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A SCOR based approach for measuring a benchmarkable supply chain performance

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Abstract Performance measurement can only help to identify the problems existing in the current supply chain, while it is helpless in exploring the root causes of these problems and thus choosing corresponding actions to improve supply chain performance. The conflict between the top-down strategy decomposition and the bottom-up implementation process is serious. Therefore, in order to overcome the above issues, it is very necessary to link strategic objectives to operations, which could help managers, especially those operating at a strategic level, to know more operational mechanism of supply chains. In this study, an integrated approach which employs analytic hierarchy process (AHP) and technique for order preference by similarity to ideal solution (TOPSIS) together is proposed for the linking strategic objectives to operations. Supply chain operations reference model is used to model the linkage of the strategic objectives and operational metrics in a hierarchical way. The AHP is used to analyze this metric hierarchy and determine weights of the metrics, and TOPSIS method is used to make a normalization of metric values having different units, so a comparison will be available. Proposed approach is applied to a problem of decision making process in a manufacturing company. Company managers found the application and results satisfactory and implementable in their decisions.

Keywords Supply chain management · Performance measures · SCOR model · AHP · TOPSIS · Normalization

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Introduction

Supply chain

Supply chain management (SCM) involves the interaction of different companies, each one performing its value-added activities, aiming to produce a final product (Makris et al. 2008). A company's supply chain comprises geographically dispersed facilities, where raw materials, intermediate products, or finished products are acquired, transformed, stored, or sold and the transportation links that connect facilities along which the products flow (Makris et al. 2011). This chain is traditionally characterized by the flow of materials and information both within and between business entities. Figure 1 demonstrates a sample of general flow. Within this flow and network, the following processes are taking place: purchasing from suppliers, supplier delivery, reception of the raw materials and semifinished products and their storage, production, storage of the finished goods, delivery through distribution network to the final customer and reverse logistics (Stefanovic and Stefanovic 2008). These processes are performed as shown in Fig. 1, derived from Min and Zhou (2002), Stefanovic and Stefanovic (2008).

Supply chain management is a relatively new term, crystallizing concepts about integrated business planning, and was suggested by the academic community in the 1950s (Chryssolouris et al. 2004).

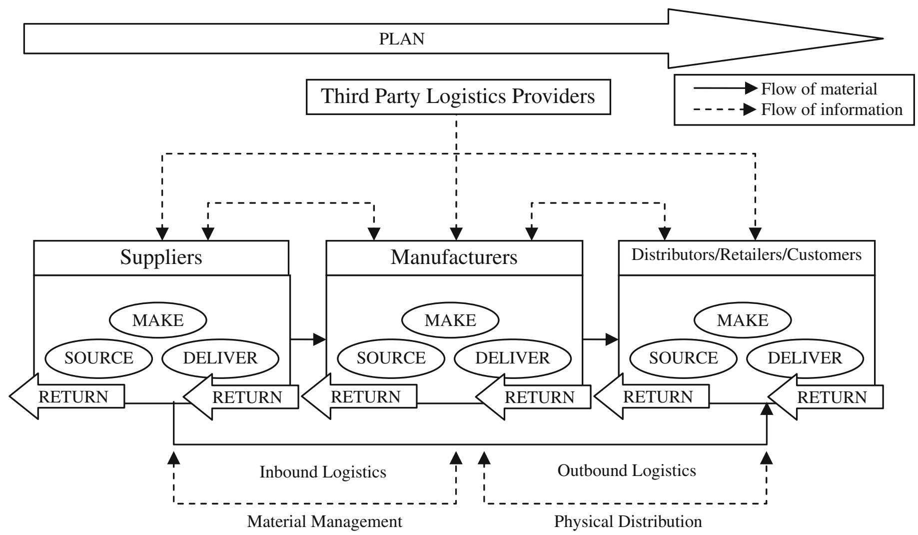

Fig. 1 The supply chain process

Mentzer (2000) defines an extended supply chain include suppliers of the immediate supplier and customers of the immediate customers all linked by one or more of the upstream and downstream flows of products, services, finances and information. Ayers (2001) added the design, maintenance and operation of supply chain processes for satisfaction of end-user in the definition of SCM.

In the modern manufacturing industry, supply chain management has become a critical issue for most manufacturing organizations to gain their competitive edge in today's market. Supply chain is a complex system that involves many system elements from various functional areas. Performance of a supply chain heavily depends on the effectiveness of communication and coordination among these system elements and functional areas (Chen and Huang 2007).

SCOR model

The Supply Chain Operations Reference (SCOR) Model released by Supply Chain Council (SCC) in 1996 has been widely studied and used in research and industry. Researchers and practitioners have found the SCOR Model a good reference that integrates most of the business processes of an organization in a cross-functional framework. SCOR is based on five distinct management processes, namely Plan, Source, Produce, Deliver and Return. These five processes form the top level of the SCOR model. Each process is further decomposed into lower levels. Level two is called configuration level where a company implements its strategy by configurations. Level three is the process elements levels to fine tune the detailed operations. Level four is the implementation level that directly deals with the practices and activities (Chen and Huang 2007).

Due to the increasing complexity and size of supply chain manufacturing industry, a large and complex supply chain usually makes it difficult to coordinate and thus degrades its performance. This motivates this study to develop a systematic approach that helps analyze and improve the performance of a supply chain.

In this paper, an AHP–TOPSIS–SCOR integrated approach for selection of the most suitable scenarios will be introduced and the implementation process will be explained with a real world example. We shall use the AHP method to analyze the structure of the strategy selection problem defined using SCOR model and determine the weights of criteria, and use TOPSIS method for normalization and final ranking. In the application, the criteria, which have the greatest effect on the strategy selection, are determined.

This paper is divided into eight sections. In the section "Introduction", the studied problem is introduced. In the section "Literature review" explained the recent studies. In "Performance metrics in SCM" generally the principles of a supply chain performance management system has defined. Section "SCOR attributes and performance metrics" explains the SCOR model and the relationship metrics and attributes. Section "Principles of AHP and TOPSIS methods" briefly describes the two proposed methodologies. In section "Proposed TOPSIS–AHP–SCOR integrated approach", proposed TOPSIS–AHP–SCOR integrated approach for strategy selection is presented and the stages of the proposed approach and steps are determined in detail. How the proposed approach is used on a real world example is explained in the section "A numerical application of proposed approach". In the section "Conclusions", conclusions and future research areas are discussed.

Literature review

To meet objectives, the output of the processes enabled by the supply chain must be measured and compared with a set of standards. Besides this, measurements should be understandable by all supply chain members and should offer minimum opportunity for manipulation. The objective of this work is to develop a model to link strategic objectives to operations, so that enables a more effective supply chain decision making.

Schniederjans and Garvin (1997) indicated that strategic objectives (cost, quality, delivery, etc.) were too highly aggregated to direct decision making. They are broad and generic categories with a multitude of possible interpretations. For example, "quality" can mean reliability, durability, or aesthetic appeal. Many researchers have indicated that the process of linking strategic objectives to actions is often overlooked and poorly implemented.

The Balanced Scorecard (BSC) (Kaplan and Norton 1992) is not only a performance measurement system, but a strategy management tool that can facilitate managers to find performance drivers, to explore and describe strategic action map precisely, to implement strategy effectively, and to learn from the circular process. The BSC can help to balance strategic focuses on four perspectives (financial, internal business process, customer, learning and growth), complex cause and effect relationships, leading and lagging indicators, and tangible and intangible indicators, and to develop more systemic aligned strategy.

However, despite the widespread recognition of the importance of the BSC in strategy management, some literatures show that the BSC theory and practice have some limitations. Akkermans and Oorschot (2002) advocated five limitations to BSC development. The limitations were "undirectional causality too simplistic", "does not separate cause and effect in time", "no mechanisms for validation", "insufficient between strategy and operations", and "too internally focused". They further proposed the theory of using system dynamics (SD) (Forrester 1961) as a method to overcome the before-mentioned limitations.

In literature, there are many other attempts (Forrester 1961; Wolstenholme 1998; Schoeneborn 2003) in developing BSC from a feedback loops perspective to understand and manage the dynamic complexity, which is generated by the complex cause-and effect relationships, the trade-offs among multiple objectives and measures, the resource and capacity constraints, and the time delays.

Santos et al. (2002) incorporated SD and multi-criteria analysis to analyze the relationships among performance metrics. Suwignjo et al. (2000) used cognitive map, cause and effect diagram, and analytic hierarchy process (AHP) to build hierarchical model and determine priorities of performance metrics.

Malina and Selto (2004) and Banker et al. (2004) made use of statistics and data mining methods to study the "balance" of BSC based on historical data.

Linking performance metrics in a logical manner could help much both on performance measurement and decision-making. In literature, the approaches of building linkages of performance metrics can be divided into two main groups, namely qualitative (Kaplan and Norton 2001; Tan and Platts 2003) and quantitative (Wolstenholme 1998; Kaplan and Norton 2001; Schoeneborn 2003; Young and Tu 2004).

The qualitative approach, representing by the traditional BSC, is weak in the expression of more accurate and dynamic factors; while the quantitative approach, representing by the adoption of SD, is too rigid in the expression of quantitative relationships, especially to those strategic objectives. No single approach could work well, so it still requires further study if it is to be effective in supporting the supply chain decision making process (Xua and Chena 2007).

In recent years we can see the new studies collected around AHP.

Rangone (1996) explained the use of non-financial performance measures makes it difficult to assess and compare the overall effectiveness of each manufacturing department, in terms of support provided to the achievement of the strategy, since to this aim it is necessary to performance measures expressed in heterogeneous measurement units. Showed the potential of the AHP for assessing and comparing the overall manufacturing performance of different departments.

Chan and Qi (2003), explained that there is no systematic grouping of the different performance measures in the existing literatures. Presented the formulization of both quantitative and qualitative performance measurements for easy representation and understanding. In addition, a multi-attribute decision-making technique, an AHP, is used to make decisions based on the priority of performance measures. This paper outlines the application and particularly the pair wise comparison which helps to identify easily the importance of different performance measurements.

Bhagwat and Sharma (2007) developed an integrated BSC AHP approach for supply chain management evaluation. Developed a BSC for SCM evaluation and proposes a method to prioritize the different performance levels in any organization using AHP methodology. Proposes a balanced performance evaluation system for SCM. While suggesting BSC, different SCM performance metrics have been distributed into four perspectives. Different performance levels are highlighted and preferred BSC perspectives are suggested.

Varma et al. (2008) suggested a combination of analytical hierarchy process and balanced scorecard for evaluating performance of the petroleum supply chain. In order to determine relative importance of criteria opinions have been collected in the form of pairwise comparisons. Using these comparisons, the AHP technique has been applied to determine the relative weights of various perspectives as well as the factors under each perspective. Opinions have been quantified using the AHP technique thus converting qualitative data to quantitative data.

Shyjith et al. (2008) focused on the use of AHP and technique for order preference by similarity to ideal solution (TOPSIS) to select an optimum maintenance strategy for a textile industry. The relative importance of multiple evaluation criteria and the extension of the TOPSIS are prioritized using AHP. The TOPSIS method is applied to compensate for the imprecise ranking of the AHP in the selection of a maintenance policy mix. An efficient ranking of alternatives can be achieved for maintenance strategy selection through the combination of AHP and TOPSIS.

In summary, we can learn from literature that "linking" is still immature and a little far from being effectively applied—the problem and difficulty lie in how to effectively link strategic objectives to operations, i.e., how to model and how to analyze.

The motivation of this study is to develop a model that links strategies to operations using AHP and TOPSIS techniques, based on SCOR model. Used metrics and hierarchy of SCOR model, the relative importance of strategic and metrics are prioritized using AHP and also the TOPSIS method is applied to compensate for the imprecise ranking of the AHP in the selection of the scenario mix.

Performance metrics in SCM

According to Chan and Qi (2003), performance measurement describes the feedback or information on activities with respect to meeting customer expectations and strategic objectives. It reflects the need for improvement in areas with unsatisfactory performance. Thus efficiency and quality can be improved.

Many methods and techniques have been suggested over the years for SCM evaluation. Traditional methods focus on well-known financial measures, such as the return on investment (ROI), net present value (NPV), the internal rate of return (IRR), and the payback period. These methods are best suited to measure the value of simple SCM applications. Unfortunately, evaluation methods that rely on financial measures are not well suited for newer generation of SCM applications. These complex supply chains typically seek to provide a wide range of benefits, including many that are intangible in nature. There is, however, a greater need to study the measures and metrics in the context of following reasons (Gunasekaran et al. 2004):

1. Lack of a balanced approach: Financial measures, which are required for examination by external stakeholders, are generally well developed. However, operational measures are typically ad hoc and lack formal structure (Gunasekaran et al. 2004). According to Kaplan and Norton (1992), while some managers and researchers have concentrated on financial measures of performance, others have concentrated on operational measures. Such equality does not lead to metrics that can present a clear picture of the organizational performance. As suggested by Maskell (1991), for a balanced approach, companies should bear in mind that, while financial performance measurements are important for strategic decisions and external reporting, day-to-day control of manufacturing and distribution operation is better handled with non-financial measures.

2. Lack of understanding on deciding on the number of metrics to be used: Quite often, companies have a large number of performance measures to which they keep on adding based on suggestions of employees and consultants, and fail to realize that performance measurements can be better addressed using a good few metrics.

3. Lack of clear distinction between metrics at strategic, tactical, and operational levels: Metrics that are used in performance measurement influence the decisions to be made at strategic, tactical, and operational levels. Using a classification based on these three levels, each metric can be assigned to a level where it would be most appropriate. Therefore, it is clear that for effective management of supply chain, measurement goals must consider the overall scenario and the metrics to be used. These should represent a balanced approach and should be classified at strategic, tactical, and operational levels, and be financial and non-financial measures, as well.

Performance measurement in the context of a supply chain now becomes extremely important. The reason is evident: Organizations start looking at ways to improve their operational performance through a better integration of operations across subsequent echelons and separated functions in the value chain. The ability to measure the performance of operations can be seen as a necessity for improvement, and companies have endeavored to enhance their capabilities of their performance measurement systems over the last years.

Gunasekaran et al. (2004) presented a framework for performance measures and metrics, classified at strategic, tactical, and operational levels, considering the four major supply chain activities/processes: (1) plan, (2) source, (3) make/assemble, and (4) deliver (Stewart 1995; Chan and Qi 2002). These processes can also be seen in SCOR model, will be described in next section. These metrics were classified at strategic, tactical and operational to clarify the appropriate level of management authority and responsibility for performance can be seen in Gunasekaran et al. (2004).

There are a number of approaches to supply chain performance measurement. Most companies are still in the informal or functional stage where they focus on the performance of their own enterprise and measure their supply chain performance with financially oriented metrics. Instead of immediately aiming for extended enterprise measurement of performance which includes a company's suppliers and customers, it is a pragmatic approach to first start with measurement of the own enterprise performance in the supply chain. Of all the approaches available, SCOR is the most comprehensive, well-recognized in industry and has been used by many companies to improve their supply chain performance.

A list of minimum requirements for any SCPM system is described below (Gintic Institute of Manufacturing Technology 2002) and can easily be compared with SCOR model:

1. *Metrics that are process based activities*: Functional department based metrics can result in each department optimizing its own performance, which seldom results in an optimal enterprise-wide performance. SCOR metrics are based on five distinct processes: Plan, Source, Make, Deliver and Return.

2. *Metrics defined at executive and operational level*: Metrics should ideally be defined both for the company's senior management (or executive level) and for the middle management (or operational level). SCOR is hierarchical with 3 levels. Each level has its own metrics with are linked through cascading.

3. *Metrics can be aligned to overall business objectives*: The supply chain performance as measured by the metrics should be able to be linked to overall business objectives such as profit, return on assets (ROA), market share etc. Level 1 SCOR metrics can easily be linked to business objectives such as cost, reliability.

4. *Metrics cover the performance of all supply chain processes in a company*: The minimum covered should therefore be metrics covering the supplier side of a company (related to inbound logistics), the internal operations within the company like purchasing, production, warehousing etc. And the customer side of a company (related to outbound logistics). The five process of SCOR cover all major functional areas in a company's supply chain like inbound logistics, sourcing/purchasing, production, order management, outbound logistics/transportation, warehousing etc.

5. *Metrics can be used cross-enterprise*: As more companies implement SCM-initiatives that aim to take some level of control or collaborate with upstream and/or downstream supply chain activities, the need for external measures for processes outside a company's control arises. Most of the SCOR metrics can be used to measure the performance of suppliers and customers, some are more internal focused.

SCOR performance attributes and metrics

The performance measure framework utilized in our research is based on SCOR-model version 5. Furthermore, we concentrate the research scope to Level 1 performance attributes and metric specifically.

The SCOR-model contains five basic management processes: Plan, Source, Make, Deliver, and Return (level 1 process) (Fig. 2). The model is hierarchical with three levels. Each process element in Level 1 can be decomposed to Level 2 process elements. Likewise, each Level 2 process element consists of Level 3 process elements.

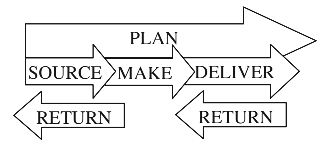

Fig. 2 SCOR main process (SCOR 5.0 2000)

In SCOR-model, each process element has its own performance metrics. Level 1 metrics (shown in Table 1) are primary and high level measures that may contain multiple SCOR processes. Level 1 metrics do not necessarily relate to a SCOR Level 1 process (Plan, Source, Make, Deliver, and Return). However, it is important to note that the metrics are intended to be hierarchical as the process elements.

The Performance Attributes are characteristics of the supply chain that permit it to be analyzed and evaluated against other supply chains with competing strategies. For example we can compare an organization that chooses to be the low-cost provider against an organization that chooses to compete on reliability and performance.

On the top of SCOR, the strategy map enables to decompose objectives in the strategic world; while on the down side, SCOR metrics provide a very good foundation for translating strategic objectives into supply chain operations of different levels.

Associated with the Performance Attributes are the Level 1 metrics. These Level 1 metrics are the calculations by which an implementing organization can measure how successful they are in achieving their desired positioning within the competitive market space. A list of metrics in Level 1 related with attributes and the calculations of metrics are listed in Table 1, derived from Gintic Institute of Manufacturing Technology (2000) and Bolstroff (2002). ("Inc.?" means will not be included illustrative example. In SCOR model version 9 the attribute "flexibility" renamed as "agility"). Also brief definitions of SCOR level 1 metrics can be seen in Table 1.

First time users of the model should be aware that the metrics in the model are hierarchical—just as the process elements are hierarchical. Level 1 metrics are created from lower level calculations. These lower level calculations (Level 2) are generally associated with a narrower subset of processes.

The SCOR-model provides an indication as to how effective a firm uses resources in creating customer value. It considers the performance expectations of member firms on both input and output sides of supply chain activities. Table 1, provides a useful framework for developing a construct and the corresponding instrument for supply chain performance measurement.

Harrington (1991) states that "If you cannot measure it, you cannot control it. If you cannot control it, you cannot

Table 1 Performance attributes and associated level 1 metrics SCOR v5

Facing	Performance attribute	Level 1 metric	Units	Calculation	No.	Inc.?
Customer facing	Supply chain 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: measures the quality of the company's performance to its Promised Order Delivery Date	Percentage	[Number of orders delivered on time and in full]/[total number of orders received]	1	
		Fill rates: can only be used when the product is shipped from stock to the customer. Fill rate represents the percentage of orders that can be shipped from stock within 24 hours of the order receipt. This shows how quickly your company can respond to customer orders in the situation where your company has decided to produce in a make-to-stock environment	Percentage	[Numbers of orders filled from stock shipped within 24 h of order receipt]/[total number of stock orders]	2A	X
		Perfect order fulfillment: defined as the right product, delivered to the right place, at the right time, in the right condition and packaging, in the right quantity, at the right cost, to the right customer. Another concept to consider as a potential alternative is the definition of replenishment	Time (in days)	[Sum actual lead times for all orders shipped]/[total number of orders shipped]	2B	
Customer facing	Supply chain RESPONSIVENESS: The velocity at which a supply chain provides products to the customer	Order fulfillment lead times: defined as the time from receipt of customer order to customer order receipt	Percentage	[Total orders shipped on time and in full—orders with faulty documentation—orders with shipping damage] / [total number of orders received]	3	

Table 1 continued

Facing	Performance attribute	Level 1 metric	Units	Calculation	No.	Inc.?
Customer facing	Supply chain FLEXIBILITY: The agility of a supply chain in responding to marketplace changes to gain or maintain competitive advantage	Supply chain response Time: The ability to react purposefully and within an appropriate time scale to significant events, opportunities or threats (especially from the external environment) to bring about or maintain competitive advantage in the marketplace	Time (in days)	[Order fulfillment lead time + source cycle time]	4	
		Production flexibility upside: The number of days required to achieve an unplanned sustainable 20% increase in production	Time (in days)	Upside flexibility [number of days required to achieve an unplanned sustainable 20% increase in production]	5A	X
		Production flexibility downside: The percentage order reduction sustainable at 30 days prior to delivery with no inventory or cost penalties	Percentage	Downside flexibility [percentage of order reduction sustainable at 30 days prior to delivery with no inventory or cost penalties]	5B	X
Internal Facing	Supply chain COSTS: The costs associated with operating the supply chain	Total supply chain Management costs: represents the sum of all costs your company incurs to run your integrated supply chain	Percentage	[Sum of supply chain related costs for MIS, finance, planning, inventory carrying, material acquisition and order management]/total revenue	6	
		Cost of Goods Sold	value (in $)		7	
		Value-added productivity: defined as the measurement of cost and productivity performance required to realize product revenue objectives. A higher number indicates a better use of resources in the supply chain transformation process	value (in $)	[Total gross annual sales—total annual material purchases]/total employment (in FTE)	8	

Table 1 continued

Facing	Performance attribute	Level 1 metric	Units	Calculation	No.	Inc.?
		Warranty/returns processing costs: a measure of a product's overall quality. Consequently, warranty costs and related information are important in product planning and development. A warranty is a producer's guarantee that a product or service will adequately meet performance requirements for a certain period	Percentage	[Total costs for warranty]/[Total revenue]	9	X
Internal facing	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	Inventory days of supply: The number of days it takes to get goods produced and sold; it is called shelf life for retail and wholesale trade. It indicates the time it takes to convert the investment in inventory into sold goods	Time (in days)	[5 point annual average of gross value of inventory at standard cost]/[annual cost of goods sold (COGS)/365]	10	
		Cash-to-cash cycle time: The time it takes for the firm to get cash back from its investment in inventory and accounts receivable, considering that purchases may be made on credit.	Time (in days)	[Inventory days of supply + days of sales outstanding—days of payables outstanding]	11	
		Asset turns: An activity ratio relates information regarding how effectively the firm's assets are being managed. The level of a firm's investment in assets depends on many factors, such as seasonal, cyclical and industry considerations	turns per year	[Total gross annual sales]/[total net assets]	12	

Table 2 Alternative evaluation techniques

Technique	Role	Outcome	Dimension	Features
Pareto(ABC) analysis	Decision making tool	Prioritized list of alternatives	Based on single criteria	Prioritize alternatives into high, medium, low
Analytic Hierarchy Process (AHP)			Based on multiple criteria	Rank alternatives
Technique for order preference by similarity to ideal solution(TOPSIS)				Rank alternatives based on relativity to the ideal solution

manage it. If you can not manage it, you cannot improve it". In fact, the lack of relevant performance measures has been recognized as one of the major problems in process management and the management of a supply chain. Because of the different views on what should constitute supply chain performance, many firms have found it difficult to practice SCM.

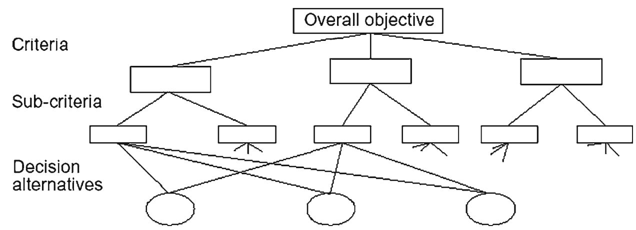

Fig. 3 The hierarchical structure of a decision problem (Rangone 1996)

Principles of AHP and TOPSIS methods

Managers may use different techniques for ranking and decision support, the technique they use depending on the situation. As mentioned earlier, ranking depends on whether the decision is made based on single or multiple criteria. For a single criterion, experience has shown that Pareto (ABC) analysis is the best tool. Both AHP and TOPSIS show good potential for multiple criteria. While one ensures the consistency of the weighting process, the other provides an indication of how far the alternative is from the ideal solution (Hwang and Yoon 1981).

Techniques such as Pareto, AHP, and TOPSIS should result in a more than sufficient level of accuracy to assist decision makers. The question, however, is when to use Pareto rather than AHP or TOPSIS. Table 2 derived from Alvarado et al. (2007) shows the differences between these techniques (Parkan and Wu 1997).

The TOPSIS method is based upon the concept that the chosen alternative should have the shortest distance to the ideal point. It requires a decision matrix as input evaluation data but uses given relative weights as the representation of preference information.

A relative advantage of TOPSIS is the ability to identify the best alternative quickly (Parkan and Wu 1997). TOPSIS has been comparatively tested with a number of other multi-attribute methods (**?**). The other methods primarily focused on generating weights (Step 2 in the prior description), with one method, preference ranking organization method for enrichment evaluations (ELECTRE) (Brans et al. 1986) including a different way to combine weights and distance measures. TOPSIS was found to perform almost as well as multiplicative additive weights and better than AHP, (Saaty 1977) in matching a base prediction model. When there were few criteria, TOPSIS had proportionately more rank reversals. When there were many criteria, TOPSIS differed more from simple additive weight results, and TOPSIS was also affected more with diverse sets of weights. TOPSIS performed less accurately than AHP on both selecting the top ranked alternative and in matching all ranks in this set of simulations.

In this study the TOPSIS applied to normalize the values that have different units. AHP is adopted to determine criteria weights to carry the strategic weights to operational metrics and used in normalization. And continuing TOPSIS procedures, achieved the final ranking of the different scenarios.

Analytic hierarchy process (AHP) methodology

AHP is a decision-making tool that can help describe the general decision operation by decomposing a complex problem into a multi-level hierarchical structure of objectives, criteria, sub criteria and alternatives (Saaty 1990) and can be seen in Fig. 3.

The AHP is a multi-attribute decision tool that allows financial and no financial quantitative and qualitative measures to be considered and trade-offs among them to be addressed. The AHP is aimed at integrating different measures into a single overall score for ranking decision alternatives. Its main characteristic is that it is based on pair wise comparison judgments. The AHP includes the following steps:

AHP Step 1. Define the unstructured problem and state clearly the objectives and outcomes.

AHP Step 2. Develop a hierarchical structure of the decision problem in terms of overall objective, criteria, sub criteria and decision alternatives. Decompose the complex problem into a hierarchical structure with decision elements (criteria, detailed criteria, and alternatives). A hierarchy has at least three levels: overall goal of the problem at the top, multiple criteria that define alternatives in the middle, and decision alternatives at the bottom (Fig. 3).

AHP Step 3. The next step is the comparison of the alternatives and the criteria. Determine, on pair wise basis, the relative priorities of criteria and sub criteria that express their importance in relation to the element at the higher level. The pairwise judgment starts from the second level and finishes in the lowest level, alternatives. In each level the criteria are compared pairwise according to their levels of influence and based on the specified criteria in the higher level. The relative importance of two elements is rated using a scale with the values 1, 3, 5, 7, and 9, where 1 refers to "equally important", 3 denotes "slightly more important", 5 equals "strongly more important", 7 represents "demonstrably more important" and 9 denotes "absolutely more important" (Saaty 1980; Chang 2010). Construct a set of pair-wise comparison matrices (size nxn) for each of the lower levels with one matrix for each element in the level using the relative scale measurements. The pair-wise comparisons are done in terms of which element dominates the other.

AHP Step 4. There are n(n−1)/judgments required to develop the set of matrices in step 3. Reciprocals are automatically assigned in each pair-wise comparison.

AHP Step 5. Hierarchical synthesis is now used to weight the eigenvectors by the weights of the criteria and the sum is taken over all weighted eigenvector entries corresponding to those in the next lower level of the hierarchy.

AHP Step 6. Having made all the pair-wise comparisons, the consistency is determined by using the eigenvalue, λ_{max}, to calculate the consistency index, CI as follows: $CI = (\lambda_{max} - n)/(n - 1)$, where n is the matrix size. Judgment consistency can be checked by taking the consistency ratio CR = CI/RI with the appropriate value in Table 3. The CR is acceptable, if it does not exceed 0.10. If it is more, the judgment matrix is inconsistent. To obtain a consistent matrix, judgments should be reviewed and improved.

AHP Step 7. Steps 3–6 are performed for all levels in the hierarchy.

AHP Step 8. Obtain composite criteria weight: The composite weights are obtained by multiplying the relative normalized weight of each factor with its corresponding normalized weight value for each alternative and making summation over all the factors for each alternative.

Recently the AHP has been applied to several and heterogeneous decision problems, e.g. investments appraisal, projects selection, human resources evaluation, vendor rating (several software packages are available to implement AHP). However, little attention has been given so far to the application of the AHP to "performance measurement", although the AHP seems to be suitable also to compare the overall results of different responsibility centers within a company when multi-attribute performance criteria are used (Rangone 1996).

We will introduce TOPSIS in the next section. Then, we further discuss about TOPSIS and AHP in the following sections.

Technique for order preference by similarity to ideal solution (TOPSIS)

The technique for order preference by similarity to ideal solution (TOPSIS) is proposed by Chen and Hwang (1992), with reference to Hwang and Yoon (1981). It is one of the principal techniques for MCDM (multi criteria decision making) problems. Although TOPSIS is based on a simple and intuitive concept, it enables consistent and systematic aggregation of the criteria. TOPSIS defines two kinds of solutions: (1) the ideal solution, and (2) the negative ideal solution. The ideal solution is regarded as the maximal benefits solution, it consists of the all best values of criteria; on the contrary, the negative idea solution is treated as the minimal benefits solution, it is composed of the all worst values of criteria. TOPSIS defines solutions as the points which are nearest to the ideal point and farthest from the negative ideal solution at the same time. In this concept, during the process of alternative selection, the optimal alternative is closest to the ideal solution and farther from the negative ideal solution.

The idea of TOPSIS can be expressed in a series of steps:

TOPSIS Step 1. Establish the decision matrix.

TOPSIS Step 2. Create normalized the decision matrix. Normalizing the performance matrix is an attempt to unify the unit of matrix entries.

Table 3 Average random consistency (RI) (Saaty 1980)

Size of matrix	1	2	3	4	5	6	7	8	9	10
Random consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

TOPSIS Step 3. Create the weighted normalized decision matrix. There are many methods that can be employed to determine weights (Hwang and Yoon 1981), such as the eigenvector method, weighted least square method, AHP, analytic network process (ANP), as well as linear programming techniques (Chen and Tzeng 2004; Tsai et al. 2008).

TOPSIS Step 4. Determine the ideal solution (A_i^*) and the negative ideal solution(A_i^-).

TOPSIS Step 5. Calculate the distance between ideal solution(S_i^*) and negative ideal solution(S_i^-) for each alternative. Using the n-dimensional Euclidean distance.

TOPSIS Step 6. Calculate the relative closeness (C_i^*) to the ideal solution of each alternative.

TOPSIS Step 7. Rank the preference order, where $0 \leq C_i^* \leq 1$. That is, an alternative i is closer to A^* as C_i^* approaches to 1. A set of alternatives can be preferentially ranked according to the descending order of C_i^* (Chang 2010).

TOPSIS–AHP–SCOR integrated approach

Problem definition

If a company does not have a clear understanding of how well its supply chain(s) are performing, it will be very hard to manage them successfully. Companies need to know how well their supply chain processes are operating first before they can decide whether to reengineer them or not. And after any improvement program is implemented, they need to continue to measure the performance to know if the changes made really delivered improvements and if they are sustained over a longer period of time.

However, how do we monitor SCOR performance metrics related with attributes immediately and obtain the useful information to make a right decision? To this end, AHP could be an essential tool to model the behavior of the performance metrics, create the structure of hierarchical metrics and illustrate a clear picture for supply chain performance. Naturally, management on a firm wants to optimize their supply chain performance. This objective is not quantifiable but SCOR provides 12 metrics. The question is, can these 12 metrics be used to derive a quantifiable supply chain performance measure?

Briefly the problems are:

- Linking “strategic” objectives to “operational” objectives.
- Each performance metric value has different units: ratio, USD, days…etc. normalization needed. Heterogeneity of the performance measurement units makes it difficult to assess and compare the overall level of supply chain strategy.
- Calculating a total score of metrics to benchmark the performance of supply chain.

Combination of AHP and SCOR

AHP’s hierarchic structure reflects the natural tendency of the human mind to sort elements of a system into different levels and to group like elements in each level, which can facilitate decision maker’s easy understanding from a human factor point of view, The SCOR model is also a hierarchical model that consists of different process levels. The performance metrics it uses are also hierarchical in nature. Therefore, it seems natural to apply AHP with SCOR metrics to construct an overall objective function (overall supply chain efficiency) for optimization.

A more serious problem under debate while using AHP is rank reversal (Huang et al. 2004). With regard to performance assessment and comparison, rank reversal is not particularly critical, since the following facts are observed:

1. The set of criteria and sub-criteria to be compared, which are SCOR model Level I performance metrics, does not change. Therefore, multiple choices in this research would not cause a rank reversal problem.
2. Different alternatives are considered, so exact copies or near copies of alternatives do not exist in this research. Therefore, no rank reversal problem will occur.
3. Absolute measurements are used (i.e., the ranking of the criteria is initially independent of the particular alternatives in the decision problem being considered), so the addition and/or deletion of alternatives will not cause any rank reversal (Wang et al. 2004)

Proposed TOPSIS–AHP–SCOR integrated approach

Based on SCOR, we can construct metric hierarchy for each strategic objective, thus achieve the decomposition of strategy into operational metrics at different levels. Figure 4 shows the whole picture of the link from a strategy map to SCOR based metric network. On the top, the strategy map enables to decompose objectives in the strategic world; while on the down side, SCOR metrics provide a very good foundation for translating strategic objectives into supply chain operations of different levels.

Although the AHP is used for MCDM problem widely, it is still often criticized by some scholars because of the following disadvantages (Cheng 1999; Chan 2003; Mikhailov 2004):

- The AHP method is mainly used in nearly crisp decision applications.
- The AHP makes use of an unbalanced scale of estimations.

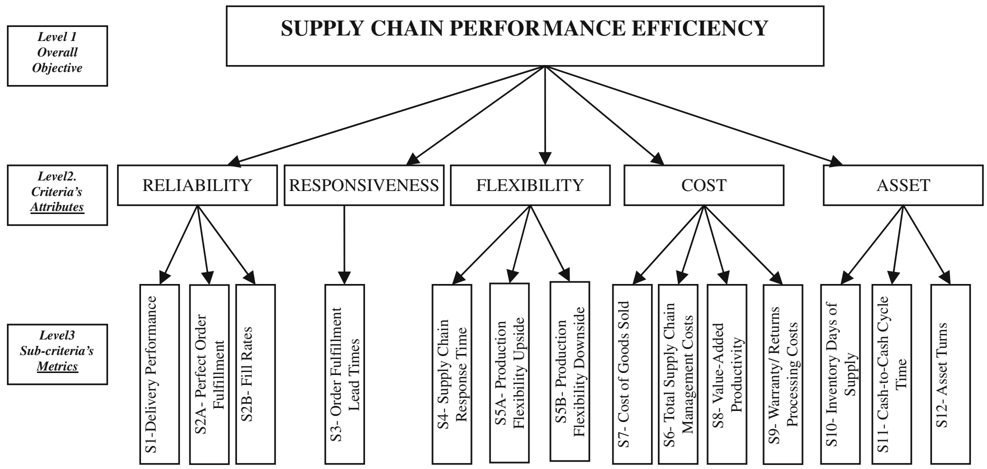

Fig. 4 SCOR based metric network

- The AHP does not take into account the uncertainty and risk in assessing the alternative's potential performance because it assumes the relative importance of criteria affecting alternative's performance is certain.
- Ranking of the AHP is not imprecise enough.
- The subjective judgment, selection and preference of decision makers result in large influence.

For this reason, we integrate the concept of TOPSIS with the AHP to overcome some of above disadvantages in our proposed model.

This integrated approach applies AHP and TOPSIS algorithms to develop a collaborative decision and evaluation processes and the following steps, see Fig. 5. The integrated approach shown in Fig. 5 comprises three stages. The first is the TOPSIS; the second, the SCOR based AHP; and finally, the integrated calculation of different scenario's total performance score's with a TOPSIS combined methodology.

The methodology of this comprises the following steps:

Step 1. Data gathering: Determine the possible SCOR based strategic attributes and performance metrics suitable for the needs. Determine the weights of attributes and metrics with decision makers. Collect the performance values of the past years for scenarios.

Step 2. Establishing and normalizing the decision matrix: Establish the decision matrix. Apply TOPSIS to normalize the values of past years' performance metrics that have different units (TOPSIS Steps 1, 2).

Step 3. Establishing weights for weighted normalized performance matrix: Calculate strategic weights (W_{AHP}) using SCOR based AHP.

Step 3.a. Construct a hierarchical structure of the performance metrics based on SCOR Level 1 performance attributes and metrics: We can define "strategic objectives" in SCOR model using relationship between performance attributes and metrics. SCOR "performance attributes" are characteristics of the supply chain that permit it to be analyzed and evaluated against other supply chains with competing strategies. Use performance metrics to define the "operational strategies" (For a benchmarkable standard, we used SCOR model). SCOR level1 performance "metrics" are associated with the performance "Attributes". These Level 1 metrics measure how successful they are in achieving their desired positioning within the competitive market space in an operational way. Level 1 metrics are created from lower level calculations and we can say that they mostly include more operational objectives. SCOR is already a cross industry standard including model and metrics. To this end, we intend to design a set of comprehensive methods to measure the supply chain performance based on the SCOR-model framework.

Step 3.b. Linking them by integrating SCOR model's hierarchy with AHP: There are many methods that can be employed to determine weights (Hwang and Yoon 1981), such as the eigenvector method, weighted least square method, AHP, analytic network process (ANP), as well as linear programming techniques (Chen and Tzeng 2004; Tsai et al. 2008). In this study, we haven't used ANP because; we didn't work on the relation between sub-criterias (metrics) depending on the SCOR model. So AHP is suitable for this study. In this step, determine the relative importance of competitive priorities of attributes and performance metrics. Develop a hierarchical structure of the decision problem (AHP Step 2). Define the criteria for ranking of performance attributes. Apply AHP to capture the behaviors of the performance attributes and the whole supply chain. Compute the overall score of each performance attribute/supply chain. Apply AHP to identify the relationship between attributes and performance metrics, and the whole supply chain. Compute the overall score of each performance metric/supply chain. (AHP Steps 3, 4, 5, and 6).

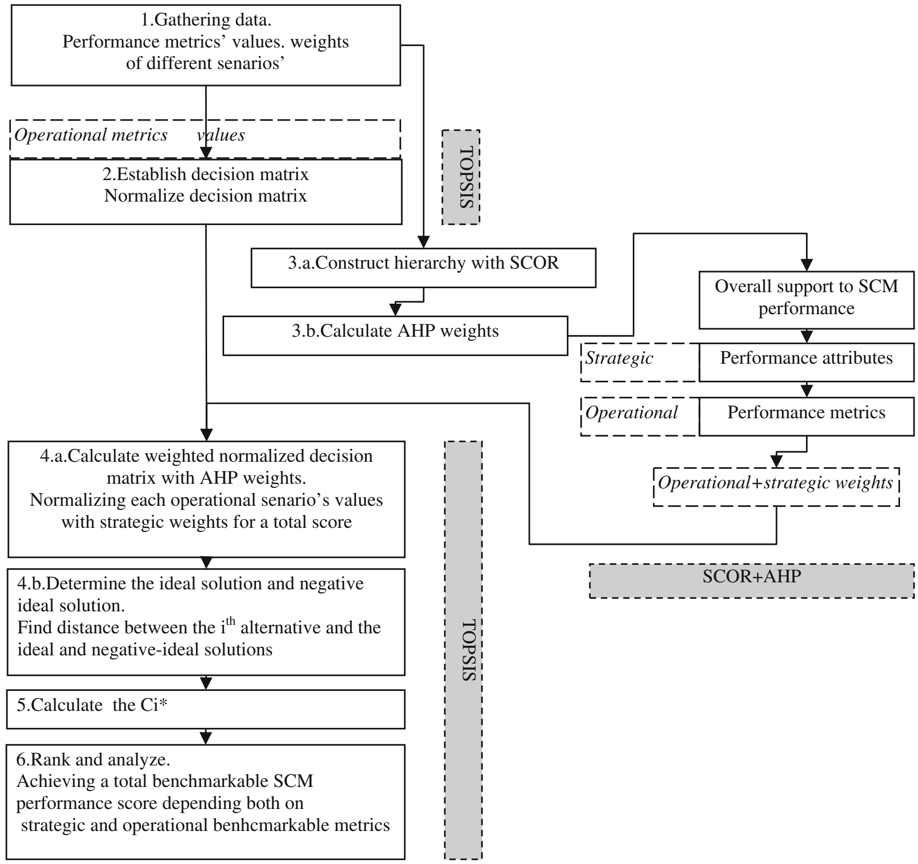

Fig. 5 Illustration of the model

Step 4. Construct the weighted normalized evaluation matrix.

Step 4.a. Use the AHP weights to calculate the normalized decision matrix (TOPSIS Step3).

Step 4.b. Determine the ideal solution and negative ideal solution using (TOPSIS Step 4). Then, the distance between the ith alternative and the ideal and negative-ideal solutions is determined (TOPSIS Step 5).

Step 5. Calculate the C_i^*: The relative closeness of each alternative to the ideal solution (C_i^*) is determined (TOPSIS Step 6). Therefore, the overall support to supply chain strategy for each scenario has been calculated.

Step 6. Rank the alternative scenarios by this order of preference. (TOPSIS Step 7). And analyze.

A numerical application of proposed approach

Company IF, has been in the design, manufacture and sales of fixing and hanging elements system for the construction industry. Today, among her product range are: pipe clamps, industrial type clamping systems, support channels, ventilation, anchor/expansion assemblies, anchor plugs, chemical anchors, insulation and seismic blocks and all related accessories. Figure 6 illustrates the supply chain of the company.

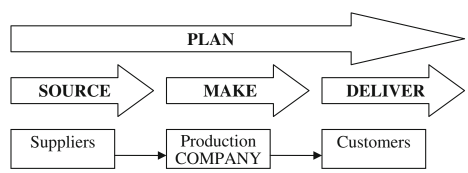

Fig. 6 Company's supply chain

The implementation of the proposed method is described below:

Step 1: Data Gathering: In the application, firstly the decision making team, which will take a part in scenario selection process, is formed. Decision making team consists of the manager of these six departments: production planning, finance, human resources, quality assurance, purchasing and sales. With a preliminary work, this decision making team determined the suitable for the needs of the company with brain storming activities. The ultimate goal of evaluating the ideal efficiency supply chain performance is achieved, followed by five-evaluation criterion(attributes) and ten sub-criteria (metrics) (Fig. 7). The evaluation criteria and sub-criteria used to evaluate the efficiency performance are defined as follows: The ten metrics used as criterias, namely S1 (Delivery Performance), S2B (Fill Rates), S3 (Order Fulfillment Lead Times), S4 (Supply Chain Response

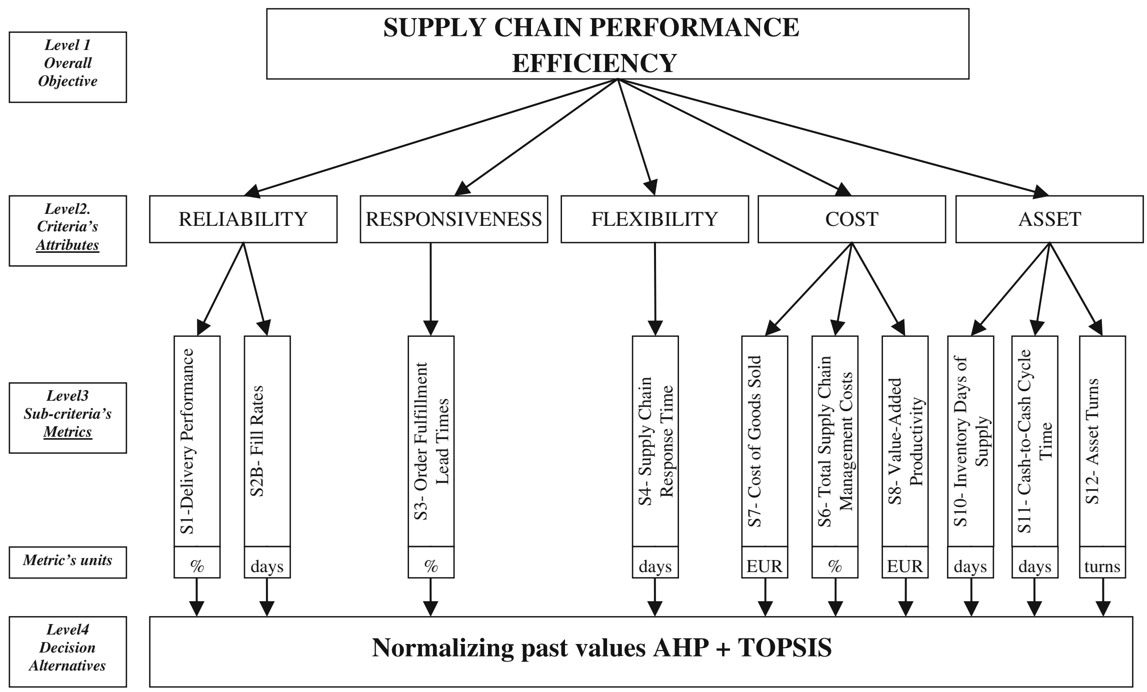

Fig. 7 Proposal AHP model for SCOR level 1 performance metrics hierarchy

Time), S7 (Cost of Goods Sold), S6 (Total Supply Chain Management Costs), S8 (Value-Added Productivity), S10 (Inventory Days of Supply), S11(Cash-to-Cash Cycle Time), S12(Asset Turns) which will be taken into account in the selection process, are determined. SCOR 1 performance metrics S2A, S5A, S5B and S9, just ignored, because of the missing dependable data on ERP. We used the data set from past years, and imported the metrics' values from the ERP (enterprise resource planning) system; and reached the values of each quarter, seen in Table 4. And to explain the strategic objectives of the management, the (five) performance attributes priorities of the company: reliability, responsiveness, flexibility, costs and assets determined. A general consensus among experts is reached to establish a model. To determine the relative weights, managers are asked to make pairwise comparations using a 1-9 preference scale. Each comparison is then transformed into numerical value.

Step 2. Establishing and normalizing the decision matrix: Established and normalized the decision matrix. We have finished the first two procedures of TOPSIS. The normalized decision matrix whose elements are given is formulated. Therefore, we have calculated "normalized" decision matrix.

Step 3. Establishing weights for weighted normalized performance matrix:

Step 3.a. Construct a hierarchical structure of the performance metrics based on SCOR Level 1 performance attributes and metrics: Six managers from different departments were issued a preliminary list five evaluation criteria from SCOR attributes and ten sub-criteria from SCOR performance metrics. From this, a general consensus was reached to establish a hierarchical structure.

The first step of the AHP consists of developing a hierarchical structure of the assessment problem. Established the AHP model and defined the evaluative criteria and sub-criteria. In the case of supply chain, the overall objective is the support obtaining a higher score strategy; the criteria are the performance attribute priorities; the sub criteria are the performance metrics; the decision alternatives are not included this study, but we will use these outputs in TOPSIS as weights. The basic assumption of that hierarchical structure is that the relation between SCOR v5 level 1 performance attributes and performance metrics.

Figure 7 shows the performance hierarchy for the example problem. At the first level of the hierarchy there are the (five) performance attributes priorities of the company: reliability, responsiveness, flexibility, costs and assets. At the second level there are performance metrics measures that play an important role in contributing to each priority. And each metric has different unit.

The performance hierarchy described above highlights performance a measurement system that is the heterogeneity of the measurement units of the indexes. The heterogeneity of the measurement units makes it difficult to assess and compare the overall level of supply chain strategy.

Step 3.b. Linking them by integrating SCOR model's hierarchy with AHP: After developing the performance hierarchy, managers determined the relative weights of performance attributes priorities and, for each priority, of the

Table 4 Past data table

No	Units	%	Days	%	Days	EUR	%	EUR	Days	Days	Turns
	PeRIOD	S1-Delivery performance	S2B-Fill rates	S3-Order fulfillment lead times	S4-Supply chain response time	S7-Cost of goods sold	S6-Total supply chain management costs	S8-Value-added productivity	S10-Inventory days of supply	S11-Cash-to-cash cycle time	S12-Asset turns
1	2005-1	0.69	37	0.69	37	65,892	0.94	312	20	20	0.97
2	2005-2	0.81	35	0.81	36	137,682	2.63	448	19	19	0.96
3	2005-3	0.80	34	0.80	34	105,376	2.49	315	15	15	0.97
4	2005-4	0.79	33	0.79	35	101,037	0.93	448	40	40	0.96
5	2006-1	0.73	31	0.73	31	307,671	3.99	882	13	12	0.54
6	2006-2	0.79	31	0.76	29	453,602	63.81	1,357	22	22	0.54
7	2006-3	0.92	37	0.88	36	488,467	15.96	1,284	22	21	0.54
8	2006-4	0.99	40	0.74	40	486,467	14.76	1,191	24	24	0.54
9	2007-1	0.97	40	0.97	40	410,384	15.86	969	11	11	0.38
10	2007-2	0.98	19	0.97	19	385,768	19.59	889	30	30	0.38
11	2007-3	0.87	10	0.87	10	649,832	11.01	1,446	12	12	0.38
12	2007-4	1.00	27	1.00	27	154,139	7.28	318	21	21	0.38

Table 5 Pairwise comparison matrix for criteria and weights, AHP ratings for performance attributes

	Supply chain	Reliability	Responsiveness	Flexibility	Cost	Assets	Weight
I	Reliability	1	0.14	0.20	0.20	0.20	0.037
II	Responsiveness	7	1	0.20	0.33	0.14	0.084
III	Flexibility	5	5	1	1.00	0.33	0.221
IV	Cost	5	3	1	1	0.33	0.200
V	Assets	5	7	3	3	1	0.457

Results: λ_{max} = 5.438, n = 5, RI = 1.12, CI = 0.11, CR = 0.10, consistent

Table 6 AHP ratings for attribute reliability and metrics

I. Reliability	S1-Delivery performance	S2B-Fill rates	Weights
S1-Delivery performance	1	0.11	0.004
S2B-Fill rates	9	1	0.034

Result: Same row elements, consistent

Table 7 AHP ratings for attribute cost and metrics

III. Cost	S7-Cost of goods sold EUR	S6-Total supply chain management costs	S8-Value-added productivity	Weights
S7-Cost of goods sold EUR	1	0.11	0.20	0.013
S6-Total supply chain management costs	9	1	0.33	0.069
S8-Value-added productivity	5	3	1	0.118

Results: λ_{max} = 1.390, n = 3, RI = 0.58, CI = −0.81, CR = −1.39, consistent

Table 8 AHP ratings for attribute assets and metrics

IV. Assets	S10-Inventory days of supply	S11-Cash-to-cash cycle time	S12-Asset turns	Weights
S10-Inventory days of supply	1	0.14	0.14	0.025
S11-Cash-to-cash cycle time	7	1	0.20	0.103
S12-Asset turns	7	5	1	0.300

Results: λ_{max} = 1.619, n = 3, RI = 0.90, CI = −0.69, CR=−0.77 consistent

performance metrics. With respect to attributes priorities the relative weights ASSESS their importance in providing support to the implementation of the supply chain strategy. As far as performance metrics are concerned, the relative weights express their importance in contributing to the corresponding attributes priority.

To determine the relative weights managers are asked to make pair wise comparisons using Saaty's scale. The relative importance of two elements is rated using a scale with the values 1, 3, 5, 7, and 9, where 1 refers to "equally important", 3 denotes "slightly more important", 5 equals "strongly more important", 7 represents "demonstrably more important" and 9 denotes "absolutely more important" (Saaty 1980).

Table 5 reports the paired comparison data and the weights of the attributes priorities of the example problem. It should be noted that the quality of the output of the AHP, i.e. the calculation of the overall support to the supply chain strategy, is strictly related to the consistency of the pair wise comparison judgments given by managers (Deng 1989). Saaty (Dubois and Prade 1980) suggests a simple procedure for checking on consistency (Hwang and Yoon 1981) (AHP Step 6).

In Table 5 pairwise comparison matrix of the five main criteria with respect to the goal can be seen. And results of the consistency calculation can be seen below of the each table.

Table 6 summarizes the calculated weights for the Reliability attribute criteria, (S1) Delivery Performance and (S2B) Fill Rates metrics sub-criteria. And checked consistency. The matrix is consistent. The final results obtained from AHP computations for attributes related with metrics are shown in "weights" column.

Also the relation of attribute Flexibility with (S4) Supply Chain Response Time metric examined. With same row elements, the matrix is consistent. Same, the relation of attribute Responsiveness with (S3) Order Fulfillment Lead Times metric examined. With same row elements, the matrix is consistent.

Table 9 AHP rating results that will be used in normalizing

Performance metrics	S1-Delivery performance	S2B-Fill rates	S3-Order fulfillment lead times	S4-Supply chain response time	S7-Cost of goods sold	S6-Total supply chain management costs	S8-Value-added productivity	S10-Inventory days of supply	S11-Cash-to-cash cycle time	S12-Asset turns	Total
Weights	0.004	0.034	0.084	0.221	0.013	0.069	0.118	0.025	0.103	0.300	0.971
Norm. weights (W_{AHP})	0.004	0.035	0.087	0.228	0.014	0.071	0.121	0.026	0.106	0.309	1.000

Table 10 Resultant of Si* and Si−

No	Period	Si*	Si−	Ci* = Si−/(Si* + Si−)
1	2005-1	0.0807	0.0967	0.545
2	2005-2	0.0775	0.0955	0.552
3	2005-3	0.0829	0.0932	0.529
4	2005-4	0.0729	0.1020	0.583
5	2006-1	0.0953	0.0529	0.357
6	2006-2	0.0668	0.0872	0.566
7	2006-3	0.0790	0.0724	0.478
8	2006-4	0.0790	0.0769	0.493
9	2007-1	0.1017	0.0686	0.403
10	2007-2	0.1025	0.0439	0.300
11	2007-3	0.1191	0.0449	0.274
12	2007-4	0.1114	0.0394	0.261

Table 11 Summary of the results of the proposed method

No	Units	%	Days	%	Days	EUR	%	%	EUR	Days	Days	Turns
	Period	Score	S1-Delivery performance	S2B-Fill rates	S3-Order fulfillment lead times	S4-Supply chain response time	S7-Cost of goods sold	S6-Total supply chain management costs	S8-Value-added productivity	S10-Inventory days of supply	S11-Cash-to-cash cycle time	S12-Asset turns
4	2005-4	0.583	0.79	33	0.79	35	101,037	0.93	448	40	40	0.96
6	2006-2	0.566	0.79	31	0.76	29	453,602	63.81	1,357	22	22	0.54
2	2005-2	0.552	0.81	35	0.81	36	137,682	2.63	448	19	19	0.96
1	2005-1	0.545	0.69	37	0.69	37	65,892	0.94	312	20	20	0.97
3	2005-3	0.529	0.80	34	0.80	34	105,376	2.49	315	15	15	0.97
8	2006-4	0.493	0.99	40	0.74	40	486,467	14.76	1,191	24	24	0.54
7	2006-3	0.478	0.92	37	0.88	36	488,467	15.96	1,284	22	21	0.54
9	2007-1	0.403	0.97	40	0.97	40	410,384	15.86	969	11	11	0.38
5	2006-1	0.357	0.73	31	0.73	31	307,671	3.99	882	13	12	0.54
10	2007-2	0.300	0.98	19	0.97	19	385,768	19.59	889	30	30	0.38
11	2007-3	0.274	0.87	10	0.87	10	649,832	11.01	1,446	12	12	0.38
12	2007-4	0.261	1.00	27	1.00	27	154,139	7.28	318	21	21	0.38

In Tables 7 and 8, for the other matrices the results of the consistency checks can be seen below of the each table. They are all consistent.

So the weights are shown to be consistent and they will be used in the TOPSIS process. Averaging these values with the weights of the attribute priorities, it is possible to determine the overall support to the achievement of the supply chain strategy. On the basis of this score, Table 9 shows the relative weighted of the elements of each metric.

Table 9 shows that (S12) Asset Turns metric has the highest score with 0.309.

Step 4. Construct the weighted normalized evaluation matrix.

Step 4.a. Construct the weighted normalized evaluation matrix: Since the sub-criteria weights (W_{AHP}) have been obtained from AHP, the normalized performance matrix and the weighted normalized performance matrix is calculated.

Step 4.b. Finally, the distance of the ith alternative from the ideal(Si*) and negative-ideal(Si−) solutions were calculated. Table 10 presents these results.

Step 5. Calculate the C_i^*: The relative closeness to the ideal solution, C_i^*, was calculated for each alternative. The last column in Table 10 presents these results.

Step 6. Rank the alternative scenarios by this order of preference: The alternatives were ranked on the basis of this value (Table 11). Thus, scenario 4 was selected as the best scenario that supports best the strategic objectives. According to Table 11 the ranking order of the three scenarios are 2005-4, (0.583), 2006-2 (0.566) and 2005-2 (0.552).

As seen in Table 11, when 2005-4 period's values (S1) Delivery Performance = 79%, (S2B) Fill Rates = 33 days, (S3) Order Fulfillment Lead Times = 79%, (S4) Supply Chain Response Time = 35 days, (S7) Cost of Goods Sold = 101,037 EUR, (S6) Total Supply Chain Management Costs = 93%, (S8) Value-Added Productivity = 448 EUR, (S10) Inventory Days of Supply = 40 days, (S11) Cash-to-Cash Cycle Time = 40 days and (S12) Asset Turns = 96% are chosen as the target performance values, if succeeds, the company will have the best overall performance related with strategic sights, among other scenarios.

So, we have normalized the given values, used AHP weights and reached the score of whole supply chain.

Conclusions

The SCOR model provides a common supply-chain framework, standard terminology, common metrics with associated benchmarks, and best practices. This study discussed issues related to the use of SCOR performance metrics for decision making. We intended to design a set of methods to measure the supply chain performance based on the

SCOR-model framework. The case study presented above illustrated how multiple criteria (e.g. SCOR Model Level 1 performance metrics) can be included in the AHP approach to permit a more flexible and inclusive uses of this data in a determining supply chain performance. It has also been demonstrated how the AHP weighting can be combined in TOPSIS to strengthen the easy ranking manner of the traditional AHP.

This proposal further combines the concepts of the AHP and TOPSIS models to evaluate and rank scenarios' supply chain performance. The AHP and TOPSIS based decision making method for constructing an evaluation method can provide decision makers or administrators with a valuable reference for evaluating the company performance. In particularly, investors and administrators frequently lack objective decision-making procedures and assessment criteria.

Finally, by applying AHP in obtaining criteria weight and TOPSIS in ranking on those results, the 2005-4 (0.583) is identified as the optimal scenario. This study used limited data for the performance evaluation and each scenario organized its statements differently, creating further limitations.

This study demonstrated a way to normalize and having a total value of measures expressed in heterogeneous measurement units, depending on specific weights. We used the values of metrics' from past data for scenarios and normalized the values including AHP's weights with TOPSIS, so we had chance to calculate more objective and quantitative results, instead of just AHP's subjective. We can see the company's supply chain performance score and it became possible to evaluate and create strategies. For further works, it can be analyzed for which criteria are more important and need to change the weights to have a higher supply chain performance score. Second, follow-up research can be the same method applied to other industries. Instead of one companies' values, value's collected from different companies will be more useful in a benchmarking project.

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