Available online at www.sciencedirect.com
ScienceDirect
Computers in Industry 58 (2007) 709–719
COMPUTERS IN INDUSTRY
www.elsevier.com/locate/compind

Towards an aggregation performance measurement system model in a supply chain context

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Available online 18 June 2007

Abstract

This study deals with the supply chain (SC) performance formalization. We propose to build performance measurement systems (PMSs) by linking an overall performance expression to elementary ones. The overall performance is associated to a global objective whose break-down provides elementary objectives. Elementary performances are thus aggregated in a corollary way. The problem in the design of such PMS's, by the break-down/aggregation model, concerns both the coherent elementary performance expressions and the definition of the links between them. Some answers are proposed in the literature, such as the weighted mean aggregation operator, to handle hierarchical links, the Choquet integral operator, for taking interactions into account. As global frameworks, the AHP or MACBETH methodologies are suggested. By considering the SCOR model break-down, we propose to extend here the proposed approaches for expressing the overall performance of a SC. An aggregation methodology, based on the Choquet integral operator and MACBETH framework, is thus adopted.

Keywords: Performance aggregation; MACBETH methodology; Choquet integral; Supply chain; SCOR model

1. Introduction – problem statement

To deal with the complexity of the current industrial context, new strategies gaining wide acceptance when driving continuous improvement [1] generally include the following steps [2]: identifying key areas, as-is situation analysis, planning and implementing changes, monitoring the results, and developing a closed-loop control system. To achieve all these functions, defining performance expressions and modelling their relationships are key activities. Indeed, according to their definition, the purpose of performance indicators is, on the one hand, to give pieces of information about the satisfaction of the objectives and on the other hand to link the current measures to the improvement actions to launch [3–5]. In this sense, so-called performance measurement systems (PMS's) are the instruments to support decision-making [4,6–10].

From a global point of view, a PMS can be seen as a multi-criteria instrument, made of a set of performance expressions (also referred to as metrics by some authors [11]), *i.e.* physical measures as well as performance evaluations, to be consistently organized with respect to the objectives of the company [12,13]. A PMS is defined w.r.t. a global objective and at the end, provides one or a set of performance expressions in order to quantify the satisfaction of this objective. Generally, the considered global objective is broken down into elementary ones along organizational levels (strategic, tactical or operational) [14] while the elementary performance expressions associated to the broken-down objectives can be aggregated, providing information about the global satisfaction. This break-down/aggregation model can be a support for decision-making. Indeed, there are limits to the decision-maker's ability to process large sets of performance expressions. So, a more synthesized piece of information completes the numerous considered scorecards, leading thus to a global vision of the involved processes. More particularly, the established links between overall and elementary performance expressions allow explanation and diagnosis of the objective's satisfactions according to the different reached performances, leading thus to

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doi:10.1016/j.compind.2007.05.012

choose or launch improvement actions [15]. More precisely, it is well known that one challenge of control is to identify ''coalitions'' of improvement between different areas in as efficient as possible a way.

One major problem in the design of such PMS, *i.e.* through a break-down/aggregation model concerns two points:

- the identification of the performance structure, *i.e.* on the one hand, the elementary criteria which contribute to the global objective and, on the other hand, the coherent expression of the performances which reflects the objective's satisfactions according to the different criteria,
- the identification of the links between the elementary expressions and the overall one in order to express the global objective's satisfaction.

The performance structure is widely considered in the literature. Indeed, most of the PMS proposals are logical frameworks for linking strategic objectives, structuring the tactical and operational criteria affecting them. For instance, the system measurement analysis and reporting technique (SMART) model proposes to break down the objectives of the company along four levels – company, business units, business operating units and departments and work centers – according to ten measures such as delay, quality, customer satisfaction... [16]. The activity based costing/activity based modelling (ABC/ABM) model identifies the activities and processes which generate value in the company [17]. The balanced scorecard (BSC) defines four axes (criteria) – processes, organisational learning, financial and customers – in order to express company performance [10,18]. In the same way, the process performance measurement system (PPMS) proposes to measure the company performance according to five aspects—financial, innovation, customer, societal and employee [19]. The ECOGRAI approach identifies three criteria – delay, quality and cost – for the definition of multi-criteria performance, and this for all the processes/activities of the company. Note that all these models generally remain flexible, *i.e.* the considered criteria can evolve according to the needs of the company. Besides, the performance expressions are usually provided from the comparison of the assigned objectives and the measures which describe the considered processes or activities' enactment. These measures generally come from physical sensors or human operators. In this sense, performance expressions can be precise or imprecise, certain or uncertain, and even expressed by numerical or linguistic values [12,20]. Nevertheless, according to Taylorian local control, performances can be simply expressed by physical measures or by productivity ratios.

The link identification problem is handled with respect to the aggregation of the elementary performance expressions. The performance aggregation is often defined as the corollary step of the objective break-down. The aggregation deals with the combination of all the performance expressions associated. In this sense, two types of approach are distinguished, the mono-criterion PMS and the multi-criteria PMS. In the mono-criterion system, the condition for the aggregation is that all the performance expressions must be expressed according to a common reference which is often the cost or the delay [21,22]. In this case, the overall performance results from the addition of elementary costs or durations. This mono-criterion PMS approach was quite natural in the Taylorian organizations where aggregation models were not useful for control decision-making, performances being conventionally used for a local control, but it is no longer adapted to the current context. Many authors have thus underlined the necessity to express a performance from multi-criteria expressions [7,10,23]. The condition of a coherent aggregation in this case is the commensurability (*i.e.* a kind of homogeneity as we will see later) of the elementary expressions.

More precisely, in order to quantify the objective break-down and the performance aggregation steps, information processing analytical methods have been implemented in a few existing PMS's. For instance, the performance criteria system (PCS) [8] identifies first the critical criteria for customers. Elementary performances are then expressed as well as the associated weights. These weights quantify the hierarchical links of the elementary expressions, *i.e.* their respective contributions to the overall performance. A qualitative pair-wise matrix is used in this sense. The overall performance expression results from the aggregation, by the weighted arithmetic mean (WAM) operator, of the involved elementary performances. The ECOGRAI method makes a mono-criterion aggregation, according to three criteria, delay cost, and quality. An overall performance is associated to each process of the company. Specific aggregation operators are used, – min, max, sum – with respect to both the involved criterion and the combination type of the activities – or, and, sequence – in processes [24]. In the quantitative model performance measurement system (QMPMS) [25], the elementary performances are identified thanks to a cognitive map. The WAM operator is used to aggregate them. However, a corrective factor is integrated to take the so-called impact between criteria into account. The quantification of the weights is based, in QMPMS, on the analytic hierarchy process (AHP) methodology [26].

From a formal point of view, AHP not only allows the quantification of the weights but also the performance elementary expression. Indeed, ratio scales[1] are built from human expertise requiring the determination of an ''absolute'' null performance. This point is a difficult task in an industrial context where the performance is particularly relative. In the same way, according to the measurement theory [27], the multi attractiveness categorical based evaluation technique (MACBETH) methodology [13,15,28,29] has been used to coherently express both the elementary and aggregated performance expressions. Ensuring the coherence requirement implies that:

- the elementary expressions must be «commensurate», *i.e.* two identical values (e.g. 0.8) according to two different criteria (e.g. *lead_time* and *quality*) must have the same meaning for the decision-makers,

[1] For the sake of conciseness, the scale aspect is not developed in this article. It is possible to find more information about ordinal, interval, ratio scales in [28,33] http://www.math.sfu.ca/~cschwarz/Stat-301/Handouts/node5.html.