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Performance measurement of lean supply chain management: a balanced scorecard proposal

The purpose of this paper is to propose a performance measurement framework to evaluate Lean Supply Chain Management (LSCM) performance. A literature review was performed to identify the main goals and performance indicators in LSCM. A questionnaire was designed that included the identified goals and measures. Next, based on data collected from international academics and practitioners with expertise in LSCM, a two-stage Delphi study using Fuzzy Delphi and Fuzzy DEMATEL methods was carried out to refine the most relevant goals and metrics and their interrelationships and establish benchmark values that are useful for managers to evaluate the performance achieved through the deployment of lean principles, practices, and techniques throughout the supply chain. Finally, an integrated performance measurement framework based on the balanced scorecard approach is proposed with a discussion of the academic and practical implications of the proposed framework.

Keywords: lean supply chain management; balanced scorecard; performance measurement; fuzzy Delphi

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1. Introduction

Lean management (LM) has been adopted by many firms in different sectors in recent decades with the expectation of improving their competitiveness (Moyano-Fuentes and Sacristán-Díaz 2012; Lyons et al. 2013; Abreu-Ledón et al. 2018; Schonberger 2020; H. Nielsen, Kristensen, and Grasso 2021). The extension of LM to all the processes in the focal firm and across suppliers and customers to eliminate waste and inefficiencies is known as Lean Supply Chain Management (LSCM) (Lamming 1996; Womack and Jones 1996; Swenseth and Olson 2016). Thus, supply chain members must implement LM principles, practices, and techniques to achieve lean goals at the supply chain level (Danese, Romano, and Bortolotti 2012; Bortolotti et al. 2016). Past empirical evidence has shown that LSCM significantly improves performance (Tortorella, Miorando, and Marodin 2017; Moyano-Fuentes et al. 2021).

Some recent studies in the LSCM literature have shown the relevance of performance assessment and this has become a key aspect of LSCM (Garcia-Buendia et al. 2021; Garcia-Buendia, Moyano-Fuentes, and Maqueira-Marín 2021). Performance assessment is important for measuring the success of lean implementation. In this context, Bellisario and Pavlov (2018) have highlighted the lack of a systematic understanding at the intersection of lean and performance management. Particularly, the absence of a clear understanding of lean performance assessment and the nonavailability of appropriate performance measures have led to conflicting results from lean implementation (Sangwa and Sangwan 2018). Similarly, the use of inappropriate monitoring and control systems for these results can lead companies to question whether the transformation to LSCM is worthwhile, with the consequent lack of motivation for the transformation process and its failure.

Recent studies have argued that a suitable performance measurement system can

have a great impact on the adoption and implementation of lean practices (Zanon, Ulhoa, and Esposto 2021; Akmal et al. 2020). So, the use of a structured performance measurement design process has been found to overcome many of the implementation problems highlighted in the literature, such as the strategy and vision being unfeasible and poorly defined measures (Bourne et al. 2002).

Similar approaches to lean measurement have been presented in the literature, e.g., in lean accounting (Maskell, Baggaley, and Grasso 2011). The lean transition requires the transformation of the accounting information systems to support the implementation process (Kennedy and Brewer 2006), so the integration of lean strategy and management accounting is important (Fullerton, Kennedy, and Widener 2014). In particular, the use of complementary management control mechanisms has been found to affect performance (H. Nielsen, Kristensen, and Grasso 2018). Moreover, Nielsen, Kristensen, and Grasso (2021) showed that the integration of lean and management accounting practices into a system enables organizations to improve their performance. Based on this, the enabling use of key performance indicators (KPIs) may enhance performance (Kristensen and Saabye 2021).

The importance of these types of management control practices for controlling the input, process, and output aspects of the lean implementation strategy has been highlighted by Netland et al. (2015). However, the concept of control can differ from traditional accounting-based control systems and be closer to lean management, creating tensions and frustrating the transformation process (Tillema and Van der Steen 2015). It is, therefore, important to appropriately define not only the performance measures to evaluate lean performance, but also the benchmark value to monitor and control when there are improvements to the obtained results.

Furthermore, performance evaluation should consider not only the obtained

results but also the organization's goals and the alignment of performance management and strategic goals (Melnyk et al. 2014; Kennedy and Brewer 2005). According to Magretta and Stone (2002), performance measurement and management enable the organization's strategy to materialize and be meaningful. The misalignment of goals and measures can lead to what the firm wants to achieve at the strategic level and what the firm measures being out of sync, which affects its ability to compete (Melnyk et al. 2014).

Therefore, the firm's strategy needs to be turned into performance targets (Seleem, Attia, and El-Assal 2016). The significance of connecting the strategic goals with the operational level was previously pointed out by Nielsen and Nielsen (2012). In this regard, the balanced scorecard (BSC) gathers all of an organization's strategic goals into a single and balanced framework (Kaplan and Norton 2006), converting business strategies into both goals and measures.

Kaplan and Norton (1992) proposed the balanced scorecard to evaluate corporate performance from four different perspectives that include the areas where managers should ensure that the business vision and strategies are consistent with each other: financial, customer, business process, and learning and growth. Brewer and Speh (2000) adapted the BSC to the sphere of the supply chain. Bhagwat and Sharma (2007) suggested that a balanced supply chain management (SCM) scorecard could be the basis for a strategic SCM system since particular development guidelines are properly followed, relevant metrics are evaluated, and key implementation obstacles are overcome.

Previous proposals have focused on an SCM strategy or a lean approach from a general point of view and in combination with other strategies, but not enough attention has been paid to the particularities of the implementation of lean along the supply chain and its evaluation with the BSC. In particular, Agarwal et al. (2006) proposed a framework based on the ANP (Analytic Network Process) approach to evaluate lean and

agile supply chains, while Carvalho et al. (2011) developed a conceptual model with lean, agile, resilient, and green practices and supply chain attributes to evaluate their effects on SC performance. Some works have proposed methods for assessing lean and green supply chain performance (Kainuma and Tawara 2006; Duarte and Cruz-Machado 2015; Thanki and Thakkar 2018).

However, as can be observed, the proposed frameworks are broader and are not oriented toward assessing the outcomes of LSCM alone, so it is essential to develop a system that allows the results achieved with LSCM to be evaluated concretely and gives managers the control required to achieve the expected benefits from the deployment of LM principles, practices, and techniques by the SC members to achieve lean goals at the SC level. Previous research has already emphasized the need for a more exhaustive and holistic focus on the practically unexamined relationships between management control and performance measurement and the formulation and implementation of the LM strategy (Bellisario and Pavlov 2018).

While LM adoption throughout the SC pursues improvements to the performance of the entire supply chain including suppliers and customers, only one specific organization assesses the outcomes, i.e., the focal firm. The focal firm commands a more comprehensive view of what is going on in the entire supply chain, both upstream and downstream. The purpose of this paper is to identify the most relevant LSCM goals and performance measures and to propose a performance measurement framework that aligns the two dimensions of an organization's strategy in a BSC to evaluate LSCM performance. Specifically, this research study investigates the following questions:

RQ1. What are the most relevant goals and performance indicators to assess LSCM performance?

RQ2. How do these performance measures influence the achievement of the goals

pursued by LSCM implementation?

RQ3. What should the objective benchmark value be against which the expected results and the real results achieved with LSCM should be compared?

This study is organized as follows. This section contextualizes and introduces the research gap, questions, and motivation for the present paper. Section 2 explains the methodology, which consists of three stages: literature review, questionnaire design and pretest, and a two-stage Delphi study using the fuzzy Delphi and fuzzy DEMATEL techniques. The main results of the study are presented in Section 3 following the structure of the abovementioned research questions, while Section 4 discusses the main findings of our work. Section 5 summarizes the paper and offers some conclusions.

2. Research design

The research method adopted to answer the research questions was inspired by the proposal by Okoli and Pawlowski (2004). First, the LSCM goals and key performance indicators were identified through a literature review. Then, a questionnaire that included the identified goals and measures was designed by the authors and a pretest was carried out to ensure that the selected elements were relevant and that the information was clearly susceptible to being further analyzed. The third step involved quantitatively testing the identified goals and indicators using a Delphi study (Okoli and Pawlowski 2004) to verify whether these were indeed relevant. This test determined the performance indicators that most contributed to achieving each of the goals and the degree to which the objectives were being met, and identified the objective benchmark values against which to compare the expected results and the real results achieved with LSCM. We used the fuzzy Delphi and the fuzzy DEMATEL approaches to make the analyses more objective. The fuzzy logic theory (Zadeh 1965) was considered to be appropriate since it addresses any lack of

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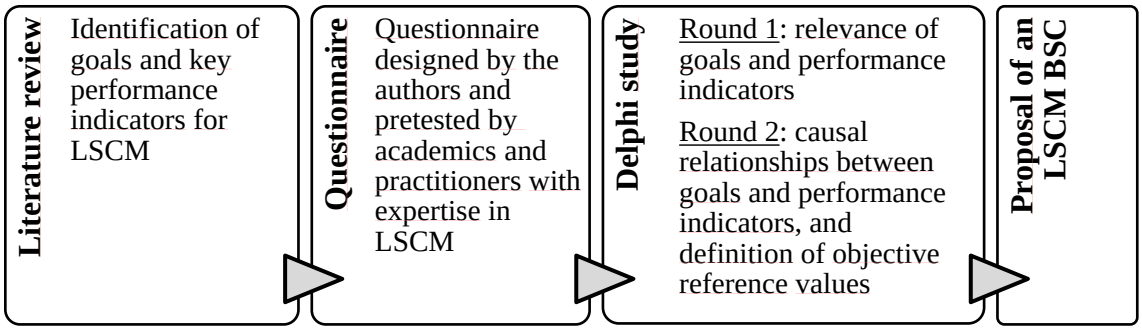
precision and incorporates the uncertainty of human decision-making behavior, thus reducing the gap between theory and reality (Caiado et al. 2021). The fuzzy Delphi method combines fuzzy set theory and the traditional Delphi technique to improve the proficiency of expert judgment, while the fuzzy DEMATEL method was used to convert the cause-effect relationships into an intelligible structural model and identify the most important elements (performance indicators) that affect other elements (goals). This provided greater objectiveness, reliability, and solid directions for the last step: to offer practical recommendations through the proposal of a balanced LSCM scorecard. Figure 1 describes the steps followed. The research phases are explained further below.

Figure 1. Procedure followed in this study



2.1. Literature review

A literature review was performed in Phase 1 to identify the main goals and performance indicators in LSCM assessment. The Web of Science Core Collection database (including Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI), and Emerging Sources Citation Index (ESCI)) was chosen for the literature review since previous research has shown its quality and rigor in terms of scientific results. The advanced search string was designed to include terms referring to LSCM, i.e., "TS=(lean NEAR/5 "supply chain*")". The "topic" field was used to include the title, abstract, keywords, and keywords plus for each document. The initial search returned 498

documents. As inclusion and exclusion criteria to filter the raw data and ensure relevant results for the topic, only articles in English published from 1996 were considered. Earlier works on this topic have determined that these criteria are suitable for the area under study (Núñez-Merino et al. 2020; Garcia-Buendia, Moyano-Fuentes, and Maqueira-Marín 2021). This refinement reduced the sample to 329 papers, which were read and analyzed to identify and select the performance indicators used to evaluate the LSCM outcomes.

A deeper study of the resulting literature revealed that 85 papers specifically dealt with performance measures for the outcomes of LSCM implementation. Note that in this study, a distinction is made between the measurement of LSCM implementation and the performance assessment resulting from its implementation; here, we focus on the latter. Papers were discarded that addressed performance from a broad perspective without specifying the measures used, i.e., general concepts such as "organizational performance", "firm performance", and "business performance". Attention was paid to any useful information that could contribute to the proposal of a balanced scorecard with practical implications.

In terms of elements that could be used in this work, the initial review returned approx. 350 performance measures from the 85 papers on the topic. The research team analyzed the raw data, removed any duplicate indicators, and selected the most-used indicators. Goal selection was based on the reading and deduction of the LSCM conceptions and approaches used in these studies. Twelve goals and twenty-nine performance indicators were selected to be included in the first draft of the questionnaire.

The literature review also identified the researchers actively studying this topic, scholars that have made key contributions to the field, and representatives from firms that are acknowledged expert practitioners in LSCM.

2.2. Questionnaire design and pretest

Phase 2 involved the design and pretest of the survey used in the Delphi study. The questionnaire was structured into different sections to classify and clarify the information included in the study for participants. First, demographic data were collected regarding the academic and professional backgrounds of the interviewees, such as job title, years in their current position, and years involved with LM in the supply chain. The definition of a lean supply chain (Vitasek, Manrodt, and Abbott 2005) was given to ensure that participants would fully understand the context in which to interpret the questions and elements. Goals and performance indicators were presented separately and classified into the four dimensions of the balanced scorecard, i.e., financial, customer, business process, and learning and growth perspectives. Definitions of all the indicators were also included so that the provided information would be as clear and unambiguous as possible.

A thorough pretest of the initial list of elements was carried out. Two academics and two practitioners with experience in LSCM examined the list of elements and definitions provided by the research team and analyzed the structure and content of the first draft. Different proposals were suggested, including the removal of some elements, the addition of some other relevant indicators, and the modification of various concepts and definitions. Suggestions and feedback were then discussed by the research team to reach a consensus and make the final decision. As a result, the number of performance indicators was increased to thirty-five.

Regarding the section dealing with the causal relationships between performance measures and goals, a matrix was designed that included these elements for the experts to rate each performance indicator's influence on achieving the LSCM goals. Finally, participants were asked to determine whether the suggested performance indicators used

to assess LSCM performance should be compared to targets set by the firm, values from the previous year, results achieved by the competition, or some other kind of benchmark.

2.3. Delphi study

In Phase 3, a two-round Delphi study was carried out that brought together experienced Danish and Spanish LSCM practitioners and leading international researchers in lean and supply chain management. The participant profile clearly stated that the unit of analysis was the focal firm's perspective of the entire supply chain. This work combines two different groups of experts – scholars and managers – in the study to identify, prioritize, and link the goals and performance indicators to evaluate the results of LSCM. Experts were also asked to suggest the most appropriate benchmark values that the results achieved with LSCM and the initially planned targets should be compared to. Since the BSC is to be derived logically and not entirely empirically (Acuña-Carvajal et al. 2019; Nørreklit 2000), we build on the empirical and logical expertise of practitioners and academics, which is based on observing, implementing, and logically deducing what the balanced scorecard should be.

The procedure for selecting experts was based on the Okoli and Pawlowski (2004) guidelines following Delbecq et al. (1975), as a rigorous method to ensure the identification of relevant experts who have a deep understanding of the issues under study. A Delphi study does not seek to be representative of any one population but to construct a group decision mechanism with qualified experts (Okoli and Pawlowski 2004).

Experts were divided into panels (Okoli and Pawlowski 2004; Melnyk et al. 2009). Their size and make-up were defined according to the research questions. In this case, two relevant categories of experts were considered to possess the most accurate and

valuable knowledge on LSCM: academics and practitioners. The study's two-panel design enabled the different groups' perspectives to be compared. To identify suitable relevant experts who would commit to taking part in the study, the research team defined a variety of approaches that considered the scientific literature, organizations, and professional roles. Initially, some personal contacts of the research team who matched the criteria were considered, although additional qualified experts were also contacted to prevent any bias.

The list of academics was populated by reviewing the LSCM and performance literature. The list of practitioners included mostly personal contacts of the research team with a long track record in LM and SCM. Experts were prioritized for an invitation to take part in the study based on their qualifications, academic production and impact, and professional experience. Following the recommendations in the Delphi literature, the target panel size was 15 participants for a final selection of at least 10 people (Okoli and Pawlowski 2004).

The research team had to invite 34 academics to take part in the study before enough confirmations were received to reach the proposed total of 15. All the 15 managers who were contacted accepted the invitation to take part. Invitations were sent via email accompanied by an explanation of the study topic, the procedure to be followed, and the required commitment to completing the study.

In round 1, participants were asked to evaluate the relevance of the proposed goals and LSCM assessment performance indicators on a 5-point Likert scale from 1 "low relevance" to 5 "extremely relevant". Blank spaces were left in the questionnaire for respondents to add comments, suggestions, or proposals. In round 2, respondents were asked to rate the influence of each key performance indicator using the linguistic scales

of VL, L, M, H, and VH, which represented "very low influence", "low influence", "moderate influence", "high influence", and "very high influence", respectively.

Round 1 of the Delphi study was completed by 12 academics from Australia, Brazil, Denmark, Italy, the Netherlands, Spain, Sweden, Switzerland, and the USA with an average of 20 years of experience in LSCM. Thirteen practitioners from different sectors such as aerospace, automotive, consulting, manufacturing, and retail and with an average of 13 years of experience replied to the first round. Delphi round 2 was responded to by 10 academics and 12 practitioners. Table 1 shows the composition of each panel during the two phases of the Delphi study.

Table 1. Composition of the Delphi panels

Delphi stage	**Panel**		**Total**
	Academics	*Practitioners*	
Accepted invitation	15	15	30
Round 1	12	13	25
Round 2	10	12	22

2.3.1. Fuzzy Delphi

The fuzzy Delphi method was used to process information from round 1 of the study. The integration of the fuzzy set theory and the traditional Delphi method was proposed by Ishikawa et al. (1993) as a way to improve the proficiency of expert judgments. This combination has previously been used in the recent operations management literature, e.g., to identify key performance factors in sustainability developments (Hsu, Chang, and Luo 2017; A.-Y. Chang and Cheng 2019), to evaluate sustainable service SCM performance under uncertainty (Tseng, Lim, et al. 2018), and sustainable tourism relationships (Tseng, Wu, et al. 2018), to help decision-making through eco-innovation (Lee, Wu, and Tseng 2018), to improve supplier selection based on corporate social responsibility (Kannan Govindan, Shankar, and Kannan 2018), to propose an assessment tool for integrated solid waste management (Tsai et al. 2020), and to identify risk in the adoption of green SC initiatives in the pharmaceutical industry (A. Kumar et al. 2019).

Some of the advantages attributed to this method are: only a small number of samples is needed to achieve objective and reasonable results, reductions in survey times, and reductions in the cost of obtaining expert opinions. Another reason why this method has been used in this study is that it offers a more objective way for participants to reach a consensus. A brief stepwise process of the fuzzy Delphi method (Ishikawa et al. 1993) is given below.

Linguistic terms were converted into their corresponding triangular fuzzy numbers based on Zadeh's (1965) membership function concept. In the Zadeh concept, the significant value of element *b* is evaluated by respondent *a* as $j = (x_{ab}; y_{ab}; z_{ab})$, $a = 1, 2, 3, \ldots, n$, and $b = 1, 2, 3, \ldots, m$. So, the weight j_b of element *b* is calculated as $j_b = (x_b; y_b; z_b)$, where $x_b = min(x_{ab})$, $y_b = (\prod_1^n y_{ab})^{1/n}$, and $z_b = max(z_{ab})$.

The triangular fuzzy numbers were thus converted from the original terms, as shown in Table 2.

Table 2. Corresponding triangular fuzzy numbers for relevance scale

Scale	Linguistic terms	Triangular Fuzzy Numbers (TFNs)
1	Low relevance	(0, 0, 0.25)
2	Moderate relevance	(0, 0.25, 0.5)
3	Relevant	(0.25, 0.5, 0.75)
4	Very relevant	(0.5, 0.75, 1)
5	Extremely relevant	(0.75, 1, 1)

A convex combination value D_b is generated by an α cut approach:

$$u_b = z_b - \alpha(z_b - y_b), \qquad l_b = x_b - \alpha(y_b - x_b); b = 1, 2, 3, \ldots, m. \tag{1}$$

where the α value can range from 0 to 1 based on the optimistic or pessimistic perception of respondents. The value of $\alpha = 0.05$ represents the intermediate condition.

The exact value of D_b can be generated as follows:

$$D_b = \int (u_b, l_b) = \lambda[u_b + (1 - \lambda)l_b] \tag{2}$$

where λ represents the degree of optimism for a decision-maker and is used to balance radical judgments from the group of experts.

Finally, $\delta=\sum_{a=1}^{n}(D_b/n)$ is the threshold for screening the most relevant elements. If Db ≥ δ, the element is accepted. Otherwise, it should be rejected.

2.3.2. Fuzzy DEMATEL

The fuzzy DEMATEL method was used to process information from round 2 of the Delphi study. The original DEMATEL method has traditionally been used to convert the relationships between cause and effect factors into an intelligible system structural model to enable a reduction in the number of factor effectiveness evaluation criteria (B. Chang, Chang, and Wu 2011). As this method identifies the most important elements that affect other elements, it would seem suitable to evaluate the influence of diverse key performance indicators on the main goals of LSCM. However, the difficulty involved in making decisions to segment complex factors in fuzzy environments has prompted the use of the so-called fuzzy DEMATEL method. Recent research on operations management has used fuzzy DEMATEL due to its benefits (Mangla et al. 2018; A. Kumar et al. 2021; Nasrollahi et al. 2021).

The fuzzy DEMATEL method transforms qualitative information into fuzzy linguistic data through the defuzzification technique (Tsai et al. 2020). This work presents a variant of the fuzzy DEMATEL method to evaluate the influence of the various LSCM performance indicators on the main LSCM goals. The present study focuses on the cause-effect directions of the KPI-goal relationships.

The fuzzy DEMATEL method was used to process and analyze the data collected from the experts. The procedure was based on and adapted from the steps proposed by the previous literature on operations management (B. Chang, Chang, and Wu 2011; Mangla et al. 2018; Lee, Wu, and Tseng 2018; Tsai et al. 2020). Thus, assuming that *K*

experts took part in the evaluation process, F_{ij}^k indicates the fuzzy weight of the i^{th} performance indicator's effect on the j^{th} goal assessed by the k^{th} expert. As mentioned above, respondents were asked to rate the influence of each of the key performance indicators on every goal. Table 3 shows the round 2 linguistic scale and the corresponding triangular fuzzy numbers. The proposed fuzzy DEMATEL procedure calculations are given below:

Step 1. Normalize the fuzzy numbers:

$$F_{ij}^k = \left(f_{l_{ij}}^k,\ f_{m_{ij}}^k,\ f_{r_{ij}}^k\right) = \left[\frac{l_{ij}^k - \min_j\left(l_{ij}^k\right)}{\Delta}, \frac{m_{ij}^k - \min_j\left(m_{ij}^k\right)}{\Delta}, \frac{r_{ij}^k - \min_j\left(r_{ij}^k\right)}{\Delta}\right] \quad (3)$$

where

$$\Delta = \max_j\left(r_{ij}^k\right) - \min_{ij}\left(l_{ij}^k, m_{ij}^k, r_{ij}^k\right) \quad (4)$$

Step 2. Compute the right (*rv*) and left (*lv*) normalized values:

$$\left(lv_{ij}^k, rv_{ij}^k\right) = \left[\frac{f_{m_{ij}}^k}{1 + f_{m_{ij}}^k - f_{l_{ij}}^k}, \frac{f_{r_{ij}}^k}{1 + f_{r_{ij}}^k - f_{m_{ij}}^k}\right] \quad (5)$$

Step 3. Compute the normalized crisp values (*x*):

$$x_{ij}^k = \frac{\left[lv_{ij}^k\left(1 - lv_{ij}^k\right) + \left(rv_{ij}^k\right)^2\right]}{\left(1 - lv_{ij}^k + rv_{ij}^k\right)} \quad (6)$$

Step 4. Integrate the crisp values ($\tilde{x}$):

$$\tilde{x}_{ij} = \frac{x_{ij}^1 + x_{ij}^2 + \cdots + x_{ij}^K}{K} \quad (7)$$

Step 5. Arrange the generalized direct relation matrix (*G*):

$$G = \left[\tilde{x}_{ij}\right]_{I \times J} \quad (8)$$

Step 6. Compute the normalized total direct relation matrix (*T*):

$$T = \tau \otimes G \quad (9)$$

where

$$\tau = \frac{1}{max\left(\sum_{i=1}^{I} \tilde{x}_{ij}\right)} \quad (10)$$

Table 3. The fuzzy linguistic scale

Scale	Linguistic terms	Triangular Fuzzy Numbers (TFNs)
VL	Very low influence	(0, 0.1, 0.3)
L	Low influence	(0.1, 0.3, 0.5)
M	Moderate influence	(0.3, 0.5, 0.7)
H	High influence	(0.5, 0.7, 0.9)
VH	Very high influence	(0.7, 0.9, 1)

3. Results

This section reports the results of the study analysis, presents and discusses the main findings, and proposes a performance measurement framework to evaluate LSCM performance.

3.1. Most relevant goals and performance indicators

Regarding RQ1, the research team analyzed the raw data from the literature review, removed any duplicate indicators, and identified the most-used indicators. Twelve goals and twenty-nine performance indicators were selected to be included in the first draft of the questionnaire and classified into the four perspectives of the balanced scorecard assessed in the first round of the Delphi study. Appendix A reports the main goals identified in the literature regarding the implementation of LM along the SC and the most commonly used performance indicators in the literature and their sources.

The discussion of the suggestions and feedback from the pretest study retained the twelve goals identified in the literature and determined thirty-five performance indicators (two indicators identified in the literature were removed and eight measures suggested by the experts in the pretest were included). Table 4 shows the definitive list of measures to be embedded in the first questionnaire of the Delphi study.

Table 4. List of performance indicators for an LSCM balanced scorecard

BSC perspective	Goal	Performance indicator
Financial	Revenue growth Return on assets Cost reduction	profitability return on investment (ROI) return on sales (ROS) return on assets (ROA) *cash conversion cycle* market share
Customer	Customer satisfaction Delivery efficiency Customer value	on-time delivery delivery service *rate* lead time customer rejection rate customer satisfaction *rate* responsiveness to customer demands *joint product development with customers* *joint problem solving with customers* *certified customer relationship*
Business process	Waste reduction Supplier relationships Process optimization	inventory turnover ratio productivity defect rate *average cost per unit* total product cycle time capacity utilization rate first time through joint problem solving *with suppliers* supplier delivery reliability supplier rejection rate joint product development *with suppliers* *supplier lead time* *certified suppliers* *degree of supply base consolidation* product development cycle time
Learning and growth	Product/process innovation Information flow Human capital management	*accident frequency rate* *employee training rate* absenteeism rate *employee turnover* employee engagement

Note: Elements in *italics* indicate additions, modifications, and suggestions based on the pretest.

Once the participants had responded to the first round of the questionnaire and rated the relevance of the various elements for LSCM performance evaluation, their responses were processed and analyzed to interpret the existing consensus. The fuzzy Delphi method was applied to refine the most relevant elements using Equations (1) and (2), with a threshold (i.e., δ) of 0.848 (see Appendix B). Table 5 shows the eight goals and sixteen performance indicators accepted after the analysis and subsequently used in the second round evaluation.

Table 5. Results after applying the fuzzy Delphi method

BSC perspective	Goal		KPI	
Financial	GF3	Cost reduction	KF5	cash conversion cycle
Customer	GC1	Customer satisfaction	KC1	on-time delivery
	GC2	Delivery efficiency	KC2	delivery service rate
	GC3	Customer value	KC3	lead time
			KC4	customer rejection rate
			KC5	customer satisfaction rate
			KC6	responsiveness to customer demands
Business process	GB1	Waste reduction	KB1	inventory turnover ratio
	GB2	Supplier relationships	KB2	productivity
	GB3	Process optimization	KB3	defect rate
			KB7	first time through
			KB9	supplier delivery reliability
			KB10	supplier rejection rate
			KB12	supplier lead time
Learning and growth	GL2	Information flow	KL1	accident frequency rate
			KL5	employee engagement

The median, mean, and standard deviation of the values given to the different elements in round 1 of the questionnaire were analyzed by the two panels. As one of the main objectives of this work is to propose a balanced scorecard for the evaluation of LSCM performance, responses from academics and practitioners were assessed jointly. However, interesting insights can be drawn if the two expert groups' responses are analyzed separately. The mean value of the average scores given by the academic panel is 3.53, while it is 3.95 for the practitioner group, indicating that practitioners have rated the proposed elements higher than academics. The customer perspective has received the highest scores from both panels, indicating that the relevance of the proposed elements is quite high for LSCM performance (4.06 for academics and 4.28 for practitioners). The second most relevant BSC perspective for academia is business process (3.59), while for practitioners it is learning and growth (3.97). The financial perspective, however, is the least relevant dimension for both panels (2.97 for academics and 3.80 for practitioners).

3.2. Causal relationships between performance indicators and goals

Concerning RQ2, after identifying the most relevant elements for LSCM performance assessment, the causal relationships between the goals and the performance indicators were investigated in the second round of the Delphi study. A variant of the fuzzy DEMATEL method was used to evaluate the influence of the various LSCM performance indicators on the main LSCM goals with the focus on the cause-effect directions of the KPI-goal relationships.

The first step of the fuzzy DEMATEL analysis shapes the initial direct relation matrices I with the use of the data collected from the experts. Appendix C shows an example of the data collected from Respondent 1 in this study. Each respondent completed an initial direct relation matrix I similar to the example reported.

As previously mentioned, respondents were asked to rate the influence of each of the performance indicators using the linguistic scale of VL, L, M, H, and VH ("very low influence", "low influence", "moderate influence", "high influence", and "very high influence", respectively) (see Table 3). The design of the fuzzy linguistic variables converts the initial direct relation matrices I into triangular fuzzy numbers using Table 3 (see Appendix D (a)), with each linguistic variable replaced by its corresponding triangular fuzzy number. A defuzzification process is carried out using Equations (3) to (5) (see Appendix D (b – c)). The resulting crisp values generate the direct relation matrices D shown in Appendix D (d), using Equation (6).

The analysis computes the average value of the direct relation matrices D with Equation (7). Appendix E shows the generalized direct relation matrix G for goals and performance indicators.

The total direct relation matrix T is obtained with Equations (9) and (10) and is presented in Table 6, which shows the causal relationships between the performance indicators and goals.

Table 6. Total direct relation matrix T

	GF3	**GC1**	**GC2**	**GC3**	**GB1**	**GB2**	**GB3**	**GL2**
KF5	0.113	0.058	0.065	0.049	0.080	0.074	0.101	0.063
KC1	0.077	0.194	0.178	0.142	0.062	0.094	0.092	0.080
KC2	0.067	0.164	0.161	0.165	0.066	0.089	0.092	0.086
KC3	0.106	0.163	0.152	0.150	0.104	0.097	0.141	0.087
KC4	0.083	0.167	0.082	0.146	0.066	0.053	0.067	0.051
KC5	0.062	0.194	0.121	0.166	0.063	0.073	0.085	0.081
KC6	0.069	0.160	0.137	0.165	0.074	0.083	0.099	0.078
KB1	0.141	0.029	0.063	0.032	0.110	0.092	0.134	0.058
KB2	0.153	0.056	0.073	0.055	0.128	0.056	0.149	0.061
KB3	0.151	0.136	0.074	0.105	0.156	0.071	0.138	0.061
KB7	0.131	0.085	0.079	0.086	0.127	0.077	0.119	0.055
KB9	0.088	0.092	0.104	0.075	0.084	0.177	0.088	0.053
KB10	0.093	0.063	0.077	0.067	0.101	0.160	0.085	0.041
KB12	0.089	0.090	0.097	0.079	0.063	0.152	0.095	0.057
KL1	0.098	0.047	0.035	0.060	0.087	0.028	0.123	0.098
KL5	0.130	0.118	0.113	0.103	0.127	0.072	0.132	0.110

Note: cost reduction (GF3), customer satisfaction (GC1), delivery efficiency (GC2), customer value (GC3), waste reduction (GB1), supplier relationships (GB2), process optimization (GB3), information flow (GL2), cash conversion cycle (KF5), on-time delivery (KC1), delivery service rate (KC2), lead time (KC3), customer rejection rate (KC4), customer satisfaction rate (KC5), responsiveness to customer demands (KC6), inventory turnover ratio (KB1), productivity (KB2), defect rate (KB3), first time through (KB7), supplier delivery reliability (KB9), supplier rejection rate (KB10), supplier lead time (KB12), accident frequency rate (KL1), and employee engagement (KL5).

Table 6 reports the intensity of the relationships between the performance indicators and the goals based on the opinions of the experts. Higher values indicate stronger causal relationships. An additional percentile-based analysis of this influence has been carried out to make it easier to interpret and understand these results. Table 7 shows the most important relationships between the performance measures and goals. Percentiles 80 and 60 have been computed as thresholds representing strong and moderate influential relationships, resulting in 0.137 and 0.098, respectively. Values above 0.098 (percentile 60) are considered to represent a moderate influence from one performance indicator to a goal and values over 0.137 (percentile 80) to reveal strong influence

relationships. This analysis indicates the intensity of the performance indicators' influence on the goals. Percentile 80 has been estimated to faithfully show the strongest level of influence, while percentile 60 is considered a suitable approach to indicate noticeable but not considerable influence. Causal relationships below these thresholds have been considered to indicate insufficient relevance.

Table 7. Relevant relationships between key performance indicators and goals

Performance indicators / Goals		F	C			BP			L&G
		Cost reduction	Customer satisfaction	Delivery efficiency	Customer value	Waste reduction	Supplier relationships	Process optimization	Information flow
F	Cash conversion cycle								
C	On-time delivery								
	Delivery service rate								
	Lead time								
	Customer rejection rate								
	Customer satisfaction rate								
	Responsiveness to customer demands								
BP	Inventory turnover ratio								
	Productivity								
	Defect rate								
	First time through								
	Supplier delivery reliability								
	Supplier rejection rate								
	Supplier lead time								
L&G	Accident frequency rate								
	Employee engagement								
	Moderate influence (percentile 60)								
	Strong influence (percentile 80)								

Note: F (Financial perspective), C (Customer perspective), BP (Business process perspective), and L&G (Learning and growth perspective)

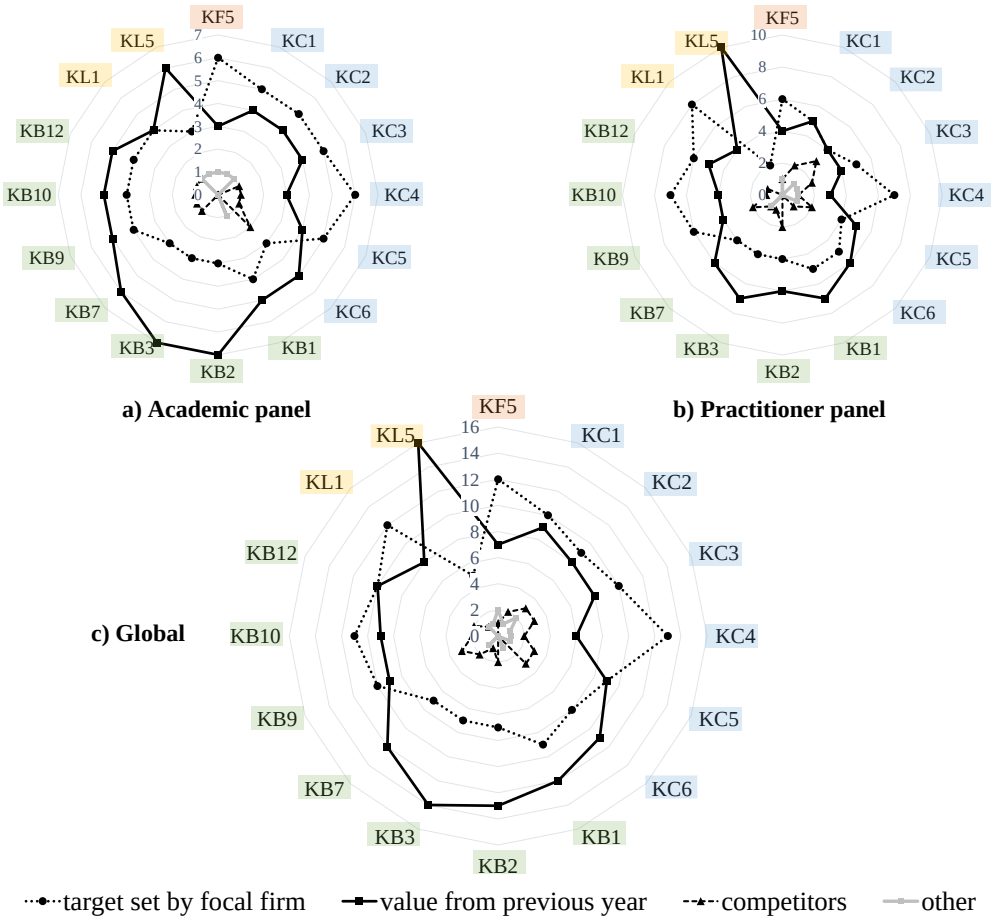
Research results show that business process performance indicators such as inventory turnover ratio, productivity, and defect rate should be used to measure the achievement of the cost reduction goal. Customer satisfaction, delivery efficiency, and customer value can be assessed by focusing on performance indicators such as on-time delivery, delivery service rate, lead time, customer rejection rate, customer satisfaction rate, and responsiveness to customer demands. Supplier-related performance indicators such as supplier delivery reliability, supplier rejection rate, and supplier lead time are closely connected to the supplier relationships goal but rather isolated from the other elements in this dimension. Lastly, cost reduction, customer satisfaction, delivery efficiency, customer value, waste reduction, process optimization, and information flow are somewhat related to worker commitment in LSCM.

Garcia-Buendia, N., Kristensen, T.B., Moyano-Fuentes, J. and Maqueira-Marín, J.M. (2022), "Performance measurement of lean supply chain management: a balanced scorecard proposal", *Production Planning & Control*, Vol. 35 No. 6, pp. 618–638, doi: https://doi.org/10.1080/09537287.2022.2114960. Accepted 16 Aug 2022.

3.3. Objective benchmark values for the performance indicators

To address RQ3, the indicators accepted in round 1 were also used in round 2 to identify the benchmark values against which the expected results and the real results achieved with LSCM should be compared. As mentioned above, participants were asked to determine whether the suggested performance indicators used to assess LSCM performance should be compared to targets established by the firm, values from the previous year, results obtained by the competition, or some other kind of benchmark. Figure 2 gives the results from this analysis for the two panels considered individually and globally.

Figure 2. Objective benchmark values



According to the expert panels, overall, values from the previous year should be used to assess business process measures such as inventory turnover ratio, productivity,

defect rate, and first time through. However, the firm could compare performance indicators such as supplier delivery reliability, supplier rejection rate, and supplier lead time with either historical or target data. Most of the customer perspective metrics are suitable for evaluation with targets or previous year data but a target is clearly preferred for customer rejection rate and a value from the previous year for responsiveness to customer demands. The cash conversion cycle financial performance indicator should be understood by the degree to which it meets a target set by the firm. Accident frequency rate and employee engagement, both from the learning and growth dimension, should be assessed using a target and a value from the previous year, respectively.

3.4. Proposal of a balanced LSCM scorecard

Based on the results of the Delphi study, a balanced LSCM scorecard has been constructed which includes the objectives, performance measures, and objective reference values that should be established for these performance measures for each of the perspectives. Figure 3a shows an overview of the proposed balanced LSCM scorecard based on the findings of the two-stage Delphi study. This figure encompasses the identified performance measures and goals in their respective BSC dimensions, including the type of objective references values assigned by the experts.

Figure 3a. Overview of proposed LSCM balanced scorecard

Garcia-Buendia, N., Kristensen, T.B., Moyano-Fuentes, J. and Maqueira-Marín, J.M. (2022), "Performance measurement of lean supply chain management: a balanced scorecard proposal", *Production Planning & Control*, Vol. 35 No. 6, pp. 618–638, doi: https://doi.org/10.1080/09537287.2022.2114960. Accepted 16 Aug 2022.

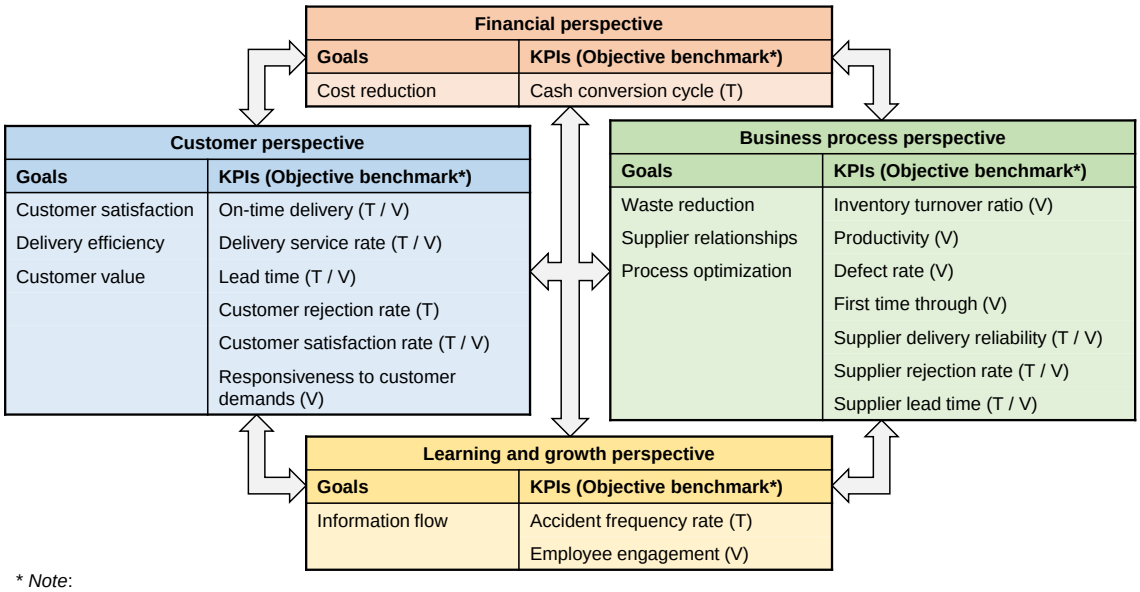


Figure 3b graphically reports the proposal in detail, which makes it possible to visualize the relationships between the strategically relevant aspects studied in the Delphi study, i.e., goals, performance measures, and objective benchmark values. Goals are represented by rectangles and performance indicators as ellipses. The strong influence of a performance indicator on a goal is represented by a continuous line, while moderate influence is indicated by a broken line.

According to our results, LSCM performance assessment must consider cost reduction as the firm's main financial goal (see Figure 3b, lower-left quadrant). Revenue growth and return on assets have been perceived as less important goals in LSCM evaluation, at least as far as the main targets to indicate LSCM performance are concerned. The cash conversion cycle is the most relevant indicator to assess LSCM performance from a financial point of view, whereas profitability, ROI, ROS, ROA, and market share are not relevant indicators. Regarding the causal relationships between goals and indicators, Figure 3b shows that the cost reduction objective should basically be assessed through inventory turnover ratio, productivity, and defect rate.

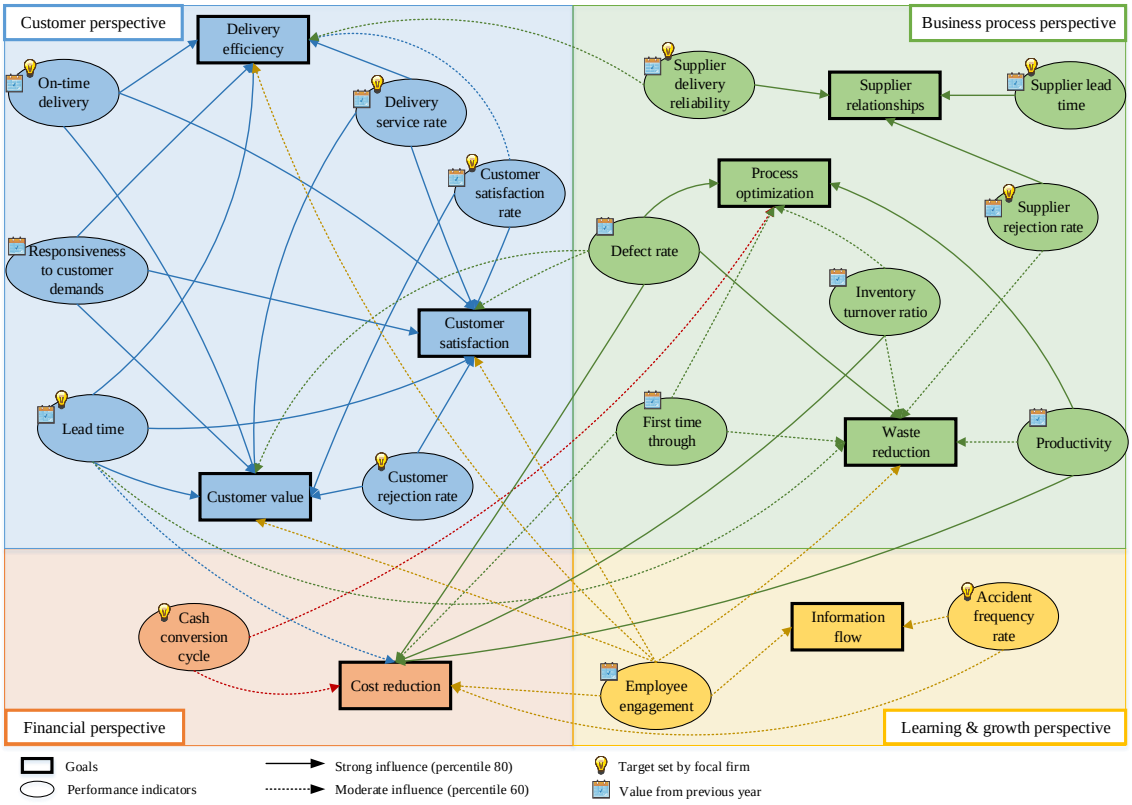
The customer dimension in LSCM performance evaluation is strongly marked by metrics related to quality and time (see Figure 3b, upper-left quadrant). On-time delivery, delivery service rate, lead time, responsiveness to customer demands, customer rejection rate, and customer satisfaction rate were the most relevant performance indicators selected to evaluate the results of LSCM. Elements based on a collaborative and cooperative relationship with customers, such as joint product development, joint problem solving, and certified quality and delivery relationships with customers have been considered to perform a nonessential role in the evaluation of LM along the supply chain. The most relevant LSCM goals in customer perspective are customer satisfaction, customer value, and delivery efficiency.

The business process perspective focuses on productivity, quality, waste reduction, and the focal firm's supplier relationships (see Figure 3b, upper-right quadrant). The three goals proposed in the questionnaire, i.e., waste reduction, supplier relationships, and process optimization have been confirmed to be genuinely relevant for LSCM. There is a consensus that inventory turnover ratio, productivity, defect rate, first time through, supplier delivery reliability, supplier rejection rate, and supplier lead time determine the most relevant performance indicators in LSCM assessment. These indicators are related to the internal process of the focal firm and also the business processes of the supply chain. In contrast, average cost per unit, total product cycle time, capacity utilization rate, joint problem solving with suppliers, joint product development with suppliers, certified suppliers for reliable quality and delivery, degree of supply base consolidation, and product development cycle time are considered to be less relevant.

Finally, the learning and growth perspective deals with information and human resources management issues (see Figure 3b, lower-right quadrant). This dimension includes information flow as the most relevant goal in LSCM, and accident frequency

rate and employee engagement as meaningful performance indicators in LSCM. Regarding the LSCM goals, product and process innovation and human capital management are considered less relevant. Similarly, performance indicators such as employee training rate, absenteeism rate, and employee turnover received lower scores.

Figure 3b. Relationships between performance indicators and goals in the proposed LSCM BSC



4. Discussion

Our contribution goes beyond previous works (Afonso and Cabrita 2015; García Buendía, Moyano Fuentes, and Maqueira Marín 2019) by using qualitative and quantitative approaches to propose a balanced scorecard focused on the extension of lean principles along the SCM. In line with Bhagwat and Sharma (2007), the proposed BSC could be used as a basis for strategic LSCM implementation through the development of courses of action that enable to focus on the key aspects and reference values that should be used for evaluation and to identify barriers that must be overcome.

The results obtained from the Delphi study underline the little importance given to financial elements in LSCM performance assessment compared to other perspectives of the BSC, which contrasts with some trends found in the literature where a more meaningful relevance has been given to the financial aspects of LSCM (Jajja et al. 2016; Qi et al. 2017; Thanki and Thakkar 2018; Novais, Maqueira Marín, and Moyano-Fuentes 2020). Indeed, some respondents did not find it easy to associate financial goals and indicators with LSCM performance assessment. This may indicate that the extension of LM along the supply chain is perceived to enable operational performance rather than financial outcomes, at least when assessed directly, as all things should lead to financial outcomes at some point in time. So, LSCM implementation might be triggered by the desire to achieve operational improvements in the supply chain, whereas financial aspects are considered to have only indirect importance. This perception could lead to weak commitment and support from top management for the decision to adopt and pursue the extension of LM across suppliers and customers. As the link between LSCM implementation and financial performance does not seem to be very relevant, the former runs the risk of appearing disconnected from essential strategic decisions in organizations.

Our results have emphasized the importance of the customer perspective, in line with the frequency trend identified in the literature (Soni and Kodali 2009; Duarte and Cruz-Machado 2015; Tortorella, Giglio, and Limon-Romero 2018; Ruiz-Benítez, López, and Real 2018). Many performance indicators contribute to the assessment of these goals, revealing that the customer dimension is strongly connected to the business process and learning and growth perspectives. Regarding the business process dimension, waste reduction is the initial main goal of LM, so its priority in the extension of LM along the supply chain is also a key aspect. Interestingly, research results indicate that performance

indicators related to the business process dimension should be used to measure cost reduction, which may indicate that the achievement of this financial goal in LSCM is closely related to waste and inefficiency reduction. Besides, supplier relationships must be a strategic objective when implementing LM along the supply chain given the influence that supplier behavior might have on focal firm activity. In fact, our examination of the causal relationships between goals and performance indicators reveals great cohesion among the supplier elements, suggesting that elements in the supplier sphere could be seen as an independent dimension in the balanced scorecard. It is essential to evaluate not only focal firm performance but also supplier performance along the supply chain (Ferreira, Silva, and Azevedo 2016).

Lastly, it should be noted that the learning and growth perspective of the BSC is possibly the least studied dimension in the LSCM and performance literature. Financial and operational measures are easy to find in previous works but issues related to the measurement of innovation and social aspects of the focal firm and the supply chain are less frequent, as already suggested in previous works (Garcia-Buendia, Moyano-Fuentes, and Maqueira-Marín 2021). This is reflected in the number of goals and performance indicators selected from the literature for the Delphi study and also in the scores provided by the experts (some respondents suggested goals related to environmental performance, reverse logistics, circular economy, and supply chain integration in this perspective). This suggests that the assessment of performance outcomes and the achievement of goals could be diminished given the inability to link measures and goals. Nevertheless, the role of the learning and growth performance indicator *employee engagement* is interesting as it has a considerable influence on the four BSC dimensions. This finding is in line with Bellisario and Pavlov (2018), who noted the ability of learning-oriented performance measurement practices to create connections across different levels of the organization.

Regarding the benchmark values for the identified performance indicators, the scarce research on target setting in a BSC context and the relevance of assigning targets to each performance indicator have been highlighted by the previous literature (Herath, Bremser, and Birnberg 2010). While there is only limited research on objective benchmark values in a BSC setting, there is none at all for an LSCM BSC. In practice, it can be challenging to reach a consensus on how to assign targets to each performance measure, so we used the Delphi study method to assist academics and practitioners in finding the best-proposed solution to this challenge.

According to the lean accounting literature, it is often beneficial to use trend curves to assess performance (Maskell, Baggaley, and Grasso 2011) as it is then easier to understand long-term trends and there is no need for a comparison with a new benchmark value every year. Comparing actual performance to a standard set by the organization also offers opportunities for assessment in the context of internal lean implementation (H. Nielsen, Kristensen, and Grasso 2021) and continuous improvements can also be measured (Monden and Lee 1993; Kristensen 2021). However, as Nielsen, Kristensen, and Grasso (2021) pointed out it is important not to get tunnel vision and fixate on only one type of benchmark in a lean context. In this sense, our findings have revealed that target data or firm historical data are preferred over the results of the competition as objective benchmarks for comparison with the achieved LSCM performance. Some respondents have added major improvements, sector average, customer requirements, and benchmarks as additional references to be considered in LSCM assessment. For some experts, the use of a single benchmark as a target set by the firm or the value from the previous year is not sufficient for a full understanding of LSCM performance.

5. Conclusions

This work has endeavored to address the lack of understanding at the intersection of lean and performance management at the supply chain level and sought to propose a performance measurement system that creates a supportive environment for lean implementation in the same context. Specifically, this paper proposes a balanced LSCM scorecard based on a consensus between experienced academics and practitioners from different sectors and countries in the field regarding the goals and performance indicators that should be used to assess the achievement of the objectives in the four BSC perspectives. This work also proposes the benchmark targets for the identified performance indicators for comparison with the expected results and the real results achieved with LSCM.

Our study has relevant managerial implications. It has identified organizational goals and a set of performance measures that can help managers to select and prioritize the best-suited performance indicators to achieve their firm's strategic goals. The connection between goals and performance indicators allows practitioners to assess the achievement of different goals through the measurement of specific KPIs. It will enable managers to monitor the LSCM implementation process, allow them to detect any significant deviations from the anticipated results, and thus, to make the right decisions at the right time to correct any deviations and achieve the expected results. The balanced scorecard would act as a monitoring and evaluation system that would allow the easy and timely detection of deviations from the values that have been established as a benchmark for LSCM implementation. This would help to achieve more robust and reliable LSCM implementation processes and so reinforce the usefulness of the lean supply chain strategy. Our paper also contributes to the evaluation of LSCM performance and its tangible impact on the firm's objectives. Future research should dig deeper into the

learning and growth dimension. This BSC perspective is extremely underdeveloped in this topic and so requires further attention. The previous literature has addressed issues related to the learning organization, yet how this progress can be effectively measured in the LSCM is still unknown.

As its main limitation, our study offers a theoretical proposal for a generalist BSC framework that needs to be empirically validated to enable its dissemination. The variety of geographic locations and professional sectors from which the study participants come is designed to enable the generalizability of the proposed framework. However, the following step should be to adapt and use this proposal in representative case studies in different industrial sectors. In addition, the framework for assessing the effects of the implementation of lean through the supply chain is conceived from the perspective of the focal company, which could make it difficult to apply in some supply chains where the focal company does not have an overview of the entire chain. However, this is a minor limitation, since the proposal is generally applicable to most supply chains where the focal company does have a broad view of the chain, as can be seen from the qualified opinions of the managers and academics interviewed.

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APPENDICES

Appendix A. Initial list of goals and performance measures identified in the literature for a LSCM balanced scorecard

Goal	**Reference**
Human resources management	(Iyer, Srivastava, and Srinivasan 2019; Tortorella, Giglio, and Limon-Romero 2018; Ruiz-Benítez, López, and Real 2018; Duarte and Cruz-Machado 2015; Piercy and Rich 2015; Kumar, Sharma, and Agarwal 2015; Lau and Wang 2013)
Revenue growth	(Novais, Maqueira Marín, and Moyano-Fuentes 2020; Thanki and Thakkar 2018; Qi et al. 2017; Adebanjo, Laosirihongthong, and Samaranayake 2016; Swenseth and Olson 2016; Duarte and Cruz-Machado 2015)
Waste reduction	(Moyano-Fuentes et al. 2021; Abideen and Mohamad 2019; Fadaki, Rahman, and Chan 2020; Fadaki, Rahman, and Chan 2019; Rossini and Portioli 2018; Ruiz-Benitez, López, and Real 2017)
Cost reduction	(Yildiz Çankaya 2020; Fadaki, Rahman, and Chan 2019; Ruiz-Benitez, López, and Real 2017; Marodin et al. 2017; Raghu Kumar, Agarwal, and Sharma 2016)
Product/process innovation	(Novais, Maqueira Marín, and Moyano-Fuentes 2020; Orji and Liu 2020; Shah and Naghi Ganji 2017; Raghu Kumar, Agarwal, and Sharma 2016; Kou and Lee 2015)
Process optimization	(Abideen and Mohamad 2019; Ruiz-Benítez, López, and Real 2018; Qi et al. 2017; Adebanjo, Laosirihongthong, and Samaranayake 2016)
Supplier relationships	(Yildiz Çankaya 2020; Ruiz-Benitez, López, and Real 2019; Tortorella, Giglio, and Limon-Romero 2018; Frazzon et al. 2017)
Delivery efficiency	(Moyano-Fuentes et al. 2021; Manville, Papadopoulos, and Garengo 2021; Paul et al. 2019; Gaudenzi and Christopher 2016)
Customer satisfaction	(Paul et al. 2019; Thanki and Thakkar 2018; Frazzon et al. 2017; Marodin et al. 2017; Duarte and Cruz-Machado 2015)
Information flow	(Ruiz-Benitez, López, and Real 2019; Rossini and Portioli 2018; Qi et al. 2017; Marodin et al. 2017)
Return on assets	(Thanki and Thakkar 2018; Jajja et al. 2016; Carvalho, Duarte, and Cruz Machado 2011)
Customer value	(Manville, Papadopoulos, and Garengo 2021; Lau and Wang 2013)
Performance measure	**Reference**
Lead time	(Tortorella, Giglio, and Limon-Romero 2018; Kazmane 2018; H. Chen, Liu, and Oderanti 2017; Adebanjo, Laosirihongthong, and Samaranayake 2016; Soni and Kodali 2009; Agarwal, Shankar, and Tiwari 2006; Borges et al. 2020; Kusrini and Parmasari 2020; Hongpiriyakul et al. 2013; Carvalho, Duarte, and Cruz Machado 2011; Ozelkan et al. 2007; M. Kumar, Garg, and Agarwal 2019; Fourie and Umeh 2017; Shah and Naghi Ganji 2017; Campos and Vazquez-Brust 2016; De Sousa Jabbour, Omodei, and Jabbour 2014; Bruce, Daly, and Towers 2004; Mason-Jones, Naylor, and Towill 2000)
Market share	(Qi et al. 2017; Adebanjo, Laosirihongthong, and Samaranayake 2016; Qrunfleh and Tarafdar 2013; Novais, Maqueira Marín, and Moyano-Fuentes 2020; Huo, Gu, and Wang 2019; Hussain, Al-Aomar, and Melhem 2019; Thanki and Thakkar 2018; Jajja et al. 2016; Kou and Lee 2015; Duarte and Cruz-Machado 2015; Qrunfleh and Tarafdar 2014; Agus and Hajinoor 2012; Qi, Zhao, and Sheu 2011; Qi, Boyer, and Zhao 2009)
Responsiveness to customer demands	(Yildiz Çankaya 2020; Gaudenzi and Christopher 2016; Arif-Uz-Zaman and Nazmul Ahsan 2014; Qrunfleh and Tarafdar 2013; Cabral, Grilo, and Cruz-Machado 2012; Soni and Kodali 2009; Vazquez-Martinez et al. 2018; R. B. R. Kumar, Sharma, and Agarwal 2015; Jajja et al. 2016; Duarte and Cruz-Machado 2015; Qrunfleh and Tarafdar 2014; Qrunfleh, Tarafdar, and Ragu-Nathan 2012; Qi, Boyer, and Zhao 2009)
Return On Investment (ROI)	(Qi et al. 2017; Adebanjo, Laosirihongthong, and Samaranayake 2016; Qrunfleh and Tarafdar 2013; Soni and Kodali 2009; Novais, Maqueira Marín, and Moyano-Fuentes 2020; Huo, Gu, and Wang 2019; Thanki and Thakkar

	2018; Duarte and Cruz-Machado 2015; Qrunfleh and Tarafdar 2014; J. C. Chen, Cheng, and Huang 2013; Qi, Zhao, and Sheu 2011; Qi, Boyer, and Zhao 2009)
Customer satisfaction	(Ruiz-Benítez, López, and Real 2018; Gaudenzi and Christopher 2016; Arif-Uz-Zaman and Nazmul Ahsan 2014; Cabral, Grilo, and Cruz-Machado 2012; Soni and Kodali 2009; Thanki and Thakkar 2018; Jajja et al. 2016; Govindan et al. 2015; Duarte and Cruz-Machado 2015; Kainuma and Tawara 2006)
On-time delivery	(Soni and Kodali 2009; Borges et al. 2020; Ozelkan et al. 2007; Novais, Maqueira Marín, and Moyano-Fuentes 2020; Orji and Liu 2020; Iyer, Srivastava, and Srinivasan 2019; Colicchia, Creazza, and Dallari 2017; Marodin et al. 2016; Kou and Lee 2015; Duarte and Cruz-Machado 2015)
Productivity	(Ruiz-Benítez, López, and Real 2018; Zhou and Ji 2015; Piercy and Rich 2015; Soni and Kodali 2009; Al-Tit 2016; Dey et al. 2019; Thanki and Thakkar 2018; Jajja et al. 2016; Duarte and Cruz-Machado 2015; De Sousa Jabbour, Omodei, and Jabbour 2014)
Quality (scrap and rework)	(Abideen and Mohamad 2019; Ruiz-Benítez, López, and Real 2018; H. Chen, Liu, and Oderanti 2017; Marodin et al. 2017; Soni and Kodali 2009; Iyer, Srivastava, and Srinivasan 2019; Thanki and Thakkar 2018; Jajja et al. 2016; Wiengarten, Fynes, and Onofrei 2013)
Delivery service level	(Tortorella, Giglio, and Limon-Romero 2018; Tortorella, Miorando, and Marodin 2017; Frazzon et al. 2017; Borges et al. 2020; Santos, Murmura, and Bravi 2019; Lau and Wang 2013; Tasdemir and Gazo 2020; Qi, Boyer, and Zhao 2009)
Profitability	(Fadaki, Rahman, and Chan 2020, 2019; Adebanjo, Laosirihongthong, and Samaranayake 2016; Zhou and Ji 2015; Thanki and Thakkar 2018; Jajja et al. 2016; Duarte and Cruz-Machado 2015; Agus and Hajinoor 2012)
Capacity utilization rate	(Ruiz-Benítez, López, and Real 2018; Adebanjo, Laosirihongthong, and Samaranayake 2016; Soni and Kodali 2009; Dey et al. 2019; Thanki and Thakkar 2018; Fahimnia, Sarkis, and Eshragh 2015; Duarte and Cruz-Machado 2015)
Defect rate	(H. Chen, Liu, and Oderanti 2017; Soni and Kodali 2009; Swenseth and Olson 2016; R. B. R. Kumar, Sharma, and Agarwal 2015; Thanki and Thakkar 2018; Campos and Vazquez-Brust 2016; Kou and Lee 2015)
Return On Sales (ROS)	(Qi et al. 2017; Novais, Maqueira Marín, and Moyano-Fuentes 2020; Huo, Gu, and Wang 2019; Thanki and Thakkar 2018; Jajja et al. 2016; Agus and Hajinoor 2012; Qi, Boyer, and Zhao 2009)
Total product cycle time	(Moyano-Fuentes et al. 2021; Arif-Uz-Zaman and Nazmul Ahsan 2014; Soni and Kodali 2009; Kusrini and Parmasari 2020; Lau and Wang 2013; Wee and Wu 2009; Qrunfleh and Tarafdar 2014)
Inventory turnover ratio	(2021; Marodin et al. 2017; Adebanjo, Laosirihongthong, and Samaranayake 2016; Soni and Kodali 2009; Iyer, Srivastava, and Srinivasan 2019; Qi, Boyer, and Zhao 2009)
Employee satisfaction rate (motivation and engagement)	(Ruiz-Benitez, López, and Real 2019; Tasdemir and Gazo 2020; López and Ruiz-Benítez 2020; Thanki and Thakkar 2018; Duarte and Cruz-Machado 2015)
Supplier delivery reliability (late or wrong delivery, lead time)	(Tortorella, Miorando, and Marodin 2017; Soni and Kodali 2009; Santos, Murmura, and Bravi 2019; Fourie and Umeh 2017; Wiengarten, Fynes, and Onofrei 2013)
Customer returns/rejection rate	(Soni and Kodali 2009; Thanki and Thakkar 2018; Duarte and Cruz-Machado 2015; Wiengarten, Fynes, and Onofrei 2013)
Return On Assets (ROA)	(Thanki and Thakkar 2018; Jajja et al. 2016; Qi, Zhao, and Sheu 2011; Kainuma and Tawara 2006)
Safety and health working environment	(Ruiz-Benitez, López, and Real 2019; López and Ruiz-Benítez 2020; Orji and Liu 2020; Huo, Gu, and Wang 2019)
Supplier rejection rate / defect free delivery	(Arif-Uz-Zaman and Nazmul Ahsan 2014; Soni and Kodali 2009; Santos, Murmura, and Bravi 2019; Wiengarten, Fynes, and Onofrei 2013)
First time through	(Manville, Papadopoulos, and Garengo 2019; Marodin et al. 2017; Wee and Wu 2009)

Joint problem solving	(Piercy and Rich 2015; Arif-Uz-Zaman and Nazmul Ahsan 2014; Soni and Kodali 2009)
Product development cycle time	(Soni and Kodali 2009; R. B. R. Kumar, Sharma, and Agarwal 2015; Jajja et al. 2016)
Absenteeism rate	(Tasdemir and Gazo 2020; Duarte and Cruz-Machado 2015)
Number of suppliers	(Thanki and Thakkar 2018; Duarte and Cruz-Machado 2015)
Training and education programs to employees	(Thanki and Thakkar 2018; Duarte and Cruz-Machado 2015)
Joint product development	(Piercy and Rich 2015)
Unit cost of manufacturing	(Moyano-Fuentes et al. 2021)

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Appendix B. Fuzzy Delphi method results after screening

Perspective	Goal / KPI	Code	u_b	l_b	D_b	Decision
Financial	Revenue growth	GF1	0.805	-0.305	0.805	Rejected
	Return on assets	GF2	0.785	-0.285	0.785	Rejected
	Cost reduction	GF3	0.885	-0.385	0.885	Accepted
	profitability	KF1	0.825	-0.325	0.825	Rejected
	return on investment (ROI)	KF2	0.775	-0.275	0.775	Rejected
	return on sales (ROS)	KF3	0.77	-0.27	0.770	Rejected
	return on assets (ROA)	KF4	0.78	-0.28	0.780	Rejected
	cash conversion cycle	KF5	0.865	-0.365	0.865	Accepted
	market share	KF6	0.745	-0.245	0.745	Rejected
Customer	Customer satisfaction	GC1	0.935	-0.06	0.935	Accepted
	Delivery efficiency	GC2	0.955	-0.08	0.955	Accepted
	Customer value	GC3	0.915	-0.415	0.915	Accepted
	on-time delivery rate	KC1	0.87	-0.37	0.970	Accepted
	delivery service rate	KC2	0.845	-0.345	0.985	Accepted
	lead time	KC3	0.895	-0.395	0.940	Accepted
	customer rejection rate	KC4	0.88	-0.38	0.885	Accepted
	customer satisfaction rate	KC5	0.775	-0.275	0.900	Accepted
	responsiveness to customer demands	KC6	0.885	-0.385	0.900	Accepted
	joint product development with customers	KC7	0.8	-0.3	0.785	Rejected
	joint problem solving with customers	KC8	0.765	-0.265	0.840	Rejected
	certified customer relationship	KC9	0.79	-0.29	0.775	Rejected
Business process	Waste reduction	GB1	0.895	-0.395	0.895	Accepted
	Supplier relationships	GB2	0.89	-0.015	0.890	Accepted
	Process optimization	GB3	0.87	-0.37	0.870	Accepted
	inventory turnover ratio	KB1	0.97	-0.095	0.870	Accepted
	supplier rejection rate	KB10	0.985	0.265	0.880	Accepted
	joint product development with suppliers	KB11	0.94	-0.065	0.775	Rejected
	supplier lead time	KB12	0.885	-0.385	0.885	Accepted
	certified suppliers	KB13	0.9	-0.4	0.800	Rejected
	degree of supply base consolidation	KB14	0.9	-0.025	0.765	Rejected
	product development cycle time	KB15	0.785	-0.285	0.790	Rejected
	productivity	KB2	0.84	-0.34	0.860	Accepted
	defect rate	KB3	0.775	-0.275	0.875	Accepted
	average cost per unit	KB4	0.87	0.005	0.830	Rejected
	total product cycle time	KB5	0.86	-0.36	0.825	Rejected
	capacity utilization rate	KB6	0.875	-0.375	0.755	Rejected
	first time through	KB7	0.83	-0.33	0.870	Accepted
	joint problem solving with suppliers	KB8	0.825	-0.325	0.845	Rejected
	supplier delivery reliability	KB9	0.755	-0.255	0.895	Accepted
Learning and growth	Product/process innovation	GL1	0.82	-0.32	0.820	Rejected
	Information flow	GL2	0.895	-0.395	0.895	Accepted
	Human capital management	GL3	0.84	-0.34	0.840	Rejected
	accident frequency rate	KL1	0.9	-0.4	0.900	Accepted

		employee training rate	KL2	0.79	-0.29	0.790	Rejected
		absenteeism rate	KL3	0.785	-0.285	0.785	Rejected
		employee turnover	KL4	0.76	-0.26	0.760	Rejected
		employee engagement	KL5	0.865	-0.365	0.865	Accepted
Threshold δ	**0.848**						

Appendix C. Initial direct relation matrix I – Respondent 1

	GF3	GC1	GC2	GC3	GB1	GB2	GB3	GL2
KF5	VL	VL	VL	VL	M	VL	M	VL
KC1	M	VH	VH	VH	M	M	VL	VL
KC2	VL	VH	VH	VH	VL	VL	VL	M
KC3	M	M	VH	M	H	M	M	H
KC4	M	VH	M	H	H	M	M	M
KC5	M	VH	M	M	VH	M	VH	VL
KC6	VL	H	H	H	M	M	M	VL
KB1	M	M	H	H	VH	VH	VH	H
KB2	VH	M	M	M	H	M	H	VL
KB3	VH	H	M	M	H	VL	VH	M
KB7	VH	VL	VL	M	H	M	H	M
KB9	H	M	VL	H	H	VH	H	M
KB10	M	M	M	M	H	H	H	H
KB12	M	M	M	M	VL	VH	M	M
KL1	VH	VL	M	M	H	VL	VH	M
KL5	VH	VH	VH	VH	VH	VH	VH	VH

Note: cost reduction (GF3), customer satisfaction (GC1), delivery efficiency (GC2), customer value (GC3), waste reduction (GB1), supplier relationships (GB2), process optimization (GB3), information flow (GL2), cash conversion cycle (KF5), on-time delivery (KC1), delivery service rate (KC2), lead time (KC3), customer rejection rate (KC4), customer satisfaction rate (KC5), responsiveness to customer demands (KC6), inventory turnover ratio (KB1), productivity (KB2), defect rate (KB3), first time through (KB7), supplier delivery reliability (KB9), supplier rejection rate (KB10), supplier lead time (KB12), accident frequency rate (KL1), and employee engagement (KL5).

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Appendix D. Triangular fuzzy numbers (a), fuzzy defuzzification process (b – c), and direct relation matrix D (d) – Respondent 1

a	**GF3**			**GC1**			**GC2**			**GC3**			**GB1**			**GB2**			**GB3**			**GL2**		
KF5	(0	0.1	0.3)	(0	0.1	0.3)	(0	0.1	0.3)	(0	0.1	0.3)	(0.3	0.5	0.7)	(0	0.1	0.3)	(0.3	0.5	0.7)	(0	0.1	0.3)
KC1	(0.3	0.5	0.7)	(0.7	0.9	1)	(0.7	0.9	1)	(0.7	0.9	1)	(0.3	0.5	0.7)	(0.3	0.5	0.7)	(0	0.1	0.3)	(0	0.1	0.3)
KC2	(0	0.1	0.3)	(0.7	0.9	1)	(0.7	0.9	1)	(0.7	0.9	1)	(0	0.1	0.3)	(0	0.1	0.3)	(0	0.1	0.3)	(0.3	0.5	0.7)
KC3	(0.3	0.5	0.7)	(0.3	0.5	0.7)	(0.7	0.9	1)	(0.3	0.5	0.7)	(0.5	0.7	0.9)	(0.3	0.5	0.7)	(0.3	0.5	0.7)	(0.5	0.7	0.9)
KC4	(0.3	0.5	0.7)	(0.7	0.9	1)	(0.3	0.5	0.7)	(0.5	0.7	0.9)	(0.5	0.7	0.9)	(0.3	0.5	0.7)	(0.3	0.5	0.7)	(0.3	0.5	0.7)
KC5	(0.3	0.5	0.7)	(0.7	0.9	1)	(0.3	0.5	0.7)	(0.3	0.5	0.7)	(0.7	0.9	1)	(0.3	0.5	0.7)	(0.7	0.9	1)	(0	0.1	0.3)
KC6	(0	0.1	0.3)	(0.5	0.7	0.9)	(0.5	0.7	0.9)	(0.5	0.7	0.9)	(0.3	0.5	0.7)	(0.3	0.5	0.7)	(0.3	0.5	0.7)	(0	0.1	0.3)
KB1	(0.3	0.5	0.7)	(0.3	0.5	0.7)	(0.5	0.7	0.9)	(0.5	0.7	0.9)	(0.7	0.9	1)	(0.7	0.9	1)	(0.7	0.9	1)	(0.5	0.7	0.9)
KB2	(0.7	0.9	1)	(0.3	0.5	0.7)	(0.3	0.5	0.7)	(0.3	0.5	0.7)	(0.5	0.7	0.9)	(0.3	0.5	0.7)	(0.5	0.7	0.9)	(0	0.1	0.3)
KB3	(0.7	0.9	1)	(0.5	0.7	0.9)	(0.3	0.5	0.7)	(0.3	0.5	0.7)	(0.5	0.7	0.9)	(0	0.1	0.3)	(0.7	0.9	1)	(0.3	0.5	0.7)
KB7	(0.7	0.9	1)	(0	0.1	0.3)	(0	0.1	0.3)	(0.3	0.5	0.7)	(0.5	0.7	0.9)	(0.3	0.5	0.7)	(0.5	0.7	0.9)	(0.3	0.5	0.7)
KB9	(0.5	0.7	0.9)	(0.3	0.5	0.7)	(0	0.1	0.3)	(0.5	0.7	0.9)	(0.5	0.7	0.9)	(0.7	0.9	1)	(0.5	0.7	0.9)	(0.3	0.5	0.7)
KB10	(0.3	0.5	0.7)	(0.3	0.5	0.7)	(0.3	0.5	0.7)	(0.3	0.5	0.7)	(0.5	0.7	0.9)	(0.5	0.7	0.9)	(0.5	0.7	0.9)	(0.5	0.7	0.9)
KB12	(0.3	0.5	0.7)	(0.3	0.5	0.7)	(0.3	0.5	0.7)	(0.3	0.5	0.7)	(0	0.1	0.3)	(0.7	0.9	1)	(0.3	0.5	0.7)	(0.3	0.5	0.7)
KL1	(0.7	0.9	1)	(0	0.1	0.3)	(0.3	0.5	0.7)	(0.3	0.5	0.7)	(0.5	0.7	0.9)	(0	0.1	0.3)	(0.7	0.9	1)	(0.3	0.5	0.7)
KL5	(0.7	0.9	1)	(0.7	0.9	1)	(0.7	0.9	1)	(0.7	0.9	1)	(0.7	0.9	1)	(0.7	0.9	1)	(0.7	0.9	1)	(0.7	0.9	1)
b	***fl***	***fm***	***fr***	***fl***	***fm***	***fr***	***fl***	***fm***	***fr***	***fl***	***fm***	***fr***	***fl***	***fm***	***fr***	***fl***	***fm***	***fr***	***fl***	***fm***	***fr***	***fl***	***fm***	***fr***
KF5	(0	0	0)	(0	0	0)	(0	0	0)	(0	0	0)	(0.3	0.4	0.4)	(0	0	0)	(0.3	0.4	0.4)	(0	0	0)
KC1	(0.3	0.4	0.4)	(0.7	0.8	0.7)	(0.7	0.8	0.7)	(0.7	0.8	0.7)	(0.3	0.4	0.4)	(0.3	0.4	0.4)	(0	0	0)	(0	0	0)
KC2	(0	0	0)	(0.7	0.8	0.7)	(0.7	0.8	0.7)	(0.7	0.8	0.7)	(0	0	0)	(0	0	0)	(0	0	0)	(0.3	0.4	0.4)
KC3	(0.3	0.4	0.4)	(0.3	0.4	0.4)	(0.7	0.8	0.7)	(0.3	0.4	0.4)	(0.5	0.6	0.6)	(0.3	0.4	0.4)	(0.3	0.4	0.4)	(0.5	0.6	0.6)
KC4	(0.3	0.4	0.4)	(0.7	0.8	0.7)	(0.3	0.4	0.4)	(0.5	0.6	0.6)	(0.5	0.6	0.6)	(0.3	0.4	0.4)	(0.3	0.4	0.4)	(0.3	0.4	0.4)
KC5	(0.3	0.4	0.4)	(0.7	0.8	0.7)	(0.3	0.4	0.4)	(0.3	0.4	0.4)	(0.7	0.8	0.7)	(0.3	0.4	0.4)	(0.7	0.8	0.7)	(0	0	0)
KC6	(0	0	0)	(0.5	0.6	0.6)	(0.5	0.6	0.6)	(0.5	0.6	0.6)	(0.3	0.4	0.4)	(0.3	0.4	0.4)	(0.3	0.4	0.4)	(0	0	0)
KB1	(0.3	0.4	0.4)	(0.3	0.4	0.4)	(0.5	0.6	0.6)	(0.5	0.6	0.6)	(0.7	0.8	0.7)	(0.7	0.8	0.7)	(0.7	0.8	0.7)	(0.5	0.6	0.6)
KB2	(0.7	0.8	0.7)	(0.3	0.4	0.4)	(0.3	0.4	0.4)	(0.3	0.4	0.4)	(0.5	0.6	0.6)	(0.3	0.4	0.4)	(0.5	0.6	0.6)	(0	0	0)

KB3	(0.7	0.8	0.7)	(0.5	0.6	0.6)	(0.3	0.4	0.4)	(0.3	0.4	0.4)	(0.5	0.6	0.6)	(0	0	0)	(0.7	0.8	0.7)	(0.3	0.4	0.4)
KB7	(0.7	0.8	0.7)	(0	0	0)	(0	0	0)	(0.3	0.4	0.4)	(0.5	0.6	0.6)	(0.3	0.4	0.4)	(0.5	0.6	0.6)	(0.3	0.4	0.4)
KB9	(0.5	0.6	0.6)	(0.3	0.4	0.4)	(0	0	0)	(0.5	0.6	0.6)	(0.5	0.6	0.6)	(0.7	0.8	0.7)	(0.5	0.6	0.6)	(0.3	0.4	0.4)
KB10	(0.3	0.4	0.4)	(0.3	0.4	0.4)	(0.3	0.4	0.4)	(0.3	0.4	0.4)	(0.5	0.6	0.6)	(0.5	0.6	0.6)	(0.5	0.6	0.6)	(0.5	0.6	0.6)
KB12	(0.3	0.4	0.4)	(0.3	0.4	0.4)	(0.3	0.4	0.4)	(0.3	0.4	0.4)	(0	0	0)	(0.7	0.8	0.7)	(0.3	0.4	0.4)	(0.3	0.4	0.4)
KL1	(0.7	0.8	0.7)	(0	0	0)	(0.3	0.4	0.4)	(0.3	0.4	0.4)	(0.5	0.6	0.6)	(0	0	0)	(0.7	0.8	0.7)	(0.3	0.4	0.4)
KL5	(0.7	0.8	0.7)	(0.7	0.8	0.7)	(0.7	0.8	0.7)	(0.7	0.8	0.7)	(0.7	0.8	0.7)	(0.7	0.8	0.7)	(0.7	0.8	0.7)	(0.7	0.8	0.7)

c	***lv***	***rv***	***lv***	***rv***	***lv***	***rv***	***lv***	***rv***	***lv***	***rv***	***lv***	***rv***	***lv***	***rv***	***lv***	***rv***
KF5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.364	0.400	0.000	0.000	0.364	0.400	0.000	0.000
KC1	0.364	0.400	0.727	0.778	0.727	0.778	0.727	0.778	0.364	0.400	0.364	0.400	0.000	0.000	0.000	0.000
KC2	0.000	0.000	0.727	0.778	0.727	0.778	0.727	0.778	0.000	0.000	0.000	0.000	0.000	0.000	0.364	0.400
KC3	0.364	0.400	0.364	0.400	0.727	0.778	0.364	0.400	0.545	0.600	0.364	0.400	0.364	0.400	0.545	0.600
KC4	0.364	0.400	0.727	0.778	0.364	0.400	0.545	0.600	0.545	0.600	0.364	0.400	0.364	0.400	0.364	0.400
KC5	0.364	0.400	0.727	0.778	0.364	0.400	0.364	0.400	0.727	0.778	0.364	0.400	0.727	0.778	0.000	0.000
KC6	0.000	0.000	0.545	0.600	0.545	0.600	0.545	0.600	0.364	0.400	0.364	0.400	0.364	0.400	0.000	0.000
KB1	0.364	0.400	0.364	0.400	0.545	0.600	0.545	0.600	0.727	0.778	0.727	0.778	0.727	0.778	0.545	0.600
KB2	0.727	0.778	0.364	0.400	0.364	0.400	0.364	0.400	0.545	0.600	0.364	0.400	0.545	0.600	0.000	0.000
KB3	0.727	0.778	0.545	0.600	0.364	0.400	0.364	0.400	0.545	0.600	0.000	0.000	0.727	0.778	0.364	0.400
KB7	0.727	0.778	0.000	0.000	0.000	0.000	0.364	0.400	0.545	0.600	0.364	0.400	0.545	0.600	0.364	0.400
KB9	0.545	0.600	0.364	0.400	0.000	0.000	0.545	0.600	0.545	0.600	0.727	0.778	0.545	0.600	0.364	0.400
KB10	0.364	0.400	0.364	0.400	0.364	0.400	0.364	0.400	0.545	0.600	0.545	0.600	0.545	0.600	0.545	0.600
KB12	0.364	0.400	0.364	0.400	0.364	0.400	0.364	0.400	0.000	0.000	0.727	0.778	0.364	0.400	0.364	0.400
KL1	0.727	0.778	0.000	0.000	0.364	0.400	0.364	0.400	0.545	0.600	0.000	0.000	0.727	0.778	0.364	0.400
KL5	0.727	0.778	0.727	0.778	0.727	0.778	0.727	0.778	0.727	0.778	0.727	0.778	0.727	0.778	0.727	0.778

d	***x***	***x***	***x***	***x***	***x***	***x***	***x***	***x***
KF5	0.000	0.000	0.000	0.000	0.378	0.000	0.378	0.000
KC1	0.378	0.765	0.765	0.765	0.378	0.378	0.000	0.000
KC2	0.000	0.765	0.765	0.765	0.000	0.000	0.000	0.378

KC3	0.378	0.378	0.765	0.378	0.576	0.378	0.378	0.576
KC4	0.378	0.765	0.378	0.576	0.576	0.378	0.378	0.378
KC5	0.378	0.765	0.378	0.378	0.765	0.378	0.765	0.000
KC6	0.000	0.576	0.576	0.576	0.378	0.378	0.378	0.000
KB1	0.378	0.378	0.576	0.576	0.765	0.765	0.765	0.576
KB2	0.765	0.378	0.378	0.378	0.576	0.378	0.576	0.000
KB3	0.765	0.576	0.378	0.378	0.576	0.000	0.765	0.378
KB7	0.765	0.000	0.000	0.378	0.576	0.378	0.576	0.378
KB9	0.576	0.378	0.000	0.576	0.576	0.765	0.576	0.378
KB10	0.378	0.378	0.378	0.378	0.576	0.576	0.576	0.576
KB12	0.378	0.378	0.378	0.378	0.000	0.765	0.378	0.378
KL1	0.765	0.000	0.378	0.378	0.576	0.000	0.765	0.378
KL5	0.765	0.765	0.765	0.765	0.765	0.765	0.765	0.765

Note: cost reduction (GF3), customer satisfaction (GC1), delivery efficiency (GC2), customer value (GC3), waste reduction (GB1), supplier relationships (GB2), process optimization (GB3), information flow (GL2), cash conversion cycle (KF5), on-time delivery (KC1), delivery service rate (KC2), lead time (KC3), customer rejection rate (KC4), customer satisfaction rate (KC5), responsiveness to customer demands (KC6), inventory turnover ratio (KB1), productivity (KB2), defect rate (KB3), first time through (KB7), supplier delivery reliability (KB9), supplier rejection rate (KB10), supplier lead time (KB12), accident frequency rate (KL1), and employee engagement (KL5).

Garcia-Buendia, N., Kristensen, T.B., Moyano-Fuentes, J. and Maqueira-Marín, J.M. (2022), "Performance measurement of lean supply chain management: a balanced scorecard proposal", *Production Planning & Control*, Vol. 35 No. 6, pp. 618–638, doi: https://doi.org/10.1080/09537287.2022.2114960. Accepted 16 Aug 2022.

Appendix E. Direction matrix G for goals and performance indicators

	GF3	**GC1**	**GC2**	**GC3**	**GB1**	**GB2**	**GB3**	**GL2**
KF5	0.399	0.205	0.229	0.175	0.284	0.261	0.357	0.221
KC1	0.273	0.686	0.631	0.502	0.221	0.334	0.324	0.282
KC2	0.238	0.581	0.568	0.584	0.235	0.316	0.325	0.304
KC3	0.377	0.578	0.538	0.530	0.368	0.343	0.499	0.307
KC4	0.294	0.593	0.289	0.515	0.233	0.186	0.237	0.179
KC5	0.220	0.686	0.427	0.586	0.224	0.258	0.300	0.288
KC6	0.245	0.565	0.486	0.584	0.262	0.295	0.352	0.277
KB1	0.498	0.103	0.223	0.113	0.389	0.326	0.473	0.206
KB2	0.541	0.199	0.259	0.193	0.455	0.200	0.526	0.217
KB3	0.536	0.481	0.263	0.372	0.551	0.252	0.490	0.216
KB7	0.463	0.303	0.280	0.303	0.450	0.274	0.423	0.194
KB9	0.312	0.324	0.367	0.265	0.297	0.625	0.312	0.189
KB10	0.330	0.224	0.272	0.236	0.358	0.567	0.302	0.143
KB12	0.314	0.317	0.342	0.279	0.224	0.539	0.336	0.201
KL1	0.347	0.165	0.126	0.213	0.307	0.100	0.436	0.347
KL5	0.461	0.419	0.399	0.366	0.450	0.254	0.468	0.388

Note: cost reduction (GF3), customer satisfaction (GC1), delivery efficiency (GC2), customer value (GC3), waste reduction (GB1), supplier relationships (GB2), process optimization (GB3), information flow (GL2), cash conversion cycle (KF5), on-time delivery (KC1), delivery service rate (KC2), lead time (KC3), customer rejection rate (KC4), customer satisfaction rate (KC5), responsiveness to customer demands (KC6), inventory turnover ratio (KB1), productivity (KB2), defect rate (KB3), first time through (KB7), supplier delivery reliability (KB9), supplier rejection rate (KB10), supplier lead time (KB12), accident frequency rate (KL1), and employee engagement (KL5).