Improvement of the SCOR model by the use of the Performance Measurement system and an aggregation approach based on the NonAdditive Fuzzy Sugeno Integral: A case study for the Selection of Automotive Suppliers

MOHAMED TAREK CHAHID[1#]

[#] Moroccan Institute for Management Sciences

12, Résidence Jardin des Oudayas, Témara

MOROCCO

[1] tarek.chahid77@gmail.com

Abstract: - This study aims to extend the SCOR model used in the supply chain (SC) context; we propose to extend here the proposed approaches for expressing the overall performance of an SC. The aggregation of appropriate Key Performance Indicators (KPI) in the global performance formula is based on a Sugeno integral operator, according to the fuzzy set theory, in order to deal with the nonlinearity of this model, makes data ambiguous in the process of multicriteria decision-making.

Therefore, this work aims to help managers to select a suitable supplier in the Supply Chain context. The approach is used to evaluate the best contractors by using the Sugeno Integral to deal with the interrelationships aspects between KPI.

Key-Words: Performance aggregation; Sugeno integral; Supply chain; SCOR model

1 Introduction

Choosing the right supplier is a strategic resolution that impacts the performance of any company. A competitive supply chain is an advantage for any company and permits it to compete effectively in the world market [1].

The selection of suppliers is considered as a multi-criteria decision-making. This selection is based on criteria such as quality, price, delivery time, and others that can be tangible or intangible.

To deal with those aspects, we adopt the fuzzy logic methodology with the use of fuzzy integral in order to select a suitable supplier by estimating the overall performance [2].

The Sugeno integral permits to have a better comprehension of the complex aspect (i.e. Nonlinear) of the performance model.

Furthermore, the next section focuses on the performance aggregation problem. Paragraph 3 presents a case study that shows the success of the proposed model in the context of the Moroccan automotive suppliers. Finally, the final comments are illustrated in the last chapter.

2 Problem Formulation

2.1.Aggregation of Performance Measurement expressions

Companies seek to reach the best performance by achieving its objectives fixed by their business strategy [3]. This achievement is fixed by the combination of machine, man, method, process and technology [4].

In consequence, companies adopt the Performance Measurement System PMS, in order to convert the measurement into information that assesses their performance. In fact, the PMS establishes objectives, collects, analyzes and interprets the performance measures. The PMS must work as a thermostat when the process shows the disparity between measures and the target [5]. So, PMS are the main tools of decision-making [6].

The design of any performance measurement system begins by the determination of performance's expressions. However, a distinction should be made between the overall objectives; which are broken down along hierarchical levels into elementary ones [7].

Hence, two kinds of performance expressions are defined: elementary expressions that identify the basic level of performance, and the aggregate expressions that are the synthesis of elementary performance expressions in the global objectives. Also, the aggregation deals with the arrangement of all the performance expressions concerned [8].

In the industrial framework, performance must be expressed in the multicriteria form [9]. The weighted arithmetic mean (WAM) is the most used operator of aggregation for matching global performance [9].

2.2.Fuzzy Measurement and Fuzzy Integral

In traditional multiple criteria measurement techniques, each criterion must be independent of the others. So, the reciprocated effects in an industrial context cannot be treated with the classic additive measures [10].

The dependency between criteria affect positively or negatively assessments of the decision. This reality can be modelled with aggregation by fuzzy integrals [11].

The use of fuzzy integral as an aggregation operator in Multi-Criteria Decision Making MCDM was introduced by Grabisch [12]. And the concept of the fuzzy integral was used in the multi-criteria evaluation by Sugeno [13].

The mean propriety of a fuzzy integral is the aptitude to represent interactions between criterions, ranging from negative interaction to positive interaction, [12].

The fuzzy sets bases are the fact that human analysis are based on linguistic markers [13]. The fuzzy concepts have the following characteristics: 1) their structures capture the dependency between inputs and outputs of a system; 2) the fuzzy linguistic sets produce ambiguities; 3) they represent nonlinear system; 4) the numeric and linguistic outputs are formed; 5) they are insensitive to random noise [14].

Furthermore, the fuzzy integral family corrected the WAM (Weighted Arithmetic Mean) operator by taking account interactions between criterions [12].

The fuzzy integrals we have additive and non-additive proprieties but in traditional integral, we have additive one only.

2.3.The Sugeno integral

The choice of λ-fuzzy measure ((λ is called the degree of interaction) is based on the fact that fuzzy measures for subsets of information sources is easy to calculate and the number of fuzzy measures to be known is reduced from into n due to the λ-rule [13].

Let a finite set $X = \{x_1, x_2, .., x_n\}$ be a set of information sources and a fuzzy density $g^i = g(\{x_1\})$ describe the degree of importance of each source x_i.
Let the set of X to be 2^X.

Then a λ-fuzzy measure is a real-valued non-additive set function g: $2^X \rightarrow (0,1)$.

Satisfying the following properties:

$$g(\emptyset) = 0; g(X) = 1 \quad (1)$$

$$g(A) \le g(B) \, if A \subset B \subset X \quad (2)$$

$$\forall A, B \subseteq X \, and A \cap B = \emptyset$$

$$g(A \cup B) = g(A) + g(B) + \lambda g(A) g(B)$$

For $\lambda \in (-1, \infty)$ (3)

λ in Equation (3) can be founded by solving a polynomial equation (4) and using the second bounded property in equation (1) and the rule λ-rule in equation (3).

$$\lambda + 1 = \prod_{i=1}^{n} (1 + \lambda g^{i}) \tag{4}$$

Let an evaluation function f: $X \to [0,1]$ be arranged in ascending order like that: $f(x_{(1)}) \le f(x_{(2)}) \le \ldots \le f(x_{(n)})$.

For partial information source x_i, sugeno fuzzy measure for a subset, can be formulated by the equation (5). here, $f(x_{(i)})$ denotes the i-th smallest function:

$$g(A_{(i)}) = g^{(i)} + g(A_{(i+1)}) + \lambda g^{(i)} g(A_{(i+1)})$$

with $g(A_{(i+1)}) = 0$ (5)

Sugeno integral can be considered as an aggregation process between assessment functions and fuzzy measures representing the importance degrees of partial information. Discrete Sugeno integral (SI) with respect to Sugeno fuzzy measure g (A (I)) over X is equation (6):

$$\int f(x)\,dg_{\lambda} = \mathop{Max}_{i=1}^{n} \left\{ Min\left[f(x_{(i)}), g(A_{(i)}) \right] \right\} \tag{6}$$

Where $f(x_{(1)}) \le f(x_{(2)}) \le \ldots \le f(x_{(n)})$.

The SI approach based on λ-fuzzy measures deals with various grades of interaction among the criteria [13].

2.4.Description of the problem

The selection of suppliers is important for the Automotive industry. In the context of globalized markets, companies are forced to reassess their suppliers regularly to make sure they comply with the exigencies. To choose their suppliers, companies choose a large number of criteria and this choice does not always consider the multiple factors that influence the success of the company [1].

3 Problem Solution

3.1.Elementary performance expression

In our previous studies [15], we find that the most important factors in the global performance of Moroccan automotive suppliers are the efficiency of production systems and the Development of Human Skills.

In fact, the global performance formula is expressed as follow:

$$GP = 100 * (0{,}09P_{Cc} + 0{,}17P_{Qs} + 0{,}43P_{Ma} + 0{,}05P_{Ab} + 0{,}02P_{Oi} + 0{,}23P_{Tdb}) \tag{7}$$

Table I: Definition of AKPI

AKPI	Definition
Cc	Rate of Customer Complaint (Cc)
Qs	Scrap Rate (Qs)
Ma	Machine Availability (Ma)
Ab	Absenteeism (Ab)
Oi	Number of Occupational Injuries (Oi)
Tdb	Training Days per Person (Tdb)

Where:

The overall performance (GP) is expressed through performance AKPI (PAKPI) P is obtained by comparing the performance level (AL) by the value of the formula measured percentage AKPI and the target value. Those AKPI are expressions of satisfaction criteria as the percentage between the current value and the target value for each AKPI.

The selection of 3 suppliers (Sup1, Sup2, Sup3) adopted in this research, is based on applying the WAM operator, overall performance of strategies, can be expressed as shown in Table II. The decision-maker can now rank the strategies Sup1, Sup2, and Sup3. The conclusion is to retain the best supplier with regards to the overall performance:

Table II: Overall performance of suppliers

	P_{Cc}	P_{Qs}	P_{Ma}	P_{Ab}	P_{Oi}	P_{Tdb}	GP
Sup1	1	0.9	0.5	0,2	0,8	0,7	**0,65**
Sup2	0,8	0,8	0,7	0,8	0.5	1	**0,79**
Sup3	0,8	0,9	1	0,1	0.5	0,7	**0,83**

The decision-maker can rank suppliers by retaining the best supplier with regards to the overall performance, in this case, the choice of Sup3 is selected in the first place, then, the Sup2 occupies the second place followed by the Sup1.

Furthermore, the decision-maker cannot combine performance parameters linearly in a manner to assist management in formulating the most suitable selection. So, the aim of this research is to treat complex and dynamic interrelationships aspects of KPIs.

3.2.The aggregated performance expression by Sugeno Integral:

1) Construction of Objectives: we introduce the notions of a space of states $X = \{x_1, x_2, \dots, x_n\}$ and a decision space (a space of alternatives). $S = \{s_1, s_2, \dots, s_n\}$

We consider a decision model in which n alternatives $s_1, s_2, \dots, s_n \in S$ act as supplier used to improve the overall performance. The suppliers should influence m states $s_1, s_2, \dots, s_n \in S$.

Table III: the efficiency of the elementary performance

Effectiveness	$U_{(g)}$
None	0
Almost none	0.1
Very little	0.2
Little	0.3
Rather little	0.4
Medium	0.5
Rather large	0.6
Large	0.7
Very large	0.8
Almost complete	0.9
Complete	1

The expert's opinion has judged the relationship between the efficiency of the elementary performance and strategies following table III. We express the connection in Table IV:

Table IV:Relationship among efficiency of the elementary performance and strategies

	P_{Cc}	P_{Qs}	P_{Ma}	P_{Ab}	P_{Oi}	P_{Tdb}
Sup1	*Compl.* $f(x_1)=$ $g_{11}=1$	*Almost Compl.* $f(x_2)=$ $g_{12}=0.9$	*Medi.* $f(x_3)=$ $g_{13}=0.5$	*Very little* $f(x_4)=$ $g_{14}=0.2$	*Very large* $f(x_5)=$ $g_{15}=0.8$	*large* $f(x_6)=$ $g_{16}=0.7$
Sup2	*Very large* $f(x_1)=$ $g_{21}=0.8$	*Very large* $f(x_2)=g_{22}=0.8$	*large* $f(x_3)=$ $g_{23}=0.7$	*Very large* $f(x_4)=$ $g_{24}=0.8$	*Medi.* $f(x_5)=$ $g_{25}=0.5$	*Compl.* $f(x_6)=$ $g_{26}=1$
Sup3	*Very large* $f(x_1)=$ $g_{31}=0.8$	*Almost compl.* $f(x_2)=$ $g_{32}=0.9$	*Compl* $f(x_3)=$ $g_{33}=1$	*Almost none* $f(x_4)=$ $g_{34}=0.1$	*Medi.* $f(x_5)=$ $g_{35}=0.5$	*large* $f(x_6)=$ $g_{36}=0.7$

Construction of Sugeno integral: The weights $w_1, w_2, w_3, \ldots, w_n$, W act as the ranges of the function g_λ: $X \to W = [0,1]$

$w_1 = g_\lambda(x_1)$, $w_2 = g_\lambda(x_2)$, $w_3 = g_\lambda(x_3)$, …, $w_n = g_\lambda(x_n)$.

So, $w_1 = w_{Cc} = g_\lambda(x_1) = 0.09$; $w_2 = w_{Qs} = g_\lambda(x_2) = 0.17$; $w_3 = w_{Ma} = g_\lambda(x_3) = 0.43$; $w_4 = w_{Ab} = g_\lambda(x_4) = 0.05$;

$w_5 = w_{Oi} = g_\lambda(x_5) = 0.02$; $w_6 = w_{Tdb} = g_\lambda(x_6) = 0.23$.

According to (4), We had the polynomial equation below:

$$0 = 0.3512\lambda^2 + 0.056738\lambda^3 + 0.0043058\lambda^4 + 0.0001417\lambda^5 + 0.0000015\lambda^6 \quad (8)$$

And the roots of the above equation will be λ = {0; 0; - 0.6168483; - 101.67515; (4.4793329 + 60.829959i); (4.4793329 - 60.829959i)}

But $\lambda \in (-1, \infty)$, We will take . λ = -0.6168 only, because λ = 0 is additively.

If. λ = -0.6168 then following equation (8), we have:

$g(x_1,x_2)$	0,25056296
$g(x_1,x_3)$	0,49612984
$g(x_1,x_4)$	0,1372244
$g(x_1,x_5)$	0,01888976
$g(x_1,x_6)$	0,30723224
$g(x_2,x_3)$	0,55491192
$g(x_2,x_4)$	0,2147572
$g(x_2,x_5)$	0,18790288
$g(x_2,x_6)$	0,37588312
$g(x_3,x_4)$	0,4667388
$g(x_3,x_5)$	0,44469552
$g(x_3,x_6)$	0,59899848

$g(x_4,x_5)$	0,0693832
$g(x_4,x_6)$	0,2729068

$g(x_1,x_2,x_3)$	0,614107649
$g(x_1,x_2,x_4)$	0,292835598
$g(x_1,x_2,x_5)$	0,267472015
$g(x_1,x_2,x_6)$	0,445017096
$g(x_1,x_3,x_4)$	0,530829196
$g(x_1,x_3,x_5)$	0,510009582
$g(x_1,x_3,x_6)$	0,655746876
$g(x_1,x_4,x_5)$	0,1555316
$g(x_1,x_4,x_6)$	0,347757198
$g(x_1,x_5,x_6)$	0,246209983
$g(x_2,x_3,x_4)$	0,587798436
$g(x_2,x_3,x_5)$	0,568066527
$g(x_2,x_3,x_6)$	0,706189895
$g(x_2,x_4,x_5)$	0,232107955
$g(x_2,x_4,x_6)$	0,414290885
$g(x_2,x_5,x_6)$	0,391246226
$g(x_3,x_4,x_5)$	0,48098111
$g(x_3,x_4,x_6)$	0,630525367
$g(x_3,x_5,x_6)$	0,611609235
$g(x_4,x_5,x_6)$	0,289540222

$g(x_1,x_2,x_3,x_4)$	0,64516857
$g(x_1,x_2,x_3,x_5)$	0,626532018
$g(x_1,x_2,x_3,x_6)$	0,756987882
$g(x_1,x_2,x_4,x_5)$	0,309223178
$g(x_1,x_2,x_4,x_6)$	0,481292769
$g(x_1,x_2,x_5,x_6)$	0,459527365

$g(x_1,x_3,x_4,x_5)$	0,544280887
$g(x_1,x_3,x_4,x_6)$	0,685523643
$g(x_1,x_3,x_5,x_6)$	0,667657583
$g(x_1,x_4,x_5,x_6)$	0,363467265
$g(x_2,x_3,x_4,x_5)$	0,600547355
$g(x_2,x_3,x_4,x_6)$	0,734410999
$g(x_3,x_4,x_5,x_6)$	0,642747206
$g(x_1,x_2,x_3,x_4,x_5)$	0,65720977
$g(x_1,x_2,x_3,x_4,x_6)$	0,783642376
$g(x_1,x_2,x_3,x_5,x_6)$	0,767649679
$g(x_1,x_3,x_4,x_5,x_6)$	0,697067023
$g(x_2,x_3,x_4,x_5,x_6)$	0,745351305
$g_\lambda(x_1,x_2,x_3,x_4,x_5,x_6)$	1

The construction of Sugeno integral in the strategies order follows equation (6):

$$\int f(x)dg_\lambda = \underset{i=1}{\overset{n}{Max}} \left\{ Min\left[f(x_{(i)}), g(A_{(i)}) \right] \right\} \qquad (6)$$

Where $f(x_{(1)}) \le f(x_{(2)}) \le \ldots \le f(x_{(n)})$.

The construction of Sugeno integral in the strategies order:

- For **Sup1**, we have:

$f(x_6)=g_{16}=0.7$; $f(x_5)=g_{15}=0.8$; $f(x_4)=g_{14}=0.2$; $f(x_3)=g_{13}=0.5$; $f(x_2)=g_{12}=0.9$; $f(x_1)=g_{11}=1$

So,

$f(x_{(4)}) \le f(x_{(3)}) = f(x_{(6)}) \le f(x_{(5)}) \le f(x_{(2)}) \le f(x_{(1)})$

Sup1$=\int f dg_\lambda$ =max(min($f(x_4)$, $g_\lambda(x_1,x_2,x_3,x_4,x_5,x_6)$); min($f(x_3)$,$g_\lambda(x_1,x_2,x_3,x_5,x_6)$); min($f(x_6)$, $g_\lambda(x_1,x_2,x_5,x_6)$); min($f(x_5)$,$g_\lambda(x_1,x_2,x_5)$); min($f(x_2)$, $g_\lambda(x_1,x_2)$); min($f(x_1)$, $g_\lambda(x_1)$))

Sup1=max(min(0.2,1);min(0.5,0.76);min(0.7,0-.46); min(0.8,0.267);min(0.9,0.25),min(1; 0.09))

Sup1=max(0.2; 0.5; 0.46; 0.267; 0.25 ; 0.09)

Sup1=0.46

- For **Sup2**, we have:

$f(x_6)=g_{26}=1$; $f(x_5)=g_{25}=0.5$; $f(x_4)=g_{24}=0.8$; $f(x_3)=g_{23}=0.7$; $f(x_2)=g_{22}=0.8$; $f(x_1)=g_{21}=0.8$

So,

$f(x_{(5)}) \le f(x_{(3)}) \le f(x_{(4)}) = f(x_{(2)}) = f(x_{(1)}) \le f(x_{(6)})$

Sup2$=\int f dg_\lambda =$ max(min($f(x_5)$, $g_\lambda(x_1,x_2,x_3,x_4,x_5,x_6)$); min($f(x_3)$, $g_\lambda(x_1,x_2,x_3,x_4,x_6)$); min($f(x_1)$, $g_\lambda(x_1,x_2,x_4,x_6)$); min($f(x_2)$, $g_\lambda(x_2,x_4,x_6)$); min($f(x_4)$, $g_\lambda(x_4,x_6)$); min($f(x_6)$, $g_\lambda(x_6)$))

Sup2= max(min(0.5; 1); min(0.7; 0,78);

min (0.8, 0.48); min (0.8, 0.41); min (0.8, 0.27),

min (1, 0,23))

Sup2=max(0.5; 0.7; 0.48; 0.41; 0.27 ; 0.23)

Sup2=0.7

- For **Sup3**, we have:

$f(x_6)=g_{36}=0.7$; $f(x_5)=g_{35}=0.5$; $f(x_4)=g_{34}=0.1$; $f(x_3)=g_{33}=1$; $f(x_2)=g_{32}=0.9$; $f(x_1)=g_{31}=0.8$

So, $f(x_{(4)}) \le f(x_{(5)}) \le f(x_{(6)}) = f(x_{(3)}) = f(x_{(2)}) \le f(x_{(3)})$

Sup3 $=\int f dg_\lambda =$ max(min $f(x_4)$, $g_\lambda(x_1,x_2,x_3,x_4,x_5,x_6)$; min $f(x_5)$, $g_\lambda(x_1,x_2,x_3,x_5,x_6)$;

min $f(x_6)$, g_λ (x_1,x_2,x_3,x_6); min $f(x_1)$, g_λ (x_1,x_2,x_3); min $f(x_2)$, g_λ (x_1,x_2); min $f(x_3)$, g_λ (x_3))

Sup3= max(min(0.1,1); min(0.5,0.77); min(0.7,0.75); min(0.8, 0.61); min(0.9, 0.25),

min (1, 0,43))

Sup3=max(0.1; 0.5; 0.7; 0.61; 0.25; 0.43)

Sup3=0.7

The interpretation of Sugeno integral in the suppliers ranking gives Sp2= Sp3≥ Sp1

In the linear model, we found in the first rank Sp1 with the overall performance equal to 0.831, then the Sp2 with 0.789, followed by the Sp1with 0.6535.

The ranking of Sup2 was improved, occupying the first place tied with Sup1 with a score of 0.7. That adjustment can substitute for other expensive strategies such whom concerning machine factors. These measurements provide indications for which the decision-maker can reduce the investment because the business policy is too generous regarding a key factor or simply maintain investment.

4 Conclusion

The Sugeno integral as an operator of the aggregation is well fitted to deal with the interactions between the performance factors. An industrial application has permitted us to show the pertinence of such a method. The algorithm studied can be used to determine the best distribution of resources on performance criteria.

Certainly, this approach requires a great manager proficiency of the method: to make the structure of the global performance to compare a number of performance situations in order to identify the Sugeno parameters.

Perspectives for future research will concern the integration of cost parameters in order to obtain the best action plan to obtain a fixed performance improvement at the lowest cost to reach a better overall performance.

References

[1]. M.Hlyal, M.T.Chahid, J. El Alami, A. Soulhi and N. El Alami, “Supplier’s Selection for the Moroccan Textile Sector by Using Performance Measurement System”, *Modern Applied Science,* vol. 9, No 3, 2015, doi: 10.5539/mas.v9n3p102.

[2]. L. Berrah,. and V. Clivelle, “Towards an aggregation performance measurement system model in a supply chain context”, *Computers in Industry*, vol. 58, 2007, pp 709-719.

[3]. L. Berrah, G. Mauris, and J. Montmain, “Monitoring the Improvement of an overall industrial performance based on a Choquet integral aggregation”, *Omega*, Vol. 36, 2008, pp 340-351.

[4]. J. Michalska, “The usage of the balanced scorecard for the estimation of the enterprise’s effectiveness”, *Journal of materials processing technology*, vol. 162-163, 2005, pp 751-758.

[5]. U.S. Bititci, P. Suwignjo, and A.S. Carrie, “Strategy management through quantitative modeling of performance measurement system ”, *International Journal of Production Economics*, vol. 69, 2001, pp 15-22.

[6]. S.A. Melnyk, U.S. Bititci, K. Platts, J. Tobias and B. Anderson, “Is performance measurement and management fit for the future?” *Management Accounting Research*, Vol. 25, No. 2, 2014, pp 173-186.

[7]. P. Kueng, A.J. Krahn, “Building a process performance measurement system: some early experiences”, *Journal of Scientific, and Industrial Research*, vol. 58, 1999, pp 149–59.

[8]. Y. Ducq, B. Vallespir, and G. Doumeingts, “Coherence analysis methods for production systems by performance aggregation”, *International Journal of Production Economics*. Vol. 7, 2001, pp 23–37.

[9]. V. Clivelle, L. Berrah and G. Mauris, " Quantitative expression and aggregation of performance measurements based on the MACBETH multi-criteria method", *International Journal of Production Economics*, vol. 105, 2006, pp 171-189.

[10]. A. Neely, "The performance measurement revolution: why now and what next?" *International Journal of Operations & Production Management*, vol. 19, No. 2, 1999, pp 205–228.

[11]. T. Takagi, and M. Sugeno, "Fuzzy Identification of Systems and Its Applications to Modeling and Control", *IEEE Transactions on Systems, Man, and Cybernetics*, Vol. smc-15, No. 1, 1985, pp 116-132.

[12]. G. Buyukozkan, and D. Ruan, "Choquet integral based aggregation approach to software development risk assessment", *Information Sciences*, Vol. 180, 2010, pp 441-451.

[13]. M. Grabisch, "A Constructive approach to multicriteria decision making", *Traitement du signal*, Vol. 22, No. 4, 2005, pp 321-338.

[14]. D. J. Jeng, "Selection of an Improvement Strategy in Internal Service Operations: The MCDM Approach with Fuzzy AHP and Nonadditive Fuzzy Integral", *International Journal of Innovative Computing, Information and Control*, Vol. 8, No. 8, 2011, pp 5917-5933.

[15] M.T. Chahid, J. El Alami, A. Soulhi and N. El Alami, "Performance Measurement Model for Moroccan Automotive Suppliers Using PMQ and AHP", *Modern Applied Science,* vol. 8, No 6, 2014, doi:10.5539/mas.v8n6p13.