A Model for the Control and Monitoring of Supply Chain Indicators

Loraine Sanchez-Jimenez, Tomás E. Salais-Fierro, and Jania A. Saucedo-Martínez

Abstract In the current competitive environment, companies are pushed to develop strategies to achieve operational excellence in pursuit of growth and profitability. A supply chain focuses primarily on reducing costs by optimizing its processes, achieving a service level that meets the required quality standards. Managing the success of the supply chain is considered an essential activity in any organization. Then, the effectiveness and efficiency of the supply chain can be determined through a performance measurement system focused especially on logistics processes. The proposal established in this research consists of a system that integrates auxiliary techniques in decision-making with the aim of establishing performance indicators within the supply logistics process. In addition, this system incorporates fuzzy logic in order to establish more realistic and robust metrics and with the ability to feed back indicators under uncertain environments or with a lack of information. The presented system is cyclical and adaptive, which includes techniques based on AHP, SCOR, and Fuzzy Logic, and they support the decision-maker in any environment, stage, or process of the supply chain by determining through projections if the objectives planted in the improvement plans have been achieved. Additionally, it identifies the attributes that impact on the supply chain and those that represent areas of opportunity to improve.

Keywords Performance · Measurement · Techniques · Supply chain · Indicators · Models

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1 Introduction

Delivery on time adding value to the customer is probably the most challenging goal in the supply chain as its complexity has increased over the past years given the competition in the market aiming to meet the customer expectations. Different functional activities are taken into account in a supply chain. These are performed along the chain and include technology, business processes, and people, and infrastructure delivered a finished good or service [1]. Therefore, supply chain management has focused on maintaining an effective organization of activities from supplier to end customer by searching for ways to reduce or eliminate risks.

In the long term, it also establishes types of cooperation between the different actors in its supply chain to avoid any type of disruption and thus achieve better products and services [3].

A performance measurement system contributes to achieving business objectives [4]. Its structure is composed of attributes that measure the supply chain effectiveness and efficiency [5]. Measuring the correct process at the right time is vital for an improved decision-making process.

A system focused on analyzing the performance of any type of operating environment and its respective elements and/or processes can be designed from different perspectives, which can range from identifying the WIP and its characteristics to ROI or identifying any type of operating excess or unnecessary processes [6]. After selecting the aspects to be verified, the next step is to control and measure the information, finally, to evaluate and obtain results for subsequent improvement.

The frequent shortcomings in performance measurement system could be summarized in the lack of connection between strategic objectives and metrics, the biased centralization in finance and the existence of conflicting measures [7], useless metrics, and a guidelines that fall short on development at different levels and processes [8], not having a clear vision to establish the appropriate level of action required, long, medium, or short terms. In some cases, companies use benchmarking unequivocally by comparing themselves to large companies that are very different from a logistics standpoint or companies that are not logistically similar [9].

When the economic factor is established, a mechanism that determines and analyzes the supply chain must be an essential part of its control process. For this reason, establishing the level of performance is defined as an evaluation process to quantitatively and qualitatively determine the operational functionality of any business [10]. The evaluation is carried out by means of metrics or logistical indicators related to various performance objectives.

It is essential to define the scope of the performance evaluation when making a measurement system, to be clear about what to measure, how to do it, and above all to know the priorities for measurement. Also, it is important to consider the resources available to carry out the practice successfully.

In the past years, researchers have developed multiple supply chain performance frameworks to measure different problems or business models [11], and most researchers compose the performance measurement system based on several criteria [6]:

– Balanced scorecard (learning and development, internal business process, customer, and finance)
– Metrics (quantitative and qualitative): Classic versus innovative measures
– Decision-making levels (long, medium, or short terms)
– KPIs elements (resources, products, and flexibility)
– KPIs-based (financial and operational)
– Metrics location for the supply chain coordination (from planning to deliver processes)

Lima-Junior and Carpinetti [10, 12] indicate that one of the most popular indicators is cost. However, to the latter, it can be considered that the response capacity falls within the group of indicators most used in the logistics area, as well as flexibility, sustainability, among others.

The proposal presented in this research work is described in the following sections that have been divided as follows: the following section (background) analyzes some of the most well-known analysis tools in the industrial area in order to identify measurement systems according to the industry scenario. After this, the methodology applied in this research based on the findings found in the literature is presented. Then, the proposed system is described as well as the expected result of its application. At the end of the document, a reflection is made on the findings of the proposal, and the possible actions to improve its application are analyzed. It is concluded that the contributions of this system are the indicators obtained with respect to the base model applicable to the procurement area of the organization. Second, it determined the relationship among KPIs found with the base model and presented an evaluation of the main indicator systems. That is, it can be determined if the output projects adequate results and also evaluates the structure of measurement systems (the number of metrics, goals, relation to strategic objectives, etc.). Finally, configurations based on a hybrid model have a cyclic and adaptive system. This model is built from the metrics and attributes of the SCOR, a FAHP for the analysis of priorities and a FIS to measure predictively and defining the contribution of the factors with the greatest impact, with which a better alignment of the actions generated is achieved of the decision process and improving the results of the improvement plans.

2 Background

Some tools for the measurement and usage are revised in the following literature review.

Approaches	Process-based approaches	
	Perspective-based approaches	Supply Chain Operations Reference Model (SCOR) Balanced Scorecard (BSC)
	Hierarchy-based approaches	
Techniques	AHP - Analytical Hierarchy Analysis	
	Simulation	
	DEA – Análisis envolvente de datos	
Models	Deterministic Models	
	Stochastic Models:	
	Business Models	Multiple-criteria decision analysis (MCDA)

Fig. 1 Approaches, techniques, and models for performance measurement [13, 14]

2.1 Techniques and Performance Evaluation

System indicators drive performance. An incorrect assessment directly impacts the core operations of any business, resulting in lost revenue leading to poor growth year after year. So, implementing techniques for the implementation of supply chain evaluations is vital for its proper functioning.

[13, 14] show some examples of different methods of evaluating the good functioning of the systems. Figure 1 shows the summarized classification of the most commonly used tools over the years.

2.1.1 Approaches

Some classifications that have been found in the literature are the approaches based on processes, perspectives, and hierarchies. For this, the trends found in the area of performance measurement are established, and these are related to each other [13].

The first one supports the fulfillment of the organizations mission, orienting the necessary activities toward the satisfaction of the main actors of the chain: customers, suppliers, employees, shareholders, and consumer market in general [5]. The perspective-based model was developed considering that a particular set of objectives follows perspectives that consequently lead to a set of performance measure [15]. This model established a differentiated framework of metrics defined by understandable perspectives, in which there is an own interpretation of the challenges and solutions presented in the business and the metrics to be used. Through this approach, a general form of performance metrics is determined along with determining the correlation between the different metrics. Two main perspective models have been considered: models based on the balanced scorecard and models based on supply chain operation references [5]:

– Balanced Scorecard (BSC): It provides detailed information of the critical supply chain elements. It is an executive information system that monitors performance by relating strategies to objectives measured through indicators linked to action plans. In its structure, it takes into account five aspects: customers, internal business perspective, finance, and training and growth [7]. It is usual for companies using dashboards to be based on financial indicators.
– Supply Chain Operations Reference Model (SCOR): It is the model considered as the based model because of its wide use; its structure allows to join links of logistic processes, re-engineering, performance indicators, benchmarking, best practices, and technologies within the supply chain, which gives an improvement in the management and in the relationship of the actors [16]. It identifies the processes that are considered the main ones, which it groups into 5 actions that range from planning to return. These integrated processes provide a clear end-to-end perspective of the process and support optimizations internally and externally. It is used to describe any kind of supply chains using usual concepts.

When it comes to analyzing different hierarchical levels within a supply chain, hierarchy-based approaches should be considered for application. With this, it is possible to get the decision-maker to take an appropriate action according to the challenge that arises [5].

2.1.2 Techniques

In this type of systems, the techniques adopted for evaluation and development are those that are taken into account for their classification; among the most used are AHP, simulation, DEA, and fuzzy logic [5, 12, 13]:

– Analytical Hierarchical Process (AHP): It classifies the alternatives of a problem by deriving priorities. Multiple objectives are set from a decision-making problem. This hierarchy is supported by criteria, sub-criteria, and alternative decisions. The AHP works by comparing one criterion to the rest, measures the importance, although relative, of the element at different levels, and helps in the decision-making process [17].
– Data Envelopment Analysis (DEA): It is usually used in the analysis of benefits and costs when there are several decision criteria. It is a method based on mathematical techniques [18].
– Simulation: It is a technique that supports decision-making since it provides an approximation of a behavior that can occur under certain conditions that affect the system. Its use serves to reduce risks and costs (that would be incurred) by not making the right decision. Simulation facilitates the management of a supply chain; it creates a model of a complex system and includes random variables. Its main advantage is in the different applications, mainly allowing to study how the

whole system is affected by small and large changes without having to actually implement them [19].

2.1.3 Models

Generally, objectives and entities are established that are considered the feeders of the systems. In general terms, they are generated for the analysis and design of the supply chain: deterministic, stochastic, and business models. Among the differences in the models, they are considered deterministic in which the behavior of each of their components (variables) is known in advance. On the other hand, probabilistic (stochastic) models have a certain degree of uncertainty in one or more variables, although probabilistic distributions of their behavior can be established. Finally, business models integrate multiple and different performance indicators in a measurement system. The best known by their degree of use and importance according to the state of the art are BSC, SCOR, and DEA (defined above), and additionally, the multi-criteria analysis methodology (MCDA) is included [14]:

– Multiple-criteria decision analysis (MCDA): It describes all the processes that evaluate quantitative and qualitative elements simultaneously, considering factors that can be conflicting or decision analysis processes that involve two or more attributes. The overall objective of MCDA is to facilitate the choice of the correct decision when there is a series of alternatives in an environment of conflicting and competing positions. Several methods have been proposed in recent years to address problems of MCDA: Value function methods, objectives, and benchmarking methods and ranking methods [20].

2.2 Approaches and Techniques Analysis

According to what is established in Sect. 2.1, a research focused on hybrid tools or models used to measure multiple aspects in companies is carried out to confirm the findings or add new forms of measurement with the purpose of creating a hybrid model that can deliver a new input to the measurement systems and measure performance. The analysis included 23 articles classified by author, economic line of business of the company applying the measurement system, artificial intelligence techniques, and models. Companies from different industry areas were taken into account for this study, such as agricultural industries, transportation, even service companies, among others. Furthermore, the strategies measured mostly relate to sustainability, three-tier supply chains, customer perceived value, supplier selection, and evaluation. Table 1 lists the articles considered. Bold values at the bottom of the table (last row) indicate the total number of articles that uses each technique.

In Fig. 2 the summarized information found is presented. The measurements with the highest application are AHP. However, an analysis of the application of the tools

Table 1 Literature review

N	Author	Industry	Techniques							Models		IA		
			AHP	ANP	DEA	DELPHI	DEMATEL	Simulation	SEM	BSC	SCOR	Fuzzy	RNA	ANFIS
1	Sellitto et al. [41]	Footwear	x								x			
2	Tajbakhsh y Hassini (2015)	Manufacturer			x									
3	Bukhori et al.(2015)	Agriculture	x								x			
4	Tavana et al.(2016)	3-level SC			x									
5	Wibowo y Sholeh(2016)	Construction	x								x			
6	Yu et al.(2016)	Transportation			x									
7	Tavana et al.(2016)	Suppliers	x											x
8	Haghighi et al.(2016)	Recycling			x					x				
9	Brandenburg (2017)	Sales	x					x						
10	Govindan et al.(2017)	Manufacturing	x									x		
11	Singh et al. (2018)	Manufacturing	x							x		x		
12	Ramezankhani et al.(2018)	Manufacturing			x		x							
13	Thanki y Thakkar(2018)	Textile case		x			x			x		x		
14	Dissanayake y Cross (2018)	Manufacturing	x		x				x		x			
15	Rasolofo-Distler and Distler(2018)	Services								x				
16	Akkawuttiwanich and Yenradee [42]	Manufacturing									x	x		
17	Miranda et al.(2019)	Maintenance						x						
18	Lima-Junior y Ribeiro Carpinetti (2019)	Investigation									x		x	
19	Zanon et al.(2020)	Customer									x	x		
20	Chand et al.(2020)	Manufacturing				x	x							
21	Jollembeck Lopes y I. Pires (2020)	Galvanization		x								x		
22	Jiang et al. (2020)	Sustainability	x									x		
23	Lima-Junior y Carpinetti (2020)	Illustrative case									x			x
Total			**9**	**2**	**6**	**1**	**3**	**2**	**1**	**4**	**8**	**7**	**1**	**2**

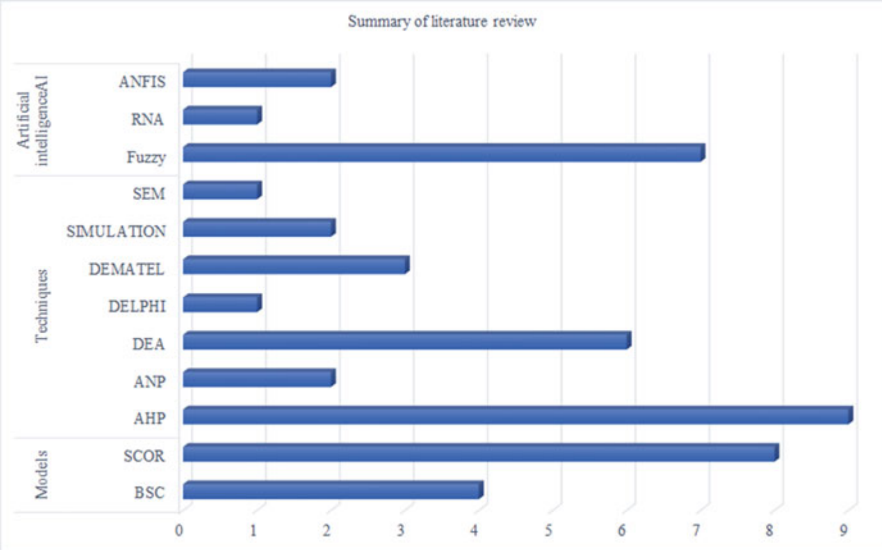

Fig. 2 Summary of literature review

is carried out with the two most widely used tools to identify their characteristics and functionalities and to choose the best option for the model.

As can be seen in the results, the metrics generated by the SCOR model are currently among the most popular, with the BSC model moving into second place. The SCOR model has a long record in research and case studies in many sectors throughout the years. This model is adaptive to the dynamic requirements of the user. Apart from the fact that the metrics considered optimal are established, the attributes represent different scenarios observed in the supply chains. It also enables a thorough assessment of the supply chain [21]. The main use of the score card model is mainly in finance despite its limitations such as fewer measures. Measuring the supply chain becomes a complex task by using this approach. In Table 2, the SCOR and BSC models are compared in terms of functionalities or the most relevant aspects, and it can be inferred that the representative figure for SCOR is due to its great adaptability.

With respect to techniques, AHP continues to be the most widely used followed by DEA. The first one is adopted for its wide applicability, simplicity, and great flexibility, in addition. It can be integrated with soft-computing techniques such as neural networks and fuzzy logic, to name a few, in order to create more robust hybrid methods. For the AHP, there are three principal operations: building hierarchies, a thorough analysis of priorities, and the verification of consistency. It is applied to determine costs and benefits, make planning, prioritize, etc. [22]. The second technique, DEA, in the allocation of resources is widely accepted, since it helps to establish qualitative analyses, in addition to helping to recognize inefficiencies and their origins, and any other evaluation that requires a qualitative approach [23].

Table 2 SCOR vs. BSC

SCOR	BSC
It generates a management system that transforms the strategy into tangible objectives and indicators.	Unifies terms and gives a standard format to describe the supply chain.
Prioritizes the most decisive processes for the success of the organization	Evaluates each process with indicators (KPIs) appropriate
Measures the impact of strategic decisions to check whether the allocation of resources of the organization is being effective	Maintains a continuous system of evaluation of KPIs and proposes future improvements

Hybrid models are techniques that are combined, which are currently being adopted. For the conformation of this model, methods that could work together with the SCOR model were investigated [24]. Making the right decision in an automated basis is a necessity addressed by the implementation of Artificial Intelligence that is lately being used in case investigations, illustrative tests, and case studies, to estimate the performance of a supply chain with different measures, and to forecast and check outcomes.

Fuzzy logic is a technique that manages vague data and knowledge, making it a useful approach when information is not available or when decision-makers.

AI provides different advantages that go beyond the adoption of guiding metrics [25]:the capacity to manage qualitative data and unpredictability for the decision-making process [26]; they are applicable and adaptable to the indicators established in the evaluation [25], and they are friendly to the operating scenario [10].

Finally, FST is added to manage unpredictability in the assessment process [27]. Therefore, to cover the lack of relevant information or inaccuracy in the data within the supply chain, a system that incorporates fuzzy logic is applied [28].

In order to propose a method that evaluates and feeds back the current measurement systems used in the companies and their performance in a cyclical way and in any layout of the supply chain, after analyzing the findings presented in this section, performance measures developed with the SCOR model in combination with fuzzy logic, FAHP, and FIS, a hybrid methodology is designed and presented. All this with the purpose of improving the actions and their respective results derived from a decision-making process.

3 Methodology

The methodology divided into the following three segments: [29]: a literature review, a thorough development, and the application. The changes made are set out in the supply chain configuration at the sourcing stage based on the SCOR performance attribute assumptions centralized in the same field of study. The components of the proposed approach are shown in Fig. 3.

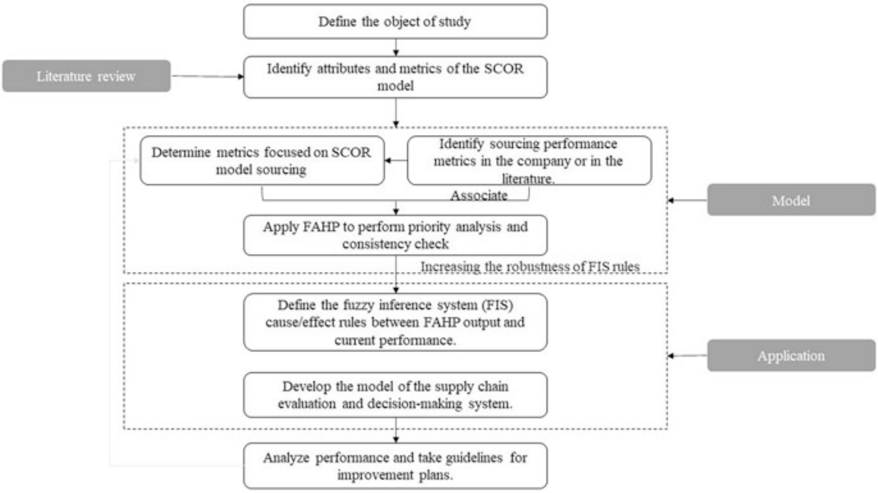

Fig. 3 Methodology

The first step would be a thorough review of the literature procuring the performance measurement. Also the SCOR model centered on indicators and attributes; as a priority analysis, we find the FAHP technique, and the fuzzy inference system (FIS) and its application to measure a supply chain.

As a second part of the approach, fuzzy logic is integrated into the AHP methodology, thereby creating a fuzzy AHP. Within this part of the approach, the results are extracted to generate the inference rules that will be processed in the FIS, which are a description of the trade-off and/or effects of the different performance metrics selected in the SCOR.

Finally, in order to demonstrate, evaluate, and validate the proposed method, it is important to acquire information generated in an actual case. For this, information generated in a company that provides its established indicators is captured, in addition to the incorporation of the user's experience.

For data collection, the model requires two inputs: the current performance of the purchasing-focused SCOR indicators, information collected through the company ERP system or metric indices, and the second input comes from user experience, which corroborates the singularities of the company environment: calculated through historical and linguistic scores. This information is applied in the construction of FIS rules.

The impact generated in this proposal is projected to focus on two main objectives, performance, and improvement. In other words, on the one hand, the sourcing area is analyzed and evaluated, and on the other hand, guidelines are obtained to develop improvement plans. In addition, the model is considered as a system component of continuous improvement, cyclical and receptive to any eventuality in the process. It is suggested that the validation of the information is to be carried out through a sensitivity analysis to verify the rules, the fuzzy operations, and the performance of the system. And, verify that the proposal is applicable in other categories of the supply chain (adaptive).

4 Development of the Methodology

4.1 Theoretical Constructs

- Sourcing: As its main function, the sourcing department is to ensure the quality of the materials and services provided by its suppliers. Today, managers emphasize evaluating the execution of this link by measuring and evaluating its contributions, delivering a positive result due to the ability to maximize value and minimize waste by taking proactive actions to improve efficiency and effectiveness in the chain [30].
- SCOR model attributes and metrics: The model establishes the link among people, processes, and best practices to meet the necessities of the end user with excellence in the supply chain [16]. SCOR recognizes five performance attributes, the first three defined below are considered client-centric, and the last two are internally focused:

  - Reliability: Ability to perform tasks as required, predictability. It takes into account delivery factors such as time, quantity, and adequate quality.
  - Responsiveness: Speed of the supply chain to perform tasks.
  - Agility: Ability to respond to changes due to external factors.
  - Cost: Operational costs of the supply chain.
  - Asset management: Ensures the organizational effectiveness with which resources and assets are used in order to meet demand.

  Level 1 strategic metrics are connected to the attribute that calculates if an organization thrives the desired positioning within the market space. Diagnostic metrics are recognized at three predefined levels. Table 3 relates the level 1 strategic metrics to their corresponding performance attributes in the SCOR model.
- Fuzzy AHP: It is based on three basic principles: the construction of a hierarchy, the comparative judgment of criteria using fuzzy numbers, and the synthesis of priorities [31–34]. The final result provides numerical priorities for the elements that embody the relative ability to achieve the objective [35]. This research proposes to use this technique to prioritize sourcing attributes and indicators to improve supply chain performance.
- Fuzzy inference system: It has been widely applied for multi-criteria decision-making due to its ability to deal with uncertainty [36, 37]. Also, it models human reasoning by means of fuzzy rules if-then [38, 39]. Furthermore, the application

Table 3 Level 1 metrics and performance attributes of the SCOR model

Level 1 strategic metrics	Performance attribute				
	External focus			Internal focus	
	Reliability	Responsiveness	Agility	Cost	Asset management
Perfect order fulfillment					
Order execution cycle time					
Superior supply chain adaptability					
Adaptability of the downstream supply chain					
Total value at risk					
Total supply chain management costs					
Costs of products sold					
Duration of the cash cycle					
Performance of fixed assets in the supply chain					
Return on working capital					

Grey shaders indicate correspondence between the metric and the attributes.

of FIS in this context is appropriate because it allows to handle the non-linear relationship between input and output variables.

4.2 Model

The proposed model is shown in Fig. 4, illustrating the effects of the supply chain indicators in the sourcing area. Also showing the steps that this revolving structure makes up, and what and how they are part of a continuous improvement, allowing to have a comprehensive scheme of its performance taking into account all areas of the organization. On the other hand, including a simulation process allows detecting critical elements in the evolution and execution of the supply chain process. The steps of the presented approach are described below:

1. Identification of indicators focused on sourcing: As a first step, a set of SCOR metrics is defined: in this step, it is determined which attributes and metrics to use according to the interest; in this chapter, a search and compilation of

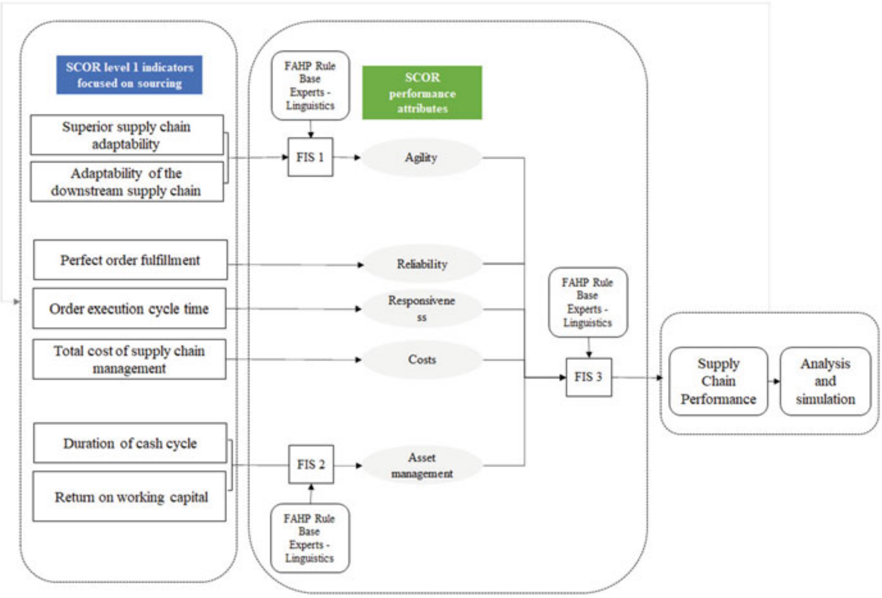

Fig. 4 Proposed model [29] .

information on the indicators focused on the SCOR model supply aligned with the competitive strategies to manage the supply chain is performed. The supply chain council [16] proposes the choice of at least one metric associated with each performance attribute in order to drive a balanced assessment and decision-making process based on different perspectives. Based on the review, all five attributes are considered appropriate for the purpose of the project. The ideal indicators identified in the hierarchical structure proposed by the SCOR model for this project are included in Table 4. It must be noted that depending on the supply chain measurement category, the attributes and metrics may vary, i.e., not necessarily all of them need to be included.

2. Fuzzy inference: The second step is to infer the sourcing values as a result of the performance of the SCOR level 1 indicators considered in Table 4. FIS 1 computes the agility from the comparable indicators. The parameters of this first FIS are rule-based and membership functions based on the perception of the panel of experts in supply chain and the performed process by the FAHP; for FIS 2, the same procedure is performed for the asset management attribute with its indicators. Finally, FIS 3 calculates the value of supply in five inputs: agility; the consequence of FIS 1, asset management; the consequence of FIS 2, perfect order fulfillment, order execution cycle time, and the total cost of supply chain management, the level 1 indicators of reliability, responsiveness and costs, respectively. It is in this stage where the semantic and the quantitative fuzzy data of the input and output variables are defined. Trilateral fuzzy numbers are frequently selected for these applications.

Table 4 Performance attributes and level 1 indicators

Attribute	Level 1 indicator
Asset management	Return on working capital
	Cash cycle time
Agility	Superior supply chain adaptability
	Downstream supply chain adaptability
Reliability	Perfect order fulfillment
Responsiveness	Order fulfillment cycle time
Costs	Total cost of supply chain management

3. The third step of the model is based on performing the scenario simulations using the response surfaces as the effect of the second FIS that provides the supply performance ranking, as an exact number, and the respective response surfaces. The ranking of the output varies in a specific range and represents the performance rating and the actual performance.

The surfaces are based on a figure showing the performance behavior as a function of attributes. Each surface indicates the performance as a function of the combination of two attributes. Consequently, ten comparative surfaces are generated:

– Reliability versus agility
– Reliability versus costs
– Reliability versus asset management
– Reliability versus responsiveness
– Agility versus responsiveness
– Agility versus costs
– Agility versus asset management
– Responsiveness versus costs
– Responsiveness versus asset management
– Costs vs. asset management

Surfaces are generated according to the number of attributes selected. The result of the simulation visualizes which attribute has the greatest impact on sourcing and which one has shortcomings; in this way, it is possible to make the required changes in the model and in the processes carried out in sourcing in order to obtain better results in performance. Additionally, with the results, it will be possible to make decisions of improvement.

4.3 Results

With the first step, the association of the company's indicators with those of the SCOR model is achieved. This part is necessary as this model is a benchmark and standard and can therefore be adapted to any metrics system used. In addition, using

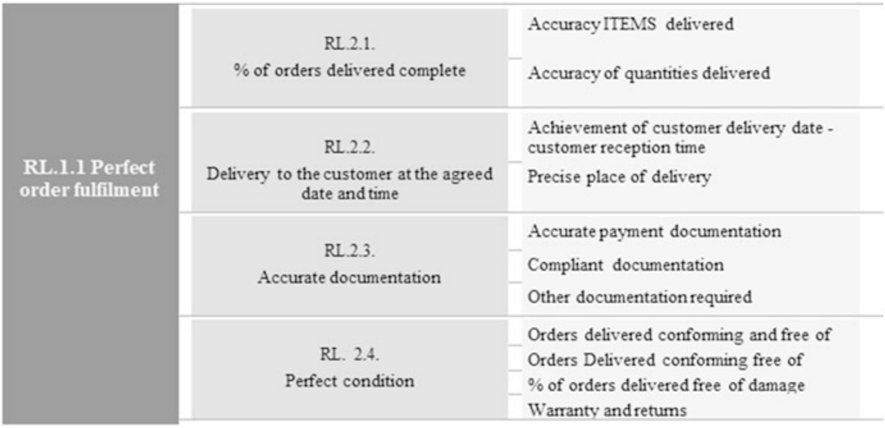

Fig. 5 Metrics levels 1, 2, and 3 of the reliability attribute

its language allows benchmarking that helps supply chains to identify gaps and make improvements. Indicators that range from levels 1 to 3 are considered relevant; therefore, it is advisable to pay attention to them. Since usually, companies do not consider the scope of their indicators and only focus on the local scope (specific to an area or a department). In contrast, the structures of level 1 and 2 indicators of the supply chain operations reference model are somewhat general. Therefore, it is essential to be familiar with all three levels. Figure 5 exemplifies the proposed revision method of the measurement levels covered by the reliability attribute.

Table 5 illustrates the relationship of KPIs and conversion of figures. Where the proportional relationship can be direct and inverse, it depends on the nature of the indicator [29]. For instance, there is better performance in the case of a higher direct ratio. The corresponding figures are converted to a range from 0 to 10 to make future comparative measurements possible. Equations (1) and (2) are used to find the values, respectively.

$$Converted\ figure = \frac{Current\ Figure}{Reference\ Figure} \tag{1}$$

$$Converted\ figure = \frac{Reference\ Figure}{Current\ Figure} \tag{2}$$

The FAHP methodology finds the priorities among the studied elements, i.e., for this case, according to the experts' conception, a categorization of the performance attributes from the most important to the least important is achieved by the value of their weights. These results, together with the conversion of the above figures, are the basis for the FIS rules.

Table 5 Association of indicators and conversion of figures

Indicator name literature	SCOR level 1 indicator	Unit	Current figure	Reference figure	Proportional relationship	Converted figure (range 0–10)
Compliance rate	Perfect order fulfilment	Percentage	0.69	0.88	Direct	8
Purchase order cycle time	Order execution cycle time	Time	7	5	Inverse	7

By applying the proposed FIS conceptual model, the result projects ten comparison surfaces between the attributes of the SCOR model: agility, responsiveness, cost and asset management. These figures express a scenario analysis of sourcing behavior under certain parameters and provide decision-makers with information on the impact on the supply chain. Based on the behavior observed through FIS 3, improvement plans can be designed connected to the organizations projected goals to optimize the current state.

The results of the simulation and its scenarios depend largely on the design of the FIS rules which we believe to be of great importance. In relation to that, FIS 3 rules should be formed from the perspective of an ideal supply. The drawbacks related with the use of FIS stem from errors in the definition of linguistic terms and fuzzy numbers, a process that can become complex. The role of experts is critical in capturing the characteristics of the supply chain and incorporating them into the rules.

The predictive system of active processes on metrics rates proactively supports the decision-making process by anticipating errors that may occur and provides the opportunity to perform analysis of critical or impact factors. Moreover, the prediction of future metrics rates in different circumstances approves the progress of process planning [40].

Among the main expected results are a predictive performance evaluation system focused on the sourcing area that can anticipate problems, a cyclical and adaptable measurement model for any bracket in the supply chain and the likelihood of a corrective comparison of the structure. The model identifies the current supply performance and makes a diagnosis of the structure of the measurement system used by the company with respective suggestions for improvement. It should be noted that for the application of the conceptual model, companies are free to adopt the proposed system or to continue with the usual one. The aim of the project is to provide feedback on the findings and offer guidelines or alternatives for the development of indicators.

5 Conclusions

In researching and analyzing the topic of reference in this chapter, we find how many methods, approaches, and techniques used for measurement can be adapted to the particular needs of the business. The design and selection of indicators dictate the overall performance and practices in logistics. Furthermore, it is evident that measurements can be adaptable in such a way that they can take into account qualitative, imprecise data and uncertain situations. If there are no measurements, there is no way to evaluate performance, identify errors, minimize costs, improve information flow and processes, ensure quality, etc. The theoretical review in this chapter provides an overview of supply chain performance measurement systems and can help researchers to identify and structure particular measurement systems according to the purpose of the measurement.

As relevant data, it is evident that companies place more interest in evaluations based on responsiveness, cost, sustainability, agility, the customer and internal supply chain processes, and flexibility. Multi-criteria decision techniques are highly taken into account. The most commonly used techniques are AHP, DEA, and simulation either in single or combined applications (hybrid models), and, in recent years, artificial intelligence techniques have been added to provide intelligent capabilities to systems such as the use of fuzzy logic and neural networks. On the other hand, there are the performance measurement frameworks of which the SCOR and BSC models were identified. Performance quantification is mainly based on expert judgments and information simulation.

The model and expected results corroborate the assumption that the use of predictive hybrid systems based on metrics and attributes (SCOR model with FAHP) for weight to be given and FIS for evaluations seems to be a feasible technique to help decision-makers in the performance management of the supply chain. SCOR level 1 indicators are applied as a means to assess the supply chain, allowing comparison with other chains and facilitating communication with stakeholders. The system offers the possibility to anticipate and prioritize. Additionally, the model assesses the amount of indicators that companies use and their objective with corrective effects; it is built to take into consideration the variability in the processes; it is a cyclical model to execute simulations by continuously changing the input data and the expected targets. It is easy to use, flexible, and versatile, applicable in different supply chain architectures.

In addition to that, the proposed system allows factors linking factors to improve the analysis and characterize the measurements, for which it is necessary to define fundamental aspects:

- Purpose: Prediction of performance (of lagging indicators from leading indicators).
- Strategy: The conceptual framework is designed for a generic supply chain.
- Scope of application: At the supply stage.
- Choice of metrics: Based on the SCOR model.
- Uncertainty modelling: Subjective assessment by multiple decision-makers through pairwise comparisons is proposed.
- Techniques: Hybrid approach (SCOR, FAHP, and FIS).

Three main contributions can be found in this chapter; first, it proposes a methodology related to the KPIs of the SCOR model applicable in the sourcing area. Second, by means of a benchmark between the indicators more frequently used by firms found in the literature and their relationship with the standard model, allows systems and their configurations to be analyzed and qualified. For instance, it is possible to determine whether the measurements delivered optimal results and also to evaluate the structure of the measurement systems (the number of metrics, targets, relationship with strategic objectives, etc.). Finally, the system that integrates metrics and characteristics of the SCOR model is cyclical and can be adapted to the design of the supply chain in question, a FAHP for priority analysis, and a FIS for predictive performance measurement, determining the performance characteristics with the top impact contributions to intelligent strategic decision-making and the creation of action plans.

However, the framework suffers from some limitations. Future research can address some of the following aspects: application of the model in a real case study, validation of the conceptual framework, and incorporation of neuro-fuzzy approaches in case large amounts of data are handled to train the system.

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