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SEARCH APPROACH FOR OPTIMAL REFERENCE VALUES FOR SCOR INDICATORS

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ABSTRACT

This paper proposes a decision strategy related to the use of SCOR (Supply Chain Operations Reference Model) indicators in an organization, now a very common tool for conducting external or exogenous benchmarking by comparing the company's SCOR values with those of industry leaders. We propose instead an internal or endogenous benchmarking comparing the SCOR values with optimal values for the same company using a mathematical optimization process for the firm. Starting with the case of indicators associated with supplier operations, we highlight the usefulness of endogenous comparison where differences between the optimal and actual SCOR values show some gaps which effectively lead to paths for improvement. These paths may include the need to review lower-level SCOR indicators based on the analysis of the upper SCOR level. Given the focus on optimization, these improvement proposals consider the best use of available resources in the company without additional investment.

KEYWORDS: SCOR model; Optimization; Supplier; Supply chain; Benchmarking.

APROXIMACIÓN A LA BÚSQUEDA DE VALORES DE REFERENCIA ÓPTIMOS PARA INDICADORES SCOR

RESUMEN

El presente artículo plantea una estrategia de decisión que parte del uso de indicadores SCOR (*Supply Chain Operations Reference Model*) en una organización, resultando ya habitual en la actualidad la realización de procesos de *benchmarking* externo o exógeno comparando los valores SCOR de la empresa respecto a aquellos de las empresas líderes de sector. Se propone, en cambio, un *benchmarking* interno o endógeno comparando los valores SCOR con aquellos valores óptimos de la misma empresa, producto de un proceso de optimización matemática de la organización. Partiendo del caso particular de indicadores asociados a las operaciones de los proveedores, se observa la utilidad de la comparación endógena donde las diferencias entre el óptimo de la empresa y el valor real del indicador conduce a unos gaps que guían efectivamente los caminos de mejoramiento. Estos caminos pueden incluir la necesidad de revisar indicadores SCOR de nivel inferior, partiendo del análisis de indicadores de nivel 1, lo cual resulta un aporte relevante en la práctica del SCOR. Dado el enfoque de optimización, estas propuestas de mejoramiento consideran el mejor uso de los recursos disponibles en la empresa, sin necesidad de inversiones adicionales.

PALABRAS CLAVES: Modelo SCOR; optimización; proveedor; cadena de abastecimiento; *Benchmarking*.

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APROXIMAÇÃO NA PESQUISA DE VALORES DE REFERÊNCIA ÓTIMOS PARA INDICADORES SCOR

RESUMO

Este artigo apresenta uma estratégia de decisão que parte do uso de indicadores SCOR (Supply Chain Operations Reference Model) numa organização, resultando já habitual na atualidade a realização de processos de benchmarking externo o exógeno comparando os valores SCOR da empresa em comparação com os valores das empresas líderes do setor. Propõe-se em cambio um benchmarking interno o endógeno comparando os valores SCOR com aqueles valores ótimos da mesma empresa, produto dum processo de optimização matemática da organização. Indo do caso particular de indicadores associados às operações dos provedores, observa-se a utilidade da comparação endógena onde as diferencias entre o ótimo para a empresa e o valor real do indicador conduze a uns gaps que guiam efetivamente os caminhos do melhoramento. Aqueles caminhos podem incluir a necessidade de revisar indicadores SCOR de nível inferior, a partir da análise de indicadores de nível 1 o qual resulta um aporte relevante na pratica do SCOR. Dado o enfoque de otimização, estas propostas de melhoramento consideram o melhor uso dos recursos disponíveis na empresa, sem necessidade de inversões adicionais.

PALAVRAS-CHAVE: Modelo SCOR; Optimização; Provedor; Cadeia de abastecimento; Benchmarking.

1. INTRODUCTION

In recent decades, several proposals for performance measurement in the internal processes of supply chains have been made (Pasutham, 2012). One of the proposals most widely accepted in the industry has been the Supply Chain Operations Reference (SCOR) Model (Supply Chain Council, 2010).

SCOR is a process reference model developed by the Supply Chain Council as a standard tool for measuring the management of a supply chain. Within its structure, it integrates the definition, identification, and hierarchy of performance metrics associated with efficiency characteristics in the supply chain, dividing the chain's characteristics according to their contexts: customer-facing and internal-facing. The metrics proposed by the SCOR model have given rise to several studies aimed at further refining the measurements that can be made in a specific industry. Examples can be found in the articles by Kasi (2005), Huang et al. (2005), Pasutham (2012), Gunakesaran et al. (2001), Zhang & Reimann (2013), Berrah & Clivillé (2007), and Chan (2003), among others. The model's indicators are divided into levels, and **Table 1** shows those on the first level. Each level 1 indicator includes a level 2 indicator number to deepen our understanding or find the causes of the problems identified in level 1. The model also includes levels 3 and 4, whose relationship with the previous levels is also that of improving the perceived diagnostic on those levels. Within the framework of a supply chain, all activities are grouped into processes according to SCOR, and each link in the chain works around five primary management processes: plan, source, make, deliver, and return. Each process can be measured through the groups of indicators, but each company must define the association between the process analyzed and the indicators that should correspond to it. Gunakesaran et al. (2001) show one association between different SCOR process metrics by dividing the indicators into strategies, tactics, and operations. According to Berrah & Clivillé (2007), this well-structured system of indicators and processes widely used for logistical performance analysis allows us to:

- Manage and improve the supply chain as a whole, and
- Compare the performance of the entire supply chain or a part of it with the average performance of chains in the same class (benchmarking).

Given that the SCOR indicators proposed by the SCC are evidently numerous, various articles have shown the advantage of using a certain number and type of indicators in practice. By way of example, we can mention the study by Gunasekaran et al. (2001), who discuss certain indicators and present a framework of indicators that should be used. They also present a link between strategic decisions, tactics, and operations with the group of indicators, which are also divided into financial and non-financial. According to Pasutham (2012), the proposal made by these authors still implies using numerous indicators and does not establish a priority among them. The hierarchy among indicators was proposed by Chae et al. (2009), and the interrelation between different indicators was studied by Cai et al. (2009). Rodríguez et al. (2009) present a framework for associating the company's strategic objectives with performance indicators and propose the Quantitative Relationships Performance Measurement System (QRPMS). With regards to the association of SCOR indicators with optimization models, Zhang & Reimann (2013) present a proposal which will be discussed later on given its relevance to this study.

The remainder of this article is organized as follows: section 2 conceptually justifies the pertinence of these optimal values, and section 3 proposes certain calculation structures. Finally, section 4 will show a hypothetical case study by Lozano & Chamorro (2010) inspired by a real situation. This will allow us to show the usefulness of the metrics proposed.

2. INTERNAL SUPPLY CHAIN REFERENCE VALUES

When a company compares itself to another leading company in its sector or with some other desired company, certain improvement proposals are made depending on whether the result of the comparison is favorable or unfavorable for the company. Internal questions immediately arise in the company: what improvement plans should be made to catch up to the leader? Can we really catch up with the available resources and with those that will be available in the future? What is the best performance that my company can achieve with the resources currently available? Are we currently doing the best we can with the available resources? These and other questions are the result of something that goes far beyond a simple comparison, but rather aims to establish concrete and,

Table 1. Relationship between performance attributes and Level 1 indicators

Performance Attribute	Definition of Performance Attribute	Strategic Level 1 Metric
Reliability of the Supply Chain	The supply chain's delivery performance: the correct product for the correct place, in the correct amount of time, in the correct conditions and with correct packaging, with the correct documentation, and for the correct client.	Perfect Order Fulfillment
Supply Chain Response	How fast the supply chain provides products to the client.	Order Fulfillment Cycle Time
Supply Chain Agility	The supply chain's agility in response to market changes in order to gain or maintain a competitive advantage.	Supply Chain Flexibility
		Upstream Supply Chain Adaptability
		Downstream Supply Chain Adaptability
Supply Chain Costs	The costs associated with the supply chain's operation.	Management of Supply Chain Costs
Management of Supply Chain Assets	An organization's effectiveness in managing its assets in order to support the satisfaction of demand. This includes administration of all assets: fixed and working capital.	Cycle Time from Register to
		Return on Supply Chain Fixed Assets
		Return on Working Capital

Source: SCOR 10.0

above all, attainable paths toward improvement. In terms of the best possible performance for a supply chain, there are several aspects to consider. Due to the theory of constraints, it is widely known that the best a supply chain can offer to a client is what is allowed by the weakest link. We might also say that a company's best performance is directly related to the best possible performance of the supply chain to which it belongs. From a mathematical programming perspective, the best performance of a company (or chain) is called optimal performance, and this state of maximum efficiency can be explored by optimizing (mathematically) the supply chain the company forms a part of. Optimization models, despite being an inexact and simplified representation of reality, show an efficiency limit or maximum efficiency (that is, the best possible use of the available resources), which allows us to identify some performance limits that cannot be easily overcome by the company or chain being analyzed. This discussion leads to a question: can those upper performance limits be associated to optimal reference values for SCOR metrics? The following section presents a proposal that is the first of its kind according to the scientific literature.

In their review associated with the SCOR model, Li et al. (2011) identified a lack of application of this model for supply chain performance optimization. In fact, Zhang & Reimann (2013) were the first to make an explicit association of SCOR metrics with supply chain optimization. In their article, the authors consider a chain with two links, represented by a provider and a plant. They propose a multi-period, multi-objective optimization strategy for a product case considering each SCOR attribute as an objective to be achieved. The solution focus was made through augmented ε-constraints considering cost minimization as the basic objective and setting parameters for the remaining four objectives (reliability, flexibility, use of assets, and response capacity) just as this method suggests in its traditional version. Zhang & Reinmann relate the cost objective with the minimization of inventory costs, backorders, and readiness. The use of assets objective is related to the minimization of inventories; the agility objective (flexibility) is related to freedom of movement in terms of each link's capacity; the reliability objective (perfect orders) is united with the demand fulfillment objective (which is also associated with the availability of inventories); and finally, the response capacity objective is defined as the minimization of backorders. We can see that for these authors, inventories and backorders play a central role in all the objectives.

3. SCOR REFERENCE METRICS PROPOSAL.

In contrast to the model proposed by Zhang & Reimann (2013), the one that we propose is multi-product with multiple plants, providers, and distribution centers. In addition, the metrics are not included as part of the mathematical model's expressions, but rather are calculated after the model has been resolved, using the optimization results that, in our case, correspond to profit maximization. This strategy has not yet been seen in the literature.

The SCOR metrics proposed in this article are associated with the provider-plant relationship. The following general nomenclature for the model is used to represent them.

Indices

r, s, p, c, z, j: indices associated with raw materials, providers, plans, distribution centers, consumer regions, and products, respectively.

Parameters

¨ DEM_{jz}: Projected demand for finished product j in region z [units/year].

¨ $CFPL_{p}$: Fixed costs for plant p [$/year].

¨ $CVPL_{jp}$: Variable production cost for finished product j in plant p [$/unit].

¨ EPL_{jp}: Efficiency of plant p for finished product j [hours/unit].

¨ $CTRPLCD_{jpc}$: Average transportation cost for finished product j from plant p to distribution center c [$/ton].

¨ $CFCD_{c}$: Fixed cost of distribution center c [$/year].

¨ $CVCD_{jc}$: Variable handling cost per unit of finished project j in distribution center c [$/unit].

¨ TCD_{c}: Maximum allowable operation time at distribution center c [hours/year].

- ECD_c: Handling efficiency at distribution center c [hours/unit].
- $CTRCDCL_{jcz}$: Transportation cost per ton of finished product j from distribution center c to consumer region z [$/ton].
- $CTRPROVPL_{sp}$: Transportation cost per ton of raw materials from provider s to plant p [$/ton].
- $CPROV_{rs}$: Production capacity of provider s of raw material r [unit/year].
- $COSTMP_{rsl}$: Unit cost of purchasing raw material r from provider s associated with a lot of size 1 [$/unit].
- PMP_{rs}: Average weight of one unit of raw material r from provider s [ton/unit measurement].
- PPT_j: Average weight of one unit of finished product j [ton/unit].
- $TMAXPL_p$: Maximum allowable production time at plant p [hours/year].
- $CPROD_{jp}$: Production capacity of product j at plant p [unit/year].
- $CMAXCD_{jp}$: Maximum allowable handling capacity for product j at distribution center c [units/year].
- $CINV_{jp}$: Cost of maintaining inventory of finished product j at production plant p [$/unit].
- PV_j: Sale Price of finished product j to end user [$/unit].
- $LTprovedor_{rs}$: Average production time for each order of raw material r from provider s [hours/order].
- PVCPT: Average sales on credit of finished product manufactured at the plant [$/year].
- $PCMPAC_s$: Average purchases of raw materials acquired on credit by the plant from provider s [$/year].
- CPU: Number of units of raw material per order [units/order].

Decision Variables (Non-negative)

- mp_{rsp}: Number of units of raw material r acquired by plant p from provider s [units/year].
- x_{jpc}: Amount of finished product j manufactured at plant p and shipped to distribution center c [units/year].
- y_{jcz}: Amount of finished product j sent from distribution center c to consumer region z [units/year].
- inv_{jp}: Inventory of finished product j at plant p [units/year].

Based on the supply chain optimization model's variables and parameters, we constructed a series of indicators proposed by the SCOR model for analyzing the logistical efficiency of the chain's providers. We must bear in mind that these strategic SCOR indicators are directly associated with the objective of profit maximization. In this sense, we are not dealing strictly with maximum or minimum reference values themselves. Instead, we are working ideally with reference values we should aim to be as close as possible to. However, this does not mean that some of the metrics can be seen as maximum or minimum reference values, as we will show. The variables that appear with an asterisk (*) refer to optimal variables generated by the model. Likewise, the indicator values with an asterisk are those calculated with the model's optimal solution, and those that do not have an asterisk in section 7 are associated with the values of indicators calculated by the company.

3.1. Provider Delivery Performance Indicator (DE_{rs})

This is a reliability indicator that can be associated with fulfilling the perfect order, which allows us to establish the number of orders for raw materials that each provider must deliver during the study period to satisfy production requirements and maximize the objective function.

$$DE^*_{rs} = \frac{1}{CPU}\sum_{p} mp^*_{rsp} \quad \forall\ r,s \qquad [\textit{Raw material orders}]$$

Receiving more or less than the value stipulated by DE^*_{rs} from the provider would damage profit maximization, meaning that this is not a value that the company should see as a maximum or minimum in the strict sense.

3.2. Fulfilling Lead Times for Orders of Raw Materials for the Supply Chain ($CLTP_{rsp}$)

This *response capacity* indicator references the lead time (LT) needed to fulfill the orders made for each raw material acquired from each provider to send to the production plant selected for the model. $CLTP^*_{rsp}$ is the factory cycle time (measured in order-hours) required to fulfill the orders of raw material r made to provider s to be sent to plant p on the optimal supply chain:

$$CLTP^*_{rsp} = \frac{1}{CPU}\,(mp^*_{rsp} * LTproveedor_{rs})\ \forall\, r,s,p \quad [order\text{-}hours]$$

This indicator can be taken as a maximum reference value.

3.3. Provider Production Capacity Flexibility (FP_{rs})

In this article, *flexibility* in the provider's production capacity is an agility indicator that is quantified as the freedom of movement in terms of capacity for taking on an unexpected demand in raw material once the originally agreed-upon demand orders have been fulfilled.

$$FP^*_{rs} = 1 - \frac{\sum_p mp^*_{rsp}}{CPROV_{rs}}\ \forall\, r,s \qquad [\%\ freedom\ in\ capacity]$$

0 % <=FP<=100 %

Without losing generality, we can arbitrarily determine that:

0–30 [%]: Flexibility for low production

70–100 [%]: Flexibility for high production

Therefore, based on this indicator we could determine which providers are appropriate for fulfilling an unexpected demand during the study period. Those providers with sufficient production capacity that are appropriate in terms of cost would be chosen to make post-optimal decisions regarding capacity. This indicator could therefore be treated as a minimum reference value for values about 0%, but it should be a maximum reference value for values equal to 0% (which implies that we do not wish for the raw material-provider combinations with 0% freedom of movement to have available capacity).

3.4. Percentage of Participation by the Provider in the Total Cost of Logistics Management (CTGLs)

This *cost* indicator (measured in %/provider) is the ratio of costs agreed upon with the provider to the total of managing the supply chain. The variable U is related to the optimal objective value.

$$CTGL^*_s = \frac{A^*}{B^*}\ \forall\, s \quad [\%\ of\ cost\ associated\ with\ provider]$$

$$A^* = \sum_r \sum_p mp^*_{rsp} * COSTMP_{rs} \qquad \forall\, s$$

$$B^* = \sum_j \sum_c \sum_z y^*_{jcz} * PV_j - U^*$$

It should be noted that the numerator A^* could also include the transportation costs from the corresponding provider, but we have omitted this without losing generality. This is a maximum reference indicator.

3.5. Cash-to-cash Cycle Time ($TCCTC_s$)

According to Zhang & Reimann (2013), this is a use of assets indicator and it is associated in this article with the time required (in days) to change the cash paid to the provider in money into cash received from the clients. The longer the cash cycle, the greater the need for current assets (with regards to current liabilities) given that it takes longer to change accounts receivable into cash. In other words, the longer the cycle time, the greater the need for working capital.

$TCCTC_s$ = Accounts receivable days – Accounts payable days.

$$TCCTC^*_s = \sum_j \sum_p \sum_c \frac{360PVCPT}{x^*_{jpc} * PV_j} - \sum_r \sum_p \frac{360PCMPAC_s}{COSTMP_{rs} * mp^*_{rsp}}\ \forall\, s\ [days]$$

This indicator is also a maximum reference value. In the indicator model, we have not considered many variables that influence the cash cycle time, such as considerations of prompt payment. **Table 2** summarizes the meaning of the indicators above.

Table 2. Interpretation of indicators as reference values

Indicator	Interpretation
DE_{rs}	The company tries to be as close as possible to it
$CLTP_{rsp}$	Maximum reference value
FP_{rs}	Maximum reference value if FP_{rs}= 0 % Minimum reference value if FP_{rs}> 0 %
$CTGL_s$	Maximum reference value
$TCCTC_s$	Maximum reference value

4. GENERIC MATHEMATICAL MODEL

Objective Function

Maximize:

$$U = \sum_j \sum_c \sum_z y_{jcz} * PV_j - \sum_p CFPL_p - \sum_c CFCD_c$$
$$- \sum_j \sum_p \sum_c CVPL_{jp} * x_{jpc} - \sum_j \sum_c \sum_z CVCD_{jc} * y_{jcz}$$
$$- \sum_j \sum_p \sum_c CTRPLCD_{jpc} * x_{jpc} * PPT_j$$
$$- \sum_r \sum_s \sum_p PMP_{rs} * FC_{rs} * mp_{rsp} * CTRPROVPL_{sp}$$
$$- \sum_j \sum_c \sum_z CTRCDCL_{jcz} * y_{jcz} * PPT_j - \sum_r \sum_s \sum_p COSTMP_{rs} * mp_{rsp}$$
$$- \sum_j \sum_c \sum_z CTRCDCL_{jcz} * y_{jcz} * PPT_j - \sum_r \sum_s \sum_p COSTMP_{rs} * mp_{rsp}$$
$$- \sum_j \sum_p CINV_{jp} * inv_{jp}$$

Restrictions

$\sum_p mp_{rsp} \leq CPROV_{rs} \quad \forall\ r,s$	(1)
$\sum_s mp_{rsp} = \sum_j \sum_c x_{jpc} + \sum_j inv_{jp} \ \forall\ p,r$	(2)
$\sum_j \sum_p x_{jpc} = \sum_j \sum_z y_{jcz} \ \forall\ c$	(3)
$\sum_j \sum_c x_{jpc} * EPL_p \leq TMAXPL_p \quad \forall\ p$	(4)
$\sum_j \sum_z y_{jcz} * ECD_C \leq TCD_C \ \forall\ c$	(5)
$IF \sum_j \sum_z DEM_{jz} \leq \sum_p CPROD_P,$ $THEN \quad \sum_j \sum_c y_{jcz} = \sum_j DEM_{jz} \quad \forall z$ $OTHERWISE$ $\left\{\sum_j \sum_c \sum_z y_{jcz} = \sum_p CPROD_P\right\} Y \left\{\sum_j \sum_c y_{jcz} \leq \sum_J DEM_{JZ} \forall z\right\}$	(6)

Based on the nomenclature, we can observe that restriction 1 is associated with the providers' capacity, and restriction 2 corresponds to the balance between the flow of raw materials acquired and what is produced in the plant. Restriction 3 corresponds to the balance between the flow of finished products between the plants and the distribution centers. Restriction 4 limits the production plants' capacity, while restriction 5 limits the distribution centers' capacity. Finally, expression 6 corresponds to the restrictions associated with fulfilling demands.

5. CASE STUDY

The following case will show an interpretation of the indicators presented above with a certain information scenario. We will analyze a production-distribution case for one product and multiple raw materials (4 in total) based on a real case from the Colombian clothing industry. The single product is represented by a pair classic men's size 32 trousers. We have 6 providers, 2 manufacturing plants, 4 distribution centers, and 5 marketing regions. This means that r = {1,...,4}, s = {1,...,6}, p = {1,...,2}, c = {1,...,4}, z = {1,...,5}. Some relevant information for the case is given below. **Table 3** shows the amount of raw materials required for each pair of trousers. One relevant piece of information for the model is that the weight of one pair of trousers is 0.85 kg. **Tables 4** and **5** show the lead time and provider capacity information since not all the providers provide all the raw materials.

Table 3. Amount of raw material needed to make one pair of trousers

AMOUNT OF RAW MATERIAL REQUIRED FOR ONE PAIR OF TROUSERS		WEIGHT
D (Drill; mt2)	1,5	0,50 kg/ mt2
T (Thread; meters)	4,5	0,01 kg/mt
B (Buttons; units)	1,0	0,02 kg/unit
Z (Zipper; units)	1,0	0,03 kg/unit

Table 4. Information on thread (T) and drill (D) providers

	PR1		PR2		PR3	
	D	T	D	T	D	T
ProviderLT [hours/order]	6,3	5,3	5,6	4,6	6,6	5,0
Provider Capacity [units/year]	63.663	75.600	71.152	86.400	60.480	80.640

Table 5. Information on button (C) and zipper (Z) providers

	PR4		PR5		PR6	
	B	Z	B	Z	B	Z
ProviderLT [hours/order]	5,25	5,16	7,66	5,66	3,00	4,66
Provider Capacity [units/year]	76.800	78.038	52.591	71.152	134.400	86.400

Table 6. Raw material transportation time from the provider to the plants

	PR1	PR2	PR3	PR4	PR5	PR6
Plant 1	18	18	4	6	1	20
Plant 2	19.5	19	6.5	8	2	22

Table 6 shows raw material transportation time from the provider to the plants.

The demand in the 5 regions in units/year is: Pasto 5,500; Bogotá 94,367; Cali 59,552; Popayán 3,542; and Bucaramanga 7,251. The price per unit sale of the finished product is COP$145.000, and the average total sales on credit is COP$400 million per year. **Table 7** shows the fixed and variable costs generated in the supply chain.

It is assumed that the plants work 5,760 hours/year (equivalent to two 8-hour daily shifts with 360 work days in the year) and that the distribution centers work 2,880 hours/year (equivalent to one 8-hour shift daily). **Table 8** presents information on the plants' efficiency and maximum annual production.

Table 7. Fixed and variable costs for plants and distribution centers

		FIXED COST [COP$/year]	VARIABLE COST [COP$/unit]
PLANT 1		2,148,000,000	45,000
PLANT 2		1,135,621,000	32,000
Distribution Centers	1	145.343.465	12.374
	2	256.796.485	11.264
	3	121.264.473	12.263
	4	201.080.500	10.687

Table 9 shows the assumed historical average of raw materials purchased on credit for the plants. The quality of raw material offered by the different

providers of thread, buttons, drill, and zippers is comparable. We therefore do not considered them to be deciding elements regarding the quality of raw materials offered in the market.

Table 8. Relevant production plant information

	EFFICIENCY [hours/unit]	MAXIMUM ANNUAL PRODUCTION [units/year]
Plant 1	0,06	96.000,00
Plant 2	0,08	72.000,00

Table 9. Average purchases on credit by plant with each provider

PR1	PR2	PR3	PR4	PR5	PR6
17.500.000	112.000.000	65.000.000	5.600.000	0	30.000.000

The values for handling efficiency (in hours/unit) at the distribution centers are assumed to be: 0.03 at DC1; 0.05 at DC2; 0.20 at DC3; 0.25 at DC4.

Given that this is a hypothetical case study whose only goal is to obtain values associated with reality to a certain degree, we considered the minimum rates previously suggested between the main cities in Colombia for the transportation costs of raw materials from the providers to the plants, of the finished product (in tons) from the plans to the distribution centers, and from there to the consumer regions. These rates were established in 2002 by the Ministerio de Transporte de Colombia (Ministry of Transportation of Colombia)[1]. Finally, the CPU parameter was arbitrarily established for use in this case at a value of 70, and the annual unit cost of finished product inventory maintenance at plants 1 and 2 was set at COP$10,800 and COP$9,000, respectively.

6. CASE STUDY RESULTS

With regards to the general results of the model, which was programmed in AMPL language and resolved with the CPLEX solver, we can mention several aspects before showing the values associated with the indicators. Plant 1 receives a total of 96,000 units of each raw material, where each material has the dimensions established in **Table 2**, producing 96,000 pairs of trousers. Of this amount, 84,480 are sent to distribution center DC1, and the remaining 11.520 are sent to distribution center DC4. Distribution center DC1 Transports the 84,480 pairs of trousers to consumer region 2, and distribution center DC4 divides its 11,520 pairs of trousers, sending 4,269 to consumer region 2 and 7,251 to consumer region 5. Plant PL2 receives 72,000 units of each raw material, manufacturing 72,000 pairs of trousers. Of this amount, 57,600 are sent to distribution center DC2, and said amount is distributed in consumer region 3. The remaining 14,400 pairs of trousers manufactured by plant 2 are sent to distribution center DC3, and this center distributes 5,500, 3,406, 1,952, and 3,542 to consumer regions 1, 2, 3, and 4, respectively. With the distribution and processing of the finished product and the raw materials, 98.7% of the total demand is filled, maximizing profit to a value of COP$7,560,354,951, using the full capacity of the two plants, 88% of distribution center DC1's capacity, and 100% of the capacity of the remaining three.

The results of the indicators constructed from the results given by the case study model are presented below.

6.1 SCOR Model Indicators

Tables 10 through **14** show the optimal results obtained for the indicators DE_{rs}, $CLTP_{rsp}$, FP_{rs}, $CTGL_s$ y $TCCTC_s$.

Table 10. Results for provider performance at delivery indicator

	PR1	PR2	PR3	PR4	PR5	PR6
Drill	865	671	864	0	0	0
Thread	600	1.029	771	0	0	0
Buttons	0	0	0	729	0	1.671
Zippers	0	0	0	1.097	69	1.234

1 The shipping table no longer applies in Colombia, but its use in this article is based on the comparability of transportation costs between cities. The table can be downloaded at: https://www.mintransporte.gov.co/documentos.php?id=14&colorder=fecha&order=ASC&offset=2

Table 11. Results for the indicator of factory time cycle for the supply chain's raw material orders for plants 1 and 2.

	PR1		PR2		PR3		PR4		PR5		PR6	
	PL1	PL2	PL1	PL2	PL1	PL2	PL1	PL2	PL1	PL2	PL1	PL2
Drill	4,428	1,055	3,780	0	0	5,709	0	0	0	0	0	0
Thread	3,198	0	0	4,750	3,861	0	0	0	0	0	0	0
Buttons	0	0	0	0	0	0	3,831	0	0	0	1,949	3,108
Zippers	0	0	0	0	0	0	5,667	0	0	390	1,298	4,496

Table 12. Results for the provider production capacity flexibility indicator.

	PR1	PR2	PR3	PR4	PR5	PR6
Drill	4.94%	33.94%	0.00%	-	-	-
Thread	44.44%	16.67%	33.04%	-	-	-
Buttons	-	-	-	33.59%	100.00%	12.95%
Zippers	-	-	-	1.59%	93.25%	0.00%

Table 13. Results of the percentage of provider participation in the total cost of logistics management indicator.

PR1	PR2	PR3	PR4	PR5	PR6
9.95%	8.95%	10.31%	0.18%	0.01%	0.30%

Table 14. Results of cash-to-cash time cycle.

PR1	PR2	PR3	PR4	PR5	PR6
2	6	6	5	6	6

As a way of interpreting the results above in the framework of supply chain strategic objective fulfillment (which is to maximize profits), the following section presents several conductors of strategic value associated with said indicators and which should be considered by companies.

6.2. Basic Interpretation of Indicators Within the Framework of Strategic Value Conductors

• *SCOR performance attribute: "Reliability in the supply chain."* [Perfect order fulfillment.]

The chain's providers should optimally be filling the orders (DErs indicators) for raw materials shown in **Table 10.** For example, PR3 should deliver an exact amount of 864 orders of drill during the study period (assuming they are made in good quality conditions) in a manufacturing time represented by $CLTP_{rsp}$ stipulated in **Table 11** in order to contribute to an appropriate customer service and the maximizations of profits in the chain.

• *SCOR performance attribute: "Receptiveness in the supply chain."* [Raw material factory cycle time.]

Under the optimal solution for raw materials purchasing given by the model, we recommended making orders for drill and thread to providers PR1, PR2, and PR3. With regards to the buttons, we suggest purchasing from providers PR4 and PR6. Finally, for ordering zippers, we recommend PR4, PR5, and PR6, all in the quantities shown in **Table 10**.

Therefore, according to **Table 11**, said providers must commit to meeting the cycle time for manufacturing said orders of raw materials in a panorama of optimal performance. For example, provider PR1 optimally should not take more than 4,428 hours to manufacture the 700 orders or drill to be sent to plant 1 and up to 1,055 to manufacture the 165 orders of drill for plant 2.

• *SCOR performance attribute: "Flexibility in the supply chain."* [Flexibility in the provider's production capacity.]

According to the values in **Table 12**, the providers with the greatest freedom of movement with regards to production capacity once they have filled the raw material orders made by the plants are: provider PR2 for drill (33.94%); provider PR1 for thread (44.44%); provider PR4 for buttons (100%), followed by PR5 (33.59%); and also PR5 for zippers (93.22%). This is due to the fact that the model suggests buying the greatest quantity of zippers and buttons from providers PR4 and PR6, while proposing providers PR1, PR2, and PR3 for purchasing drill and thread. PR3 does not show production capacity, and neither does provider PR2 for the raw material drill.

• *SCOR performance attribute: "Supply chain costs."* [Cost of raw materials.]

According to **Table 13**, when looking for a control for supply costs in the chain, it is necessary for the optimal percentage of provider participation in the total cost of logistics management (CTGLs) to have a higher proportion for providers PR1, PR2, and PR3. We can observe that the upper limit suggested for the participation of providers PR3, PR4, and PR5 is the total logistical cost is very small.

• *SCOR performance attribute: "Management of supply chain assets."* [Cash-to-cash cycle time.]

According to the indicators associated with the strategic value conductors for improvement of customer service and reduction of the total cost of logistics management, it is possible to minimize the time required to change the cash paid to providers into cash received from the clients ($TCCTC_s$) as can be seen in **Table 14**. We could say that the supply chain can have a good level of efficiency with regards to its management of working capital assuming that the optimal values obtained are not significantly large. According to this, we could expect return on the investment in purchasing raw material in sales generated from the finished product within a reasonable amount of time.

7. MEASUREMENT AND MONITORING DYNAMIC IN THE COMPANY

Beyond the basic interpretation of the indicators given in the previous section and shown in a particular case study, what is really interesting for a company is to compare these optimal indicators with the real indicators for the company. This is an endogenous benchmarking, as opposed to the exogenous benchmarking when making a comparison with a different company.

Once the company has calculated the optimal reference values, it must proceed to calculate the differences (which we will refer to as gaps) between the real values for the company and the optimal values. Thereby, we have, for example, $|DE^*_{rs} - DE_{rs}| = Gap_1$, proceeding in a similar fashion for the remaining indicators in order to obtain five (5) gaps. The goal is for these differences to be as close as possible to zero or for the company to stipulate a value of acceptable closeness δ. EThat is, within the framework of gap monitoring, the company can establish a control rule like: gap $\leq \delta$.

Figure 1 shows a performance control strategy based on looking for optimal indicators and then comparing them with the real situation in the company, thereby establishing gaps. The representation of the gaps in **Figure 1** is associated with the type of reference value represented by each indicator according to **Table 2**. The analysis of the gaps is actually a decision-making tool, always bearing in mind that the metrics proposed are for level 1 (strategic) and associated with providers, but that this could be extended to metrics on another level in the SCOR framework, relating other actors in the production chain.

Figure 2 shows the decision potential that can arise with this strategic methodology.

Figure 1. Proposed control methodology

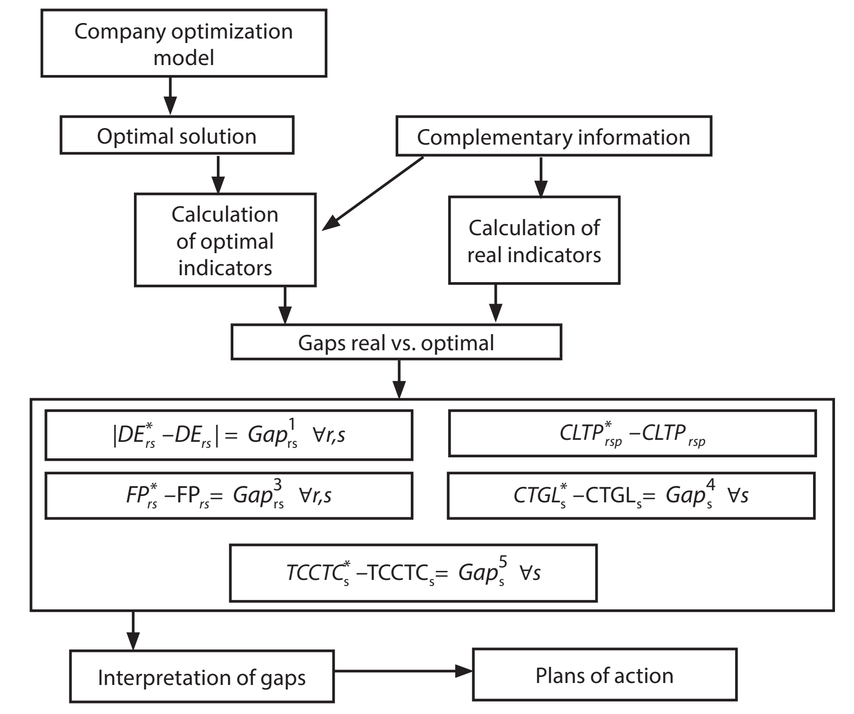
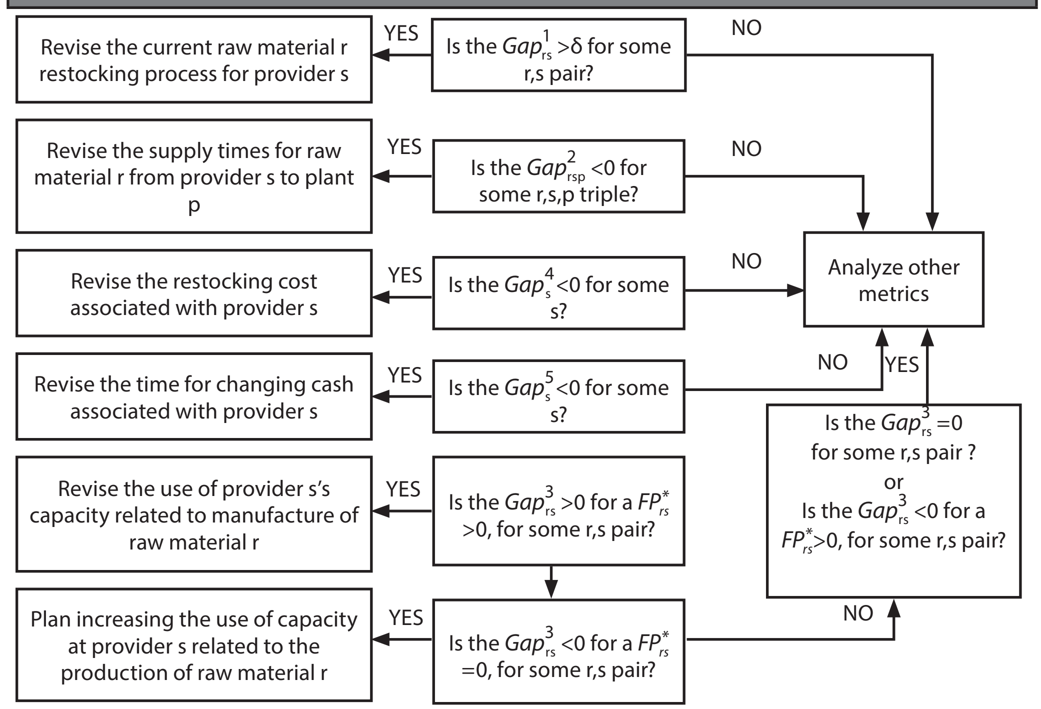


Figure 2. Decision map for gap analysis



The decision rules proposed in **Figure 2** show paths that lead not only to revising current processes, but also to looking at other metrics that can be on the same level or even on a different level. In other words, when a strategic level or level 1 metric is in an acceptable state, it may be advisable to look at the problem from another level, that is, from a more tactical/operative perspective, perhaps exploring indicators associated with daily operations, in order to find potential sources of improvement. This fills a hole in the use of SCOR in practice since it has not been sufficiently clear how to proceed from one level of indicators to another. Also, given that the comparison is made with the optimal values for the company based on its available resources, these improvements determine at important limit with regards to what the company can actually do without making new investments.

8. CONCLUSIONS AND FUTURE RESEARCH

This article proposes a decision strategy based on the use of SCOR® indicators in an organization. External or exogenous benchmarking processes are now common, comparing the company's SCOR values with those of leading companies in the sector. Instead, we propose an internal or endogenous benchmarking that compares SCOR values with the optimal values for the same company, which are the product of a mathematical optimization for the organization. Based on the particular case of indicators associated with provider operations, we can observe the usefulness of endogenous comparison where the differences between the optimal values for the company and the real value of the indicator show gaps that effectively lead to paths of improvement. Despite having used a simple case from the clothing sector, our intention was not to perform an analysis for this sector, which would no doubt require a much more complete study with a variety of references and temporal considerations. Our aim is to show how optimization models can be used to design indicators that will make endogenous benchmarking based on the SCOR model possible. Future research could include an exploration of SCOR indicators in the framework of a whole-mixed linear optimization model with multiple objectives in which the solution methods could play an important role.

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