

Supply Chain Performance Measurement: Proposal of an Integral Indicator with a Multiple Criteria Approach for Supporting Decision Making

Delgado Sobrino, D. Cagaňová, and M. Čambál

Abstract—Due to the importance and need of giving managers an overall tool for supporting the decision making process from a more general perspective, the present paper introduces an Integral Indicator of the Supply Chain Performance (IISCP), with a multiple criteria approach in the aggregation of the specific metrics and their groups. At the same time, this proposal also introduces some simple modifications to the classical performance management cycle, making possible this way and through a shorter feedback loop, the analysis of certain indicators since the very beginning, instead of waiting till the end of the period. The paper is based on a good literature review and enriched taking into account some of the gaps remaining in the state of the art and practice.

Keywords—Integral Indicator of the Supply Chain Performance (IISCP), Key Performance Indicators (KPIs), Supply Chain Management, (SCM), Supply Chain Performance (Measurement), (System) [SCP(M)(S)].

I. INTRODUCTION

IN today's complex and dynamic markets it has become increasingly necessary for managers to be aware of the current status of their companies and to have under control how to improve the performance [1]. All this has become even more difficult and necessary to better face and set the competition after the development of the SCM as an integration philosophy. Under these circumstances, the SCPM as an important part of the so called "Quick scan", "Health check" or simply diagnostic, has become a relevant guaranty for change or improvement strategies in the supply chain and a way for facing a dynamic environment. The SCPM allows to compare two or more performances each from a different period, what is also known in the literature as "before and after comparison", this means it can be also used as a validation tool where required [7], [8] and [13], and also gives pieces of information about the satisfaction, contradictions and redundancies of the objectives, while also allows linking the

current measures to the improvement actions to launch, [2]. Related to all this and when analyzing the states of the art and practice, it happens that sometimes managers despite not having the tools, have to cope with a great deal of information which separately may mean nothing to the decision maker. Unrefined and isolated analysis of the KPIs not always leads to good global decisions and even when having the values of all the criteria or indicators, it may not exist any kind of dominance among these, for instance Pareto's, and only the assignment of weights and the application of aggregation techniques could lead to a final selection or result supporting decision making from a general viewpoint.

In the field of SCM, all these elements have been also analyzed and been the concern, although some other way pointed out, of [3], [14]–[17], where even the Supply Chain Operations Reference Model (SCOR) and the Balanced Scorecard (BSC) have been included. Besides the elements already mentioned, some other relevant difficulties have been also noticed when conducting a deeper analysis, i.e.: (1) a lack of analysis in the relationships among KPIs, their groups and their correspondence with the upstream objectives they are related to, also stated in [5] and [22], (2) the disuse of weighting techniques both for respectively knowing the importance of such KPIs and their groups, or for prioritizing the measures to be taken, (3) the continued use of the classical performance management cycle by almost all the SCM actors, which implies to wait to the end of the planned period to act correctively on the unfulfilled KPIs, meaning it is not being done systematically (lack of systematic thinking) and with a short feedback loop as it must be and (4) the SCPM has been very frequently carried out under a narrow scope, which most of the time is aimed at the operational aspects of the supply chain or processes under study, without regarding a lot of customer-facing elements and the satisfaction of all parties that influence the results. As all these elements, although analyzed in some cases, have relatively received less attention in previous research, significant gaps still remain between practical needs and their effective solutions. The authors believe, which becomes the essence of this paper, that one way to better contribute to solve such problems, rests on grouping all the properly selected KPIs in an integral indicator that represents, in a general way, the performance of the supply chain or even processes of it under analysis. This way, and also including and having analyzed the weights of each

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KPI and groups of them, the relationships among them and with the upstream objectives they are related to, the prioritization of the measures to be taken, a shorter feedback loop to correct the KPIs before they have started running and besides operational aspects, some other customer-facing elements and interests of all the parties involved [24], it would be possible for managers to count on a wide supply chain/process- basis to better understand the situations contributing to an improvement in the decision making process. The rest of the paper will be organized in section 2 “Conceptual background”, section 3 “Proposal of an integral indicator with a multiple criteria approach” and section 4 “Conclusions and further research issues”

II. CONCEPTUAL BACKGROUND

Since the increasing pressure of companies to survive in the market started, tied to the development of ICT and the globalization process, managers have been engaged in some managerial aspects that passed from playing a passive role to an active one, among all these it has become important due to its incidence in the company’s reaction of speed, the performance measurement. SCPM has been studied for a long time; however this literature shows there is no total consensus on what it should cover and on what it could represent for the supply chain.

[19]define performance measurement as “effectiveness and efficiency in accomplishing a given task in relation to how well a goal is met”. In the logistics and supply chain context, effectiveness is concerned with the extent to which goals are accomplished and they may include lead-time, stockout probability, reliability, availability among others, efficiency measures how well the resources are utilized, for which the measures may include inventory costs, operating costs, faulty products, etc. While many firms recognize these two main aspects of performance, they still fail to understand them from a perspective of a balanced framework for performance measurement [4] this could be disruptive for performance management in a supply chain. It could be that one firm may be concentrated on operational efficiency, while the others are more concerned with service effectiveness in the supply chain. The differences in the views of SCP would lead to inconsistency in the performance measures used across member firms in a supply chain and consequently suboptimize supply chain-wide performance [2], [6] and [11]. Some other authors like [16], besides effectiveness and efficiency also consider a third component of performance measurement: Relevance, they define it measures the adequacy of the means to the objectives.

Traditional performance measures such as profitability are less relevant nowadays for measuring SCP since they tend to have an individual focus and fail to consider chain wide areas for performance improvement. It has been proved in practice than even when profits are going down for a while; it does not necessarily mean the supply chain is upside down. Bechtel and Jayaram (1997) advocate the use of integrated measures, in addition to non-integrated measures, that motivate firms to consider chain-wide performance, rather than their own individual performance measures, i.e. : some other parties

involved and more customer-facing elements should be analyzed.

Other authors have been also working in the SCPM to address this problem; these have used Balanced Scorecard (BSC) and Activity Based Costing (ABC) as methods to evaluate SCP, [17], other researchers have also proposed similar balanced frameworks, such as Performance Measurement Matrix, Results-Determinants Framework, Performance Pyramid, break-down/aggregation models, etc. (Neely, 2005), while some others like Caplice & Sheffi (1995) and Fahmy Salama et al. (2009), have dedicated their efforts to analyze a great deal of literature proposing new methodologies for the SCPM.

From a process perspective, the SCOR has been developed to facilitate the construction of a systematic SCPM and improvement tool; it has often been recognized as a systematic approach for identifying, evaluating and monitoring supply chain performance and it recognizes that there are not only operational but internal and customer-related reasons for performance measurement (Lai et al. 2002, 2004). However as stated in Cai et al. (2009), with who the authors agree, this last approach has some limitations since involves a lot of individual metrics that separately may mean nothing, and besides cannot be all easily handled by decision makers. It does not provide either cause-effect relationships between the individual KPIs or groups of them, assuming all these are not coupled when most of the time they really are, as it can be inferred from Rodríguez Rodríguez et al. (2009) and Cai et al. (2009). This emphasis on the need of global measures for the whole supply chain or even processes of it, is besides also stated in [3] and [16] and contributes to better justify the goal of this paper.

As for summarizing what the authors could infer from the state of the art and practice and their own experiences in the field, some partial conclusions have been elaborated:

- There is not solid a knowledge on what the SCPM must encompass and it is frequently being carried out empirically and subjectively.
- Supply chain members very often have different interests and are focused on isolated and different elements of the supply chain what can be disruptive for a good measurement process.
- There is a tendency to consider for SCPM; just the operational aspects and some other customer-related elements like the satisfaction of their needs, level of commitment achieved, the logical compliance of third parties logistics, among others, are not being taking into account.
- A huge amount of KPIs exists and sometimes managers besides not being sure on which to apply cannot consider all of them at the same time for making a good global decision.
- The relationships between KPIs and their groups are not commonly analyzed, as well as there is not a clear and unequivocal traceability in most of the SCPMS that directly links the KPIs with their upstream objectives and, in some cases it is being thought all KPIs are uncoupled when they almost never are.
- Weighting techniques are not commonly used for prioritizing and comparing each KPI with the others of the

same dimension (certain group of indicators), whole dimensions of KPIs and the measure to be taken. This could guide the decision making process on which elements must be first considered.

▪ Just a few authors have proposed an integral indicator for the SCPM and none of the proposal has covered several gaps remaining in the states of the art and practice, used a multiple criteria approach and been also flexible enough as for being applied to various isolated processes of the supply chain.

III. PROPOSAL OF AN INTEGRAL INDICATOR WITH A MULTIPLE CRITERIA APPROACH

The IISCP presented in this section, has been intended under a multiple criteria approach and the use of weighting techniques, this way it better shows the impact of each dimension and their specific KPIs in the final results. The proposal rests on the problematic situation and gaps described before, and it becomes an important tool for decision makers since it offers both general and specific information. It can be applied either to all the supply chain, isolated processes of it or even to other companies not under the Supply Chain Philosophy under certain modifications, it is up to decision makers where to implement it, and it could only imply changing the input KPIs and considering the interdependencies with some other processes. The proposal constitutes the core of a good diagnostic method and also becomes a validation pattern and a basis for change and improvements strategies inside the supply chain; for its calculation the dynamics of the current environment must be taken into account so that in case of any change, it is possible to come back and correct what is necessary. The IISCP has been enhanced by the revision of the cited literature, verifying from it some of the author's ideas and taken what seemed important; it has been structured as follows:

A. Establishment, organization and training of the work team

Determining an optimal number of experts, selecting the best from all the universe of candidates and working in their training, becomes the first step of the calculation method. Emphasis must be made on the techniques they could use as well as on the importance the study has for the supply chain or the processes under study, the expression for determining the optimal number of experts is:

$$n = \frac{p*(1-p)*k}{i^2} \quad (1)$$

Where:

i- Desired precision level; p- Estimated proportion of expert's mistakes

k- Constant value associated to the selected level of confidence.

and:

Level of confidence (%) Value of k

99 6.6564

95 3.8416
90 2.6896

After this calculation, the definite selection of the work team members from all the universe of candidates is carried out, the quality of the experts substantially influences in the accuracy and reliability of the results and it has to do mainly with the technical qualification and the specific knowledge they have on what to evaluate, in this paper all this rests on the application of the competences index proposed by Hurtado de Mendoza (2003), it has also been successfully applied before in Delgado Sobrino & Marrero Delgado (2009). In brief, this proposal consists on asking the experts several questions quantifying them so as to calculate the information or knowledge index, then the argumentation index, and finally, as a result of these ones, the competences index. This contributes eliminating the subjective decision making in selecting the experts, it has been proved that not necessarily the high level staff members are the most appropriate to integrate the work teams.

To further evaluate the concordance among the judgments of experts every time is needed through this proposal, the authors recommend the use of Kendall's concordance coefficient and the hypothesis tests it involves; all this appears widely mentioned in previous literature and software, specially the different versions of the SPSS.

B. Determination and analysis of the dimensions of the IISCP and their specific KPIs

Once structured the work team, this based on the current status of the supply chain, benchmarking activities, worker's opinions, literature and being consequent with the goal of the study which could be framed in all the supply chain or just in a process of it, defines the dimensions and their KPIs by means of a work team technique. These dimensions and KPIs, not necessarily could be extended to some other case studies and they should not just be focused on operational aspects but must also consider for a better performance measurement, some other customer-facing elements and the interest of all the parties of the supply chain. The KPIs must be intended based on the upstream objectives so that there is a clear traceability among these ones. An analysis looking for possible redundancies when stating a new KPI must be also carried out and, in case redundancies show up, besides taking the appropriate measures for eliminating them since they could alter SCPM, they must be projected upstream looking for possible relationships in the supply chain or process objectives linked to such KPIs, this way if one objective is not being reached, managers could count on another piece of information for analyzing if such effect objective is being influenced by another cause objective and their dependent KPIs. This could be done either subjectively or taking into account some elements from Rodríguez Rodríguez et al. (2009), then cause-effect relationships between KPIs and objectives could be better understood and measures could be taken. Some usual groups of indicators, referred as dimensions herein, when measuring the performance of a supply chain or

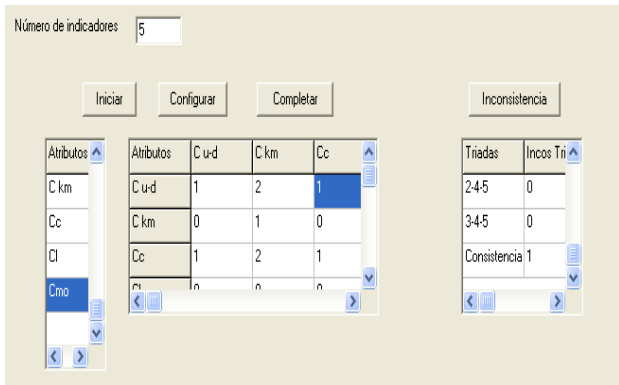


Fig. 2 Interface of the application used for calculation the expert's consistency

This is one of the outputs of an application created by the authors which could also been used for determining the consistency of the experts judgments. The application is in Spanish language.

Notice that as a way of homogenization, the quotient $(\frac{E_{rk-practical}}{E_{rk-theoretical}})$, initially intended for KPIs with a maximum sense of optimality, must be inverted according to the variation of such optimality sense of the indicator k. In case anyone of the cited quotients exceed the value 1, being this a maximum or minimum indicator, the measurement process meets then an anomaly that could have taken place because of a wrong establishment of the goals or calculation of the indicator, then it becomes necessary to go back and repeat as many steps as necessary trying to figure out if there were any problems, if the predefined goals remain the same and there is no calculation mistakes, it could simply show a rise in the performance. The data for the KPIs must be also homogenized to the same time period. The aggregation method to use within the IISCP is the weighted sum.

$$IISCP = \frac{WSD}{MD} \tag{2}$$

$$WSD = \sum_r W_r * QD_r \quad r = 1(\wedge) c \tag{3}$$

$$MD = \sum_r W_r \quad r = 1(\wedge) c \tag{4}$$

$$\text{but } \sum_r W_r = 1 \quad r = 1(\wedge) c, \text{ therefore: } MD = 1 \tag{5}$$

$$QD_r = \sum_k W_{rk} * (\frac{E_{rk-practical}}{E_{rk-theoretical}}) \tag{6}$$

$$r = 1(\wedge) c \text{ y } k = 1(\wedge) p$$

Where:

IISCP: Integral Indicator of the Supply Chain Performance

WSD: Weighted sum of the qualification of the dimensions

MD: Maximum qualification of the dimensions

Wr: Relative importance of the dimension r

Wrk: Relative importance of the indicator k from the dimension r

QDr: Qualification of the dimension r

Erk-practical: Real evaluation of the indicator k from the dimension r

Erk-theoretical: Theoretical evaluation (goal) of the indicator k from the dimension r.

K. Appraisal of the IISCP and presentation of the results

Either being seen this indicator as the basis for before and after comparisons or moreover, if this referential or comparison base did not exist, it allows anyway managers to count on another tool for the audit and control that from a general supply chain or process perspective, contributes to a better decision making and plays the role the new dynamic SCM demands.

Since there are not many previous applications of the proposal besides those ones carried out by one of the authors, it becomes really difficult to set scale ranges to conclude if the performance of the supply chain or process can be evaluated as Very good, Good, Regular or Medium, Bad, Very bad or regarding any other evaluation nomenclature. However, in a first approximation and taking into account the result of such few previous applications, some scale is herein proposed which moves between 0 and 1. It is important to state that this evaluation scale has proved to vary from one case study to another and even from one process to another inside the same supply chain, hence in each application it must be analyzed or just taken as a reference while making it better fit to the particular case study. The scale ranges are as follows: Very good (1, 00-0, 92); Good (0, 91-0, 82); Regular or medium (0, 81-0, 72); Bad (0, 71-0, 61); Very bad (any value under 0, 61). Once calculated the IISCP, this scale will allow concluding how the performance under consideration is. The process of creating such scale basically consists on a group work by the members of the work team (experts), and is listed in a few steps as follows and briefly illustrated through the table. I.

1. In a brainstorming several scale ranges for each evaluation are proposed. In case there is a full consensus on a certain scale range for a certain evaluation, e.g. values between 0,9 and 1 correspond to a Very good performance, then there will be no need of proposing several of these
2. For each evaluation, it will be generated a table which will include the Competing Scale Ranges (CSR) and each one of the experts (E), who will make judgments according to another scale, e.g. from 0 till 5 or 10, where either sense of the optimality, i.e. minimum or maximum, could be taken as a reference. Notice that CSR= 1(∧) s and E=1(∧) x. The judgments or values issued by the experts over each

scale range, regarding its fit to a certain evaluation of the IISCP, will be called as J, and each value inside such table will be denominated according to the numbers of the expert and the CSR, e.g. J_{3, 6}, describes the judgment of the expert 6 on the competing range scale 3. Notice that even when the number of experts could apparently take any value, it should usually move between 7 and 15 so as to guarantee and adequate level of confidence and qualification in the study, this can be inferred if analyzing the elements of the expression 1.

- The judgments are summed by rows into a Total per row column and by columns into a Total per column row, as described by the following sums:

$$\sum_{e=1}^x J_{s,x} \tag{7}$$

$$\sum_{CSR=1}^s J_{s,x} \tag{8}$$

- The Total per row column and the Total per column row are summed into the Total sum of all the values cell as shown by the following sum:

$$\sum_{e=1}^x \sum_{CSR=1}^s J_{s,x} \tag{9}$$

- Each value from the Total per row column is divided per the value of (9) and written down into the weight column, then based on the defined sense of optimality; it will be possible to analyze which one of the scale ranges better fits the evaluation under consideration.

TABLE I
EXAMPLE OF THE ADJUSTMENT OF THE COMPETING SCALE RANGES TO A CERTAIN EVALUATION (VERY BAD)

		Experts					(7)	Weight
		E1	E2	E3	E _x			
CSR	0,6-0,68	5	4	5	E _{x,1}	14	0,4117	
	0,62-0,7	3	3	2	E _{x,2}	8	0,2352	
	0,65-0,7	4	4	4	E _{x,3}	12	0,3529	
	SR _s	SR _{s,1}	SR _{s,2}	SR _{s,3}	SR _{s,x}	?	?	
(8)		12	11	11		(9) = 34	1	

Notice that the J values are from another scale which moves between 1 and 5 and the sense of optimality is moved to maximum.

IV. CONCLUSIONS AND FURTHER RESEARCH ISSUES

This paper presented an integral indicator supported in the multiple criteria approach for the SCPM. It offers decision makers a single piece of information contributing to help

decision making from a more general perspective while still having the chance to analyze each particular KPI. A brief but rich conceptual background was created for supporting such proposal, and some of the gaps remaining in literature were considered for its improvement. At the end some relevant aspects can be numbered from all this paper:

- The method proposes to consider not only operative elements but also customer-facing ones in the SCPM
- The selection of the work team members is proposed to be done based on their competences, rather than in the hierarchy inside the process/chain or subjectivity as it almost always happens
- It was slightly modified the performance management cycle, since the calculation of the KPIs was intended to be preceded by an offline analysis, correcting them or the fixed goals if necessary, without waiting to the end of the period to do it. It makes the feedback loop shorter and contributes to a systematic thinking
- It was employed the multiple criteria approach for aggregating each indicator to the overall one, allowing this way, based on the assignment of weights to each one of the KPIs and their dimensions, knowing the impact of them in the general result. The tool also helps managers in easily checking the fulfillment or not of the defined goal values.
- The tool provides managers and SCM practitioners with a wide supply chain or process basis for making decision making better, this does not mean an exhaustive analysis on each KPI must be eliminated but that now their particular contribution to the final results can be better understood and better attention could be paid in particular KPIs.

Some authors' idea for further research, besides continuing improving the IISCP calculation method, have to do with (1) its insertion in a (2) supply chain-focused diagnostic method for better measuring the health of the supply chain and (3) the proposal of an improved calculation method for the CSL, which becomes, even when there is not enough awareness of it, the main goal of each supply chain. Commonly customer service activities seem to focus on resolving problems rather than proactively meeting the customer needs; this proposal will lie on the application of the "seven R's rule" to which the authors besides, having the right product, in the right quantity, in the right condition, at the right place, at the right time, for the right customer, and at the right cost service, think to consider adding the "right after transaction services".

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