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STUDY OF SOME PERFORMANCE MEASUREMENT INDICES OF SUPPLY CHAIN MANAGEMENT

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Abstract*—This paper discusses some performance measurement indices of supply chain management for measuring performance of supply chain management using various methods. In this paper we have discussed Balance score card and Analytical Hierarchy Process (AHP) for assessing performance measurement of supply chain effectiveness. Balance score card focuses on goal of supply chain management and compare its current data, and inform about the weakness and strength of supply chain management. SCOR model help in identifying a set of supply chain processes that are generally used to evaluate supply chain performance in larger firms.*

Index Terms—Supply Chain Management, BSC Model,SCORE Model, AHP Model.

INTRODUCTION

Supply chain: The supply chain, which is also referred to as the logistics network, consists of suppliers, manufacturing centers, warehouses, distribution centers, and retail outlets, as well as raw materials, work-in-process inventory, and finished products that flow between the facilities.

Supply chain management: "Supply chain management is a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system wide costs while satisfying service level requirements".[1].

I. PERFORMANCE MEASUREMENT

Researchers have defined PM from different perspectives since the definitions of performance measures vary from author to author .Performance measurement is the process of quantifying the efficiency and effectiveness of action , or the process of evaluating performance relative to a defined goal , which means that PM is not only observing the past data but also a tool for leading the organization into a better future. PM is executed through different performance measures and represents the enabler for organizations to plan, track/monitor the implementation of their plans (through reporting, benchmarking etc.), and determine if any corrective actions are needed. Thus with the use of PM, companies can identify problems in the processes (e.g., bottlenecks, non-value adding activities) in their action plans (e.g., penetration in a new market segment) and in their strategy and they can perform corrective actions.

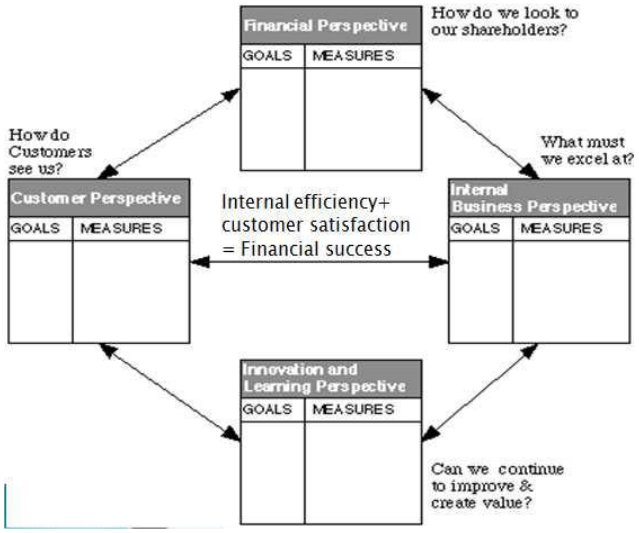
Moreover, PM can aid in understanding how the business works and, consequently, enhances decision making both at the top management and at the operating level. PM influences the behavior of employees and thus it has been used for many years to communicate decision-relevant information to people inside the organization. Finally, PM can be used to motivate employees, increase accountability, and reward certain behaviors and results.

II. IMPORTANCE OF SUPPLY CHAIN PERFORMANCE MEASUREMENT:

The objective of SCPM has to facilitate and enhance the efficiency and effectiveness of SCM. The main goal of SCPM models support management by helping them to measure business performance, analyze and improve business operational efficiency through better decision-making processes. SCPM can facilitate inter-understanding and integration among the SC members. It makes an indispensable contribution to decision making in SCM, particularly in re-designing business goals and strategies, and re-engineering processes.

BALANCE SCORE CARD:

Balance score card is a planning and management system that used in business and industries and nonprofit organizations worldwide to align business activities to the vision and strategy of the organization, improve internal and external communications, and monitor organization performance against strategic goals.



-*The financial perspective* represents the long-term financial objectives for growth and productivity and incorporates the tangible outcomes of the strategy in traditional financial terms, this is the perspective that appeals mostly to shareholders.

-*The customer perspective* defines the value proposition that the organization will apply in order to satisfy its customers and represents the way in which intangible assets create value . Thus, the measures that are selected should measure both the value that is derived for the customer (time, quality, and cost) and the outcomes that result (customer satisfaction, retention, market share).

-*The internal business process perspective* is concerned with the processes required to provide the value expected by the customers and the relevant measures are time-to market, defects, new products etc.

-*The learning and growth perspective* focuses on the intangible assets: mainly on the internal skills and capabilities that are required to support the internal processes. It refers to the company's employees; their training, skills, cultural attitudes, and the relevant measures are employee retention, training efficiency, etc. Obviously, each one of these four perspectives has to be in accordance with the business strategy of the organization. Through monitoring metrics and maintaining equilibrium between all perspectives, management can control the strategy implementation process, not just to realize short-term financial outcomes, but also to develop long-term competitive capabilities.

Adaptation of the Standard BSC to SCM:

The SCM framework that has been applied in company A was based on the metrics that Bhagwat and Sharma proposed for SCM performance evaluation. The authors used the Balanced Scorecard four perspectives and developed a new framework structurally similar to BSC with corresponding metrics that reflect SCM strategy and goals. Each of the four perspectives was translated into corresponding metrics and measures that reflect SCM goals and objectives (see Table 2.1). In addition, the authors explained that the following steps are recommended for linking the BSC to SCM objectives-

(1)Create awareness for the concept of BSC in the organization.

(2)Collect data on the following items:

— Goals and objectives related to corporate, business, and SCM strategy — Traditional metrics already in use for SCM evaluation

— Potential metrics related to four perspectives of BSC (3) Determine the company-specific objectives and goals of the SCM function for each of the four perspectives.

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

(5)Achieve a consensus on the balanced SCM scorecard that will be used by the organization.

(6)Communicate both the balanced SCM scorecard and its underlying rationale to all stakeholders.

Table 2.1. Performance Metrics for the Financial and Customer Perspectives [3]

Performance metrics	Year performance (in %)	Target (in %)
Financial perspective metrics		
Gross margin	+1	+4
Productivity	+5	+10
Import cost	+10	−10
Inventory holding cost	+15	−5
Cost of obsolete stock	+30	−10
Customer perspective metrics		
Range of products and services	+50	+50
Delivery lead time	−10	−50
Defect-free deliveries	+10	+15
Revenue per customer	N/A	
Internal process metrics		
Category A		
No. of import invoices	+20	+10
No. of sales invoices	+15	+5
Time for suppliers to respond to quality problems	−5	−10
Supplier's defect-free deliveries	N/A	
Category B		
No. of information-reporting errors	+5	−10
Sales forecasting accuracy	N/A	
Learning and growth metrics		
Technical support staff training hours	+5	+5
Administrative staff training hours	N/A	
Employee satisfaction	N/A	

AHP METHOD WITH SCORE MODEL FOR PERFORMANCE MEASUREMENT OF SCM

Analytical hierarchy process (AHP):

The Analytical Hierarchy Process (AHP), introduced in 1970, has become one of the most popular methods for multiple criteria decision-making (MCDM). It is a decision approach designed to assist in the solution of complex multiple criteria problems in a number of application areas. AHP is a problem-solving framework, a flexible and organized method employed to represent the elements of a compound problem, hierarchically[7]. It has been considered to be an essential tool for both practitioners and academic researchers in organizing and analyzing complex problems[8]. AHP has been extensively used for selection process such as comparing the overall performance of manufacturing departments[10], manufacturing supply chain[11] , benchmarking logistics performance[9] , and vendor evaluation and selection [12]. More researchers are realizing that AHP is an effective technique and are applying it to several manufacturing areas[11] .

The AHP procedure to solve a complex problem involves four steps:

1- Breaking down the complexity of a problem into multiple levels and synthesizing the relations of the components are the underlying concepts of AHP.

2- Pair-wise comparison aims to determine the relative importance of the components in each level of the hierarchy. It starts from the second level and ends at the lowest. A set of comparison matrices of all components in a level of the hierarchy with respect to an component of the immediately higher level are built so as to prioritize and convert individual comparative judgments into ratio scale measurements. The preferences are quantified by using a nine-point scale. The decision maker needs to express preference between each pair of the components
in terms of how much more important one component is as compared to another.

3- Relative weight calculation: After the pair-wise comparison matrix is developed, a vector of priorities (i.e. eigenvector) in the matrix is calculated and is then normalized 4- to a sum of 1.0.

4- Consistency check: A consistency ratio (CR) is used to measure the consistency in the pair-wise comparison. The purpose is to ensure that the judgments of decision makers are consistent.

Supply chain operations reference (SCOR):

The Supply chain Council has developed the SCOR model. The model is a reference model and SCOR stands for Supply Chain Operations Reference.
The purpose for the model is to:

1. provide a standard language for SCM that can be used cross-industry
2. facilitate external benchmarking
3. establish a basis for analyse of Supply chains
4. compare the current Supply chain with the target for the future

Supply Chain Council (SCC) is a global non-profit organization formed in 1996 to create and evolve a standard industry process reference model of the supply chain for the benefit of helping enterprises improve supply chain operations. SCC has established the supply chain framework-the (SCOR) process reference model for evaluating and comparing supply chain activities and related performance (19). The SCOR model consists of standard supply chain processes, standard performance attributes and metrics,

standard practices and standard job skills. The SCOR model processes include plan, source, make, deliver, return and enable. However, the source, make, and return processes are considered as the execution processes. Each process is broken down to five levels. For example, source process represents the scope or level 1, level 2 is the configuration process where the practitioner has to identify the type of source process i.e. source stocked products, source maketo- order and source engineer-to-order products. Level 3 represents activities and tasks involved in each level 2 process. Level 4 provides workflow and steps involved in each of level 3 processes. In this paper we used level 1 supply chain execution and return processes to the model. The objectives of each process are shown in table 3.1.

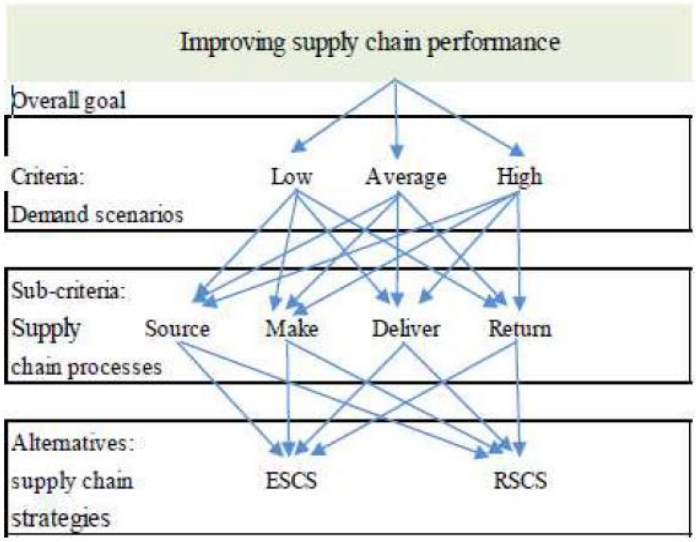
Table 3.1. Major supply chain processes and objectives[12].

Process	Objectives-
Source (sS)	The ordering, delivery, receipt and transfer of raw material items, sub-assemblies, product, packaging and/or services.
Make (sM)	The conversion process of adding value to products through mixing, separating, forming, machining, and chemical processes, repair, refurbishment and/or decomposition.
Deliver (sD)	Perform customer-facing order management, shipping and order fulfilment activities including outbound logistics.
Return (sR)	Moving material from customer back through supply chain to address defects in product, ordering, or manufacturing, or to perform upkeep activties

The aim of SCOR is to provide a standard way to measure Supply chain performance and to use common metrics to benchmark against other organizations according to Christopher (1998).
The SCOR model has three levels:
-Top level: defines the scope and content for the Supply chain.
-Configuration level: designs the Supply chain
- Process element level: gives detailed information on each process.

AHP approach with SCORE model: Manufacturing firms are required to adjust their operations and strategies in order to meet rapid and various business environment changes. The evaluation of the alternative supply chain strategies; effective (ESCS) or responsive (RSCS) requires that the performance of the strategies on source, make, deliver, and return processes to be re-evaluated, re-prioritized, quantified and aggregated to capture the new business goals. However, this process is not a straight forward task, since the performance and strategy evaluation process depend on many factors that by nature are interconnected and require a specific level of skill and qualifications that mostly do not exist in many SMEs. The frame work outlined in this paper aims to help SMEs construct and build a strategic performance improvement system which involves and links two key supply chain strategies (Efficient or Responsive), and supply chain processes

based on SCOR model. In addition, the framework utilizes AHP approach to integrate, evaluate, and prioritize supply chain processes and strategies in one comprehensive model (Figure1).



The evaluation of alternative strategies has to be carried out level by level starting from top to bottom. At the second level, there are three possible demand scenarios: low, average, and high demand. The first evaluation process assesses the occurrence probability of the demand scenarios within the planning period.
For example, what would be the probability of having low demand during the planning period? The second evaluation process evaluates the relative effects of
each process on performance within particular market scenarios. For instance, what are the relative effects of source, make, deliver, and return on the overall performance when the demand is high. The third evaluation process assesses the overall performance of the alternatives. The comparison and the evaluation of each and every component in the criteria and sub-criteria levels must be done through the pair wise comparison procedure described in section 2 of this paper.

The supply chain model is created and used for two main reasons. First, SMEs need to think and act based on wider business processes. Secondly, this effort aims at bridging the gap between supply chain, improvement models and SMEs by linking supply chain management and operations, strategies and the small and medium-sized enterprises. The Expert Choice software was used as a tool in building the hierarchal structure of the company's overall goal, market scenarios, processes and supply chain strategies. Export Choice is intuitive, graphically based, and structured in a user-friendly fashion so as to be valuable for conceptual and analytical thinkers, novices, and category [13] . The AHP and Expert Choice software engage decision makers in structuring a decision into smaller parts, proceeding from the goal to objectives to sub-objectives down to the alternative course of action. Decision makers then make simple pair wise comparison judgments throughout the hierarchy to arrive at overall priorities for the alternatives[20] . This model is illustrated in the next section on a case of a medium-sized manufacturing enterprise. As shown in figure 1, two key supply chain strategies are considered at the last level which represents the available alternatives that the decision maker has to choose from based on market conditions, business environment and company's product type and overall goal. The third level, the processes level, includes: source, make, deliver, and return. The second level or the scenario level shows various market conditions: low demand, average demand and high demand. Each and every business encounters one or more of these market conditions, but the question of how, when, and why one supply chain strategy is chosen over the other and on what basis usually remains fairly open. Some of these issues will be highlighted in the next section through the presented case study[13].

Case study: A family-owned medium-size manufacturing firm, call it company X, specializes in production of plastic pipes and fittings products. The company's strategy is to produce and deliver high quality products to its customers at the agreed delivery time and process. Most of its customers are large firms, mega project contractors and government agencies. The company has a fairly strong position in its highly competitive market, and its product prices are almost the highest compared to similar products from competitors. Based on the information collected about the company products, policy and operations, the Expert Choice software was used to translate and build the four level hierarchical structures: the goal, scenarios, criteria, and alternatives levels. The evaluation of these alternative strategies was carried out level-by-level, starting from the top down towards the lower levels. The process begins at level two by assessing likelihood of occurrence of a particular demand during the planning period. The evaluation process starts with asking questions such as, what is the probability of having low demand compared to average and high demand during the planning period. The assessment should be based on previous historical data and actual or expected orders. For company X, it is believed that they will be facing a high demand during the first few months in the planning period, thus their preference is to put high probability for high demand. The evaluation process of different scenarios according to company X is shown in table 8. The results of the second level evaluation process show that the possibility of high demand scenario occurrence is relatively higher than others with about a 52% chance. The probability of having average and low demands during the planning period are 36% and 12% respectively, see figure 3.2

Sum of column 1 (c1) = 8
Sum of column 2 (c2) = 3.25
Sum of column 3 (c3) = 1.83
The element of column 1 is divided by c1, a11= 0.125
b21= 0.5
c31= 0.375
The element of column 2 is divided by c2, a12= 0.076
b22= 0.3076
c32= 0.615
The element of column 3 is divided by c3, a13= 0.18
b23= 0.27
c33=0.546
Add. Element of row and calculate eigen vector $\lambda 1=0.124$
$\lambda 2=0.359$
$\lambda 3=0.517$

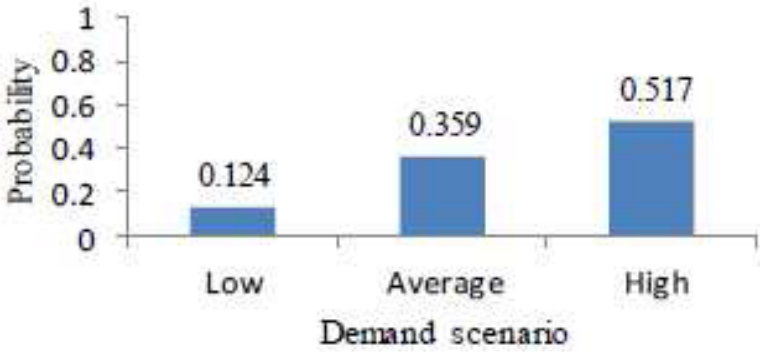


Fig.3.2 The likelihood of different market scenarios

The second step evaluates the relative effects of each criterion "process" on performance under a specific scenario. For example, what would be the relative
effect of source (sS), make (sM), deliver (sD), return (sR), on performance if demand is low? The evaluation process starts with asking questions such as: which process is more important: source or make, source or deliver, etc.? In our case, company X puts more value to make and deliver processes than to source and return, and more value to source than to return process, see table 4. For example, company X gave value of 4 to deliver process compared to source process which means that deliver process is more important than the source process when market demand is low.

Process	Ss	sM	sD	sR
Ss	1	1/2	1/4	5
sM	2	1	2	7
sD	4	0.50	1	7
sR	0.20	0.14	0.14	1

Table 3.3. Pair-wise comparison for level 3 under low demand

Sum of column 1(c1) = 7.20
Sum of column 2 (c2) = 2.14
Sum of column 3 (c3) = 3.39
Sum of column 4 (c4) = 20
The element of column 1 is divided by c1, a11= 0.138
b21= 0.277
c31= 0.555
d41= 0.0277
The element of column 2 is divided by c2, a12= 0.2336
b22= 0.4672
c32= 0.2336
d42=0.0654
The element of column 3 is divided by c3, a13= 0.0737
b23= 0.5899
c33=0.2949
d43= 0.0412
The element of column 4 is divided by c4, a14= 0.25
b24= 0.35
c34= 0.35
d44= 0.05
Add. Element of row and calculate eigen vector λ1=0.164
λ2=0.425
λ3=0.366
λ4= 0.045

Under low market demand and based on the evaluation process, the make process is the most important process (0.425 or 42.5%) among the others. Deliver process comes second with 0.366 or 36.6 %. The figure shows that the make and deliver processes are

the key players and vital improvement areas when market is low. Note that the relative effect of each process or criterion may vary depending on market conditions or product type. The results obtained from the evaluation of the processes are shown in figure 3.3.In order

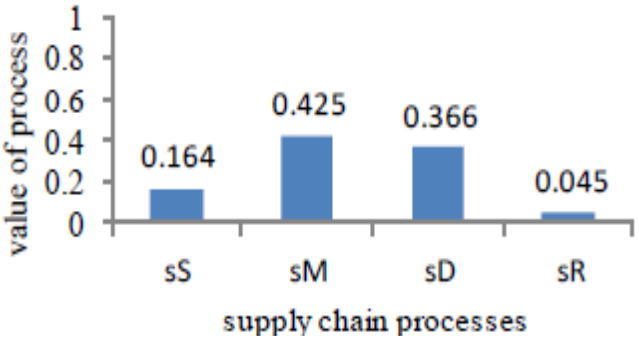
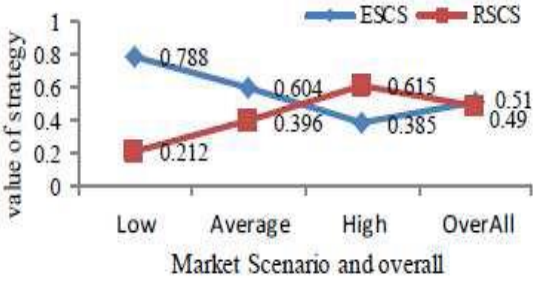


Fig 3.3: Weights of processes under low market demand

to complete the level calculations; one needs two more comparison processes for average and high market demand. The third step addresses the performance of each strategy on each performance criterion. Finally, the overall performance of each strategy can be calculated through the composition process by using Expert Choice. The performance of the two alternatives: efficient and responsive supply chain strategy is shown in figure 15. The initial evaluation process shows that the performance of efficient supply chain strategy (ESCS = 0.510) is better than the performance of responsive supply chain strategy (RSCS = 0.490), given the likelihood for having low, average, and high demand are 12.4%, 35.9%, and 51.7%.



Conclusion: A quantitative model for supply chain performance improvement with the example used illustrates how practitioners especially in SMEs can implement the model in order to improve business performance. Using SCOR model helped in identifying a set of supply chain processes that are generally used to evaluate supply chain performance in larger firms. The use of AHP approach was useful in structuring and simplifying the model to four levels: overall goal, scenarios, criteria and alternatives. The use of Expert Choice software facilitated an outstanding environment in structuring the model hierarchically, carrying out evaluation by level, and making final alternatives evaluation and selection. Some sensitivity analysis was performed in order to sense the difference when changes occur in the external environment through the model. We noticed that the link between product type and supply chain strategy type works very well which proves the previous suggestions but when market demand was added into the whole picture it gave another look. The authors of this paper believe that the outlined model achieves important directions of nontraditional performance improvement systems such as flexibility, easy and ready to use, up to date, and comprehensive approaches. Unlike previous supply chain performance models and implementations of AHP and or SCOR model, the proposed model introduces a new approach that SMEs can use to evaluate internal overall performance and the selection of supply chain strategy based on external conditions. This can be done by combining the two approaches correctly. The proposed model also efficiently engages users, mainly in SMEs, to the world of supply chain management and operations.

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