Implementing the Living Standards Measurement Study Survey*: The World Bank.

Gunasekaran, A., Patel, C., & McGaughey, R. E. (2004). A framework for supply chain performance measurement. *International Journal of Production Economics, 87*(3), 333-347.

Gunasekaran, A., Patel, C., & Tirtiroglu, E. (2001). Performance measures and metrics in a supply chain environment. *International Journal of Operations and Production Management, 21*(1-2), 71-87.

Harrington, T. C., & Lambert, D. M. (1991). A methodology for measuring vendor performance. *Journal of Business Logistics, 12*(1), 83-104.

Harrison, A., & New, C. (2002). The role of coherent supply chain strategy and performance management in achieving competitive advantage: an international survey. *Journal of the Operational Research Society, 53*(3), 263-271.

Hausman W. H. (2002). Supply chain performance metrics. In: Billington C, Harrison T, Lee H and Neale J (eds). *The Practice of Supply Chain Management*, Kluwer: Boston.

Hirschman, A. O. (1958). *The strategy of economic development*. New Haven, CT: Yale University Press.

Hofman, D. (2004). The hierarchy of supply chain metrics. *Supply Chain Management Review, 8*(6), 28-37.

Hofmann, E. (2006). Quantifying and setting off network performance. *International Journal of Networking and Virtual Organisations, 3*(3), 317-339.

Holmberg, S. (2000). A systems perspective on supply chain measurements. *International Journal of Physical Distribution & Logistics Management, 30*(10), 847-868.

Huan, S.; Sheoran, S. & Wang, G. (2004). A review and analysis of supply chain operations reference (SCOR) model. Supply Chain Management: An International Journal, 9(1), pp. 23 – 29.

Huang, S. H., & Keskar, H. (2007). Comprehensive and configurable metrics for supplier selection. *International Journal of Production Economics, 105*(2), 510-523.

Huang, S. H., Sheoran, S. K., & Keskar, H. (2005). Computer-assisted supply chain configuration based on supply chain operations reference (SCOR) model. *Computers and Industrial Engineering, 48*(2), 377-394.

Iarossi, G. (2006). *The Power of Survey Design: A User's Guide for Managing Surveys, Interpreting Results, and Influencing Respondents*: World Bank Publications.

Jeavons, A., & Bayer, L. (1997). The Harris Poll Online. *Internet, Marketing and Research, 4*, 15-16.

Johnson, M. E., & Pyke, D. F. (2000). A Framework for Teaching Supply Chain Management. *Production and Operations Management 9*(1), 2–18.

Kainuma, Y., & Tawara, N. (2006). A multiple attribute utility theory approach to lean and green supply chain management. *International Journal of Production Economics, 101*(1 SPEC. ISS.), 99-108.

Keeney, R. L., & Raiffa, H. (1976). *Decisions with Multiple Objectives: Preferences and Tradeoffs*: Wiley.

Kehoe, C. M., & Pitkow, J. E. (1996). Surveying the Territory: GVU's Five WWW User Surveys. *The World Wide Web Journal, 1*(3), 77-84.

Kittleson, M. J. (1997). Determining effective follow-up of e-mail surveys. *American Journal of Health Behavior, 21*(3), 193-196.

Khoo, L. P., & Yin, X. F. (2003). An extended graph-based virtual clustering-enhanced approach to supply chain optimisation. *The International Journal of Advanced Manufacturing Technology, 22*(11), 836-847.

Kleijnen, J. P. C., & Smits, M. T. (2003). Performance metrics in supply chain management. *Journal of the Operational Research Society, 54*(5), 507-514.

Krosnick, J. A. (1999). Survey Methodology. *Annual Review of Psychology, 50*, 537-567.

Lambert, D. M., & Pohlen, T. L. (2001). Supply Chain Metrics. *The International Journal of Logistics Management, 12*(1), 1-19.

Laura, X. X. X., William, L., Chai, L. S., & Li, Z. (2005). Performance metrics design framework for software focused supply chain. *2005 3rd IEEE International Conference on Industrial Informatics, INDIN, 2005*, 176-180.

Larson, P. D. & Halldorsson, A. (2002). What is SCM? And, where is it? *The Journal of Supply Chain Management, 38*(4), 36-45.

Lee, H. L., & Billington, C. (1992). Managing supply chain inventory: pitfalls and opportunities. *MIT Sloan Management Review, 33*(3), 65-73.

Levine, D. M., Berenson, M. L., Stephan, D., & Krehbiel, T. C. (2001). *Statistics for Managers Using Microsoft Excel*: Prentice Hall PTR Upper Saddle River, NJ, USA.

Lockamy, A., & McCormack, K. (2004). Linking SCOR planning practices to supply chain performance. *International Journal of Operations and Production Management, 24*(12), 1192–1218.

Lohman, C., Fortuin, L., & Wouters, M. (2004). Designing a performance measurement system: A case study. *European Journal of Operational Research, 156*(2), 267-286.

McCrea, B. (2006). Metrics take center stage. *Logistics Management, 45*(1), 39-42.

Melnyk, S. A., Stewart, D. M., & Swink, M. (2004). Metrics and performance measurement in operations management: Dealing with the metrics maze. *Journal of Operations Management, 22*(3), 209-217.

Mentzer, J. T. (1991). An efficiency/effectiveness approach to logistics performance analysis. *Journal of Business Logistics, 12*(1), 33-62.

Miller, G. A. (1956). The magic number seven, plus or minus two. *Psychological Review, 63*(2).

Neely, A. (2005). The evolution of performance measurement research: Developments in the last decade and a research agenda for the next. *International Journal of Operations and Production Management, 25(*12), pp. 1264-1277.

Neely, A. (1999). The performance measurement revolution: why now and what next? *International Journal of Operations and Production Management, 19*(2), pp. 205-228

Neely, A., Gregory, & Platts, K. (2005). Performance measurement system design: A literature review and research agenda. *International Journal of Operations and Production Management, 25*(12), pp. 1228- 1263.

Otto, A., & Kotzab, H. (2003). Does supply chain management really pay? Six perspectives to measure the performance of managing a supply chain. *European Journal of Operational Research, 144*(2), 306-320.

Paxson, M. C. (1992). Follow-up mail surveys. *Industrial Marketing Management, 21*(3), 195-201.

Rabelo, L., Eskandari, H., Shalan, T., & Helal, M. (2005). Supporting simulation-based decision making with the use of AHP analysis. *Proceedings of the 37th conference on Winter simulation*, 2042-2051.

Ramdas, K., & Spekman, R. E. (2000). Chain or Shackles: Understanding What Drives Supply-Chain Performance. *Interfaces, 30*(4), 3-21.

Röder, A., & Tibken, B. (2006). A methodology for modeling inter-company supply chains and for evaluating a method of integrated product and process documentation. *European Journal of Operational Research, 169*(3), 1010-1029.

Russell, C. J., & Bobko, P. (1992). Moderated regression analysis and Likert scales: Too coarse for comfort. *Journal of Applied Psycholog, 77*(3), 336-342.

Sakakibara, S., Flynn, B. B., & Schroeder, R. G. (1993). A framework and measurement instrument for just-in-time manufacturing. *J Production and Operations Management, 2*(3), 177-194.

Schaefer, D. R., & Dillman, D. (1998). Development of a Standard E-Mail Methodology: Results of an Experiment. *Public Opinion Quarterly, 62*(3), 378-397.

Schneiderman, A. M. (1996). Metrics for the order fulfillment process (part 1). *Journal of Cost Management, 10*(2), 30-42.

Schneiderman, A. M. (1996). Metrics for the order fulfillment process (part 2). *Journal of Cost Management, 10*(3), 6-18.

Shepherd, C., & Günter, H. (2006). Measuring supply chain performance: Current research and future directions. *International Journal of Productivity and Performance Management, 55*(3-4), 242-258.

Simatupang, T. M., & Sridharan, R. (2004). A benchmarking scheme for supply chain collaboration. *Benchmarking, 11*(1), 9-30.

Smits, M., & Kuo, D. C. L. (2003). Performance of Integrated Supply Chains: An International Case Study in High Tech Manufacturing. *Proceedings of the 36th Hawaii International Conference on System Sciences*.

Smits, M., van den Heuvel, W. J., & Huisman, W. (2006). The Tacit Liaison between Networkability and Supply Chain Performance. *Proceedings of the 39th Annual Hawaii International Conference on System Sciences, 08*.

Stephens, S. (2001). Supply Chain Operations Reference Model Version 5.0: A New Tool to Improve Supply Chain Efficiency and Achieve Best Practice. *Information Systems Frontiers, 3*(4), 471-476.

Stewart, G. (1995). Supply chain performance benchmarking study reveals keys to supply chain excellence. *Logistics Information Management, 8*(2), 38-44.

Tan, K. C. (2002). Supply chain management: practices, concerns, and performance issues. *The Journal of Supply Chain Management, 38*(1), 42-53.

Tang, N. K. H., Benton, H., Love, D., Albores, P., Ball, P., MacBryde, J., et al. (2004). Developing an enterprise simulator to support electronic supply-chain management for B2B electronic business. *Production Planning & Control, 15*(6), 572-583.

Tennenhouse, D. L., Smith, J. M., Sincoskie, W. D., Wetherall, D. J., & Minden, G. J. (1997). A survey of active network research. *Communications Magazine, IEEE, 35*(1), 80-86.

van Hoek, R. I. (1998). " Measuring the unmeasurable"-measuring and improving performance in the supply chain. *3*(4), 187-192.

Van Landeghem, R., & Persoons, K. (2001). Benchmarking of logistical operations based on a causal model. *International Journal of Operations & Production Management, 21*(1-2), 254-266.

Vehovar, V. (2001). Sensitivity of Electronic Commerce Measurement to the Survey Instrument. *International Journal of Electronic Commerce, 6*(1), 31-51.

Viswanadham, N., & Raghavan, N. R. S. (2000). Performance analysis and design of supply chains: a Petri net approach. *Journal of the Operational Research Society, 51*(10), 1158-1169.

Wang, G., Huang, S. H., & Dismukes, J. P. (2004). Product-driven supply chain selection using integrated multi-criteria decision-making methodology. *International Journal of Production Economics, 91*(1), 1-15.

Womack, J. P., Jones, D. T., & Roos, D. (1990). *The machine that changed the world*. New York: Macmillan.

Yang, C. C., & Chen, B. S. (2006). Supplier selection using combined analytical hierarchy process and grey relational analysis. *Journal of Manufacturing Technology Management, 17*(7), 926-941.

Yu, Z.; Yan, H.; & Cheng, T. (2001) Benefits of information sharing with supply chain partnerships. *Industrial Management and Data Systems, 101* (3&4), pp. 114-119.

APPENDICES

Appendix A

Dear:

We would like to invite you to participate in a study of performance metrics and practices in world class supply chain organizations. The study will help us to create a comprehensive picture of Downstream Supply Chain activities. As a supporter of research activities of supply chain professional organizations (e.g. CSCMP, ISM, APICS), your contribution to this study is very valuable. It will help us to enlarge the scientific knowledge base about supply chain practices and provide you with a better understanding of emerging and new practices.

Your participation is voluntary and will remain anonymous.

All study participants, regardless of participation status, will receive an executive summary and benchmark report of downstream supply chain distribution performance metrics and practices later this fall of 2007. We hope you can assist us by clicking on this SurveyMonkey (survey administration software) URL and provide your data at:

To provide a complete picture of company practices all parts of the survey are considered important. Please provide, as much as possible, a complete survey response.

Thank you for your consideration and we greatly appreciate your participation. If you have any questions, please contact Horatiu Cirtita, at (210) 434-6711 x0154 or hcirtita@ollusa.edu, or contact Dr. Daniel Glaser-Segura, at (210) 434-6711 x0154 or glasd@lake.ollusa.edu.

Sincerely,

Appendix B

Performance Metrics in Downstream Supply Chain

3. Performance Metrics

Please provide your ideas and comments to improve the questions on this page.

3.1. Please indicate the degree of importance for each the following performance metrics of your downstream supply chain

A. Delivery reliability

INSTRUCTIONS: On a scale of 1 to 7, please express the degree of importance at your location for each of the following statements (1=not important to 7=very important)

	1-Not Important	2	3	4	5	6	7-Very Important
A1. The ability to meet promised delivery date defined as on-time and in full shipments	○	○	○	○	○	○	○
A2. The accuracy in filling order	○	○	○	○	○	○	○
A3. Order cycle consistency such that there is a minimal variance in promised versus actual delivery	○	○	○	○	○	○	○
A4. Fill rate on base line/in stock items (% of order included in initial shipment)	○	○	○	○	○	○	○
A5. Completeness of order (% of line items eventually shipped complete)	○	○	○	○	○	○	○

B. Responsiveness

INSTRUCTIONS: On a scale of 1 to 7, please express the degree of importance at your location for each of the following statements (1=not important to 7=very important)

	1-Not Important	2	3	4	5	6	7-Very Important
B1. Length of promised order cycle (lead) times (from order submission to delivery)	○	○	○	○	○	○	○
B2. Length of time to answer distribution partners/customers' queries	○	○	○	○	○	○	○
B3. Length of time to process a received order	○	○	○	○	○	○	○
B4. Length of time to produce and ship a received order	○	○	○	○	○	○	○

C. Flexibility

INSTRUCTIONS: On a scale of 1 to 7, please express the degree of importance at your location for each of the following statements (1=not important to 7=very important)

	1-Not Important	2	3	4	5	6	7-Very Important
C1. The ability to identify and supply high volumes in a "quick ship" mode	○	○	○	○	○	○	○
C2. The ability to automatically back order base line/in stock items under "quick ship" mode	○	○	○	○	○	○	○
C3. The ability to meet specific customer service needs	○	○	○	○	○	○	○
C4. The ability to plan, source, make and deliver unplanned orders with minimal cost penalties	○	○	○	○	○	○	○

D. Supply chain cost

INSTRUCTIONS: On a scale of 1 to 7, please express the degree of importance at your location for each of the following statements (1=not important to 7=very important)

Performance Metrics in Downstream Supply Chain

	1-Not Important	2	3	4	5	6	7-Very Important
D1. Cost for order management (such as purchase order, expediting, etc.)	○	○	○	○	○	○	○
D2. Cost of goods (such as direct cost of material and direct labor)	○	○	○	○	○	○	○
D3. Cost of sales, contract administration, engineering, and lab support of products	○	○	○	○	○	○	○
D4. Cost of carrying inventory (such as warehouse and retail inventory)	○	○	○	○	○	○	○
D5. Cost of transportation	○	○	○	○	○	○	○
D6. Cost of warranty/return processing	○	○	○	○	○	○	○
D7. Total supply chain management cost	○	○	○	○	○	○	○

E. Supply chain asset management efficiency
INSTRUCTIONS: On a scale of 1 to 7, please express the degree of importance at your location for each of the following statements (1=not important to 7=very important)

	1-Not Important	2	3	4	5	6	7-Very Important
E1. Cash-to-cash cycle time	○	○	○	○	○	○	○
E2. Inventory days of supply	○	○	○	○	○	○	○
E3. Asset Turns	○	○	○	○	○	○	○
E4. Gross Margin	○	○	○	○	○	○	○
E5. Operating Income	○	○	○	○	○	○	○
E6. Return on Assets	○	○	○	○	○	○	○
E7. Earnings per share	○	○	○	○	○	○	○

Performance Metrics-part two

3.2. Using letters, as shown in the diagram below, indicate the degree that you measure the various parts of the order cycle (for example A to D)

	From	To
Order cycle parts	☐▾	☐▾

Customer Places Order	Order Receipt	Order Processed	Order Shipped	Order Received by Customer
A	B	C	D	E

3.4. The average total order cycle time in days is.

3.5. The total range for the total order cycle time in days is (for example 3-21 days).

3.6. To satisfy customer requirements, your delivery system is: (Please check one)

Performance Metrics in Downstream Supply Chain

- ◯ By request
- ◯ To commit
- ◯ Both

3.7. What is total logistics cost as a percentage of product value? (%)

3.8. What is transportation cost as a percentage of total logistics cost? (%)

3.9. What is holding cost as percentage of total logistics cost? (%)

3.10. Please estimate the average measures for the following:

On-time delivery rate (orders delivered on-time per total orders - %)

Order fill rate (order filled complete per total orders - %)

Order accuracy (error-free orders per total orders - %)

Perfect order rate (perfect deliveries per total deliveries - %)

3.11. Indicate the degree of competition which your products experience in the marketplace

- ◯ Little competition
- ◯ Moderate competition
- ◯ Intensive competition

Thank you for your participation.

Appendix C

SCOR Dimensions

(Combinations of Performance Metrics and Best Practices)

Delivery reliability
A6. The ability to meet promised delivery date defined as on-time and in full shipments ***(delivery performance)DRA1***
A7. The accuracy in filling order ***(perfect order fulfillment) DRA2***
A8. Order cycle consistency such that there is a minimal variance in promised versus actual delivery
A9. Fill rate on base line/in stock items (% of order included in initial shipment) ***(line item fill rate)DRA4***
A10. Completeness of order (% of line items eventually shipped complete)

Responsiveness
B5. Length of promised order cycle (lead) times (from order submission to delivery) ***(order fulfillment lead time)REB1***
B6. Length of time to answer to distribution partners/customers' queries
B7. Length of time to process a received order
B8. Length of time to produce and ship a received order ***(supply chain response time)REB4***

Flexibility
C5. The ability of manufacturer to identify and supply high volume product as part of "quick ship" program
C6. The ability of manufacturer to automatically back orders base line/in stock items ordered under "quick ship" programs
C7. The ability of manufacturer to meet specific and/or unique customer service and delivery needs of individual customers
C8. The ability of manufacturer to plan, source, make and deliver an unplanned increase or decrease in orders without cost penalty ***(production flexibility)FLC3***

Supply chain cost
D8. Cost for order management (such as purchase order, expediting, etc.)
D9. Cost of goods (such as direct cost of material and labor) ***(cost of goods)SCD2***
D10. Cost of sales, contract administration, engineering, and lab support of products ***(SGA costs)SCD3***
D11. Cost of carrying inventory (such as trucking, warehouse, retail)
D12. Cost of transportation
D13. Cost of warranty/returns processing ***(warranty/returns processing costs)SCD6***
D14. Total supply chain management cost ***(total supply chain cost)SCD7***

Supply chain asset management efficiency
E8. Cash-to-Cash cycle time ***(cash-to-cash cycle time)AME1***
E9. Inventory days of supply ***(inventory days of supply)AME2***
E10. Asset Turns ***(asset turns)AME3***
E11. Gross Margin
E12. Operating Income
E13. Return on Assets
E14. Earnings per share