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Research Article

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Developing and prioritizing lean key performance indicators for plastering supply chains

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Abstract

Paper aims: The aim of this study was to propose a hybrid approach to develop and prioritize the indicators which should be used to monitor the development of plastering supply chains while using lean manufacturing practices.

Originality: This approach proposed the integration of a Balanced Scorecard (BSC) - a multi-perspective tool for performance evaluation and strategic planning, and FITradeoff for the ranking problematic – a multicriteria method that features a robust axiomatic structure and uses partial information.

Research method: The results showed that the approach provided a set of indicators to assist the company's manager to monitor and improve the company's competitiveness and sustainability.

Main findings: The results showed that the approach was able to provide a set of KPIs to assist the company's manager to monitor and improve the plastering company management in terms of competitiveness and sustainability.

Implications for theory and practice: The results allowed evaluation of important issues for the strategic, economic, and environmental stability in complex business environments.

Keywords

Balanced Scorecard. FITradeoff. Lean Manufacturing.

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1. Introduction

According to Fagnani & Guimarães (2017), the constant population growth and consumption patterns brought impacts due to unrestricted waste generation, which may lead to breakdowns with serious environmental, economic, and social consequences. One of the sectors which contribute to this situation is the building sector.

In this context, Klepa et al. (2019) state that the building sector is among the foremost leading sectors of a country's economy, providing a remarkable contribution to its Gross Domestic Product (GDP). Also, the building sector features a major prominence while generating income in local and regional economies, through the supply of raw materials for the building sector in its urban structure development projects. However, Esa et al. (2017) presented the main negative impacts of these industries in terms of sustainability, including but not limited to high power consumption and greenhouse gas emissions. As a key part of this sector, one can find the industries which comprise the local plaster productive arrangements.

In Brazil's Northeast Pernambuco State, the Local Productive Arrangement (LPA) of plaster stands out for its volume and quality production, reaching most of the domestic Brazilian demand. However, despite the potential presented, the industries which comprise this LPA face difficulties as they compete in a scenario with other industries which often operate in the black economy, and given this situation, informal companies manage to get more attractive prices for their products, however, the lower quality exhibited. Therefore, formal plaster LPA industries in Pernambuco State face problems to level the operational and managerial performance to make them more competitive in this niche market (Instituto de Tecnologia de Pernambuco, 2019).

From this perspective, how these supply chains manage complex business environments remains a challenge for academics and practitioners (Nooraie et al., 2020).

Rebutting this scenario, complex business environments often force supply chains to prioritize efficiency in processes and abandon other stances, such as sustainable stances, which give them a competitive advantage over their competitors (Bui et al., 2021).

In this sense, measures focus on two postures of companies in these supply chains, the first is when companies cannot stand the pressure imposed by competitors and withdraw from the market, and the second is the reengineering of their processes to a cleaner format (Echegaray, 2021).

The adoption of cleaner models helps the organization to understand how to manage what generates value and competitive advantage, endowing it with organizational ambidexterity that improves its performance equitably in terms of cost, environmentally, and socially, having as a final consequence the improvement of the company's image (Rocha & Sattler,2009; Majumdar et al., 2020). As in lean manufacturing systems.

The concept of lean manufacturing comprises a set of dynamic practices, as knowledge-oriented aiming the continuous effort of waste reduction, create value, and guarantee the satisfaction of its consumers (Baines et al., 2007). Besides adding value, Abreu et al. (2017) claim that lean practices can associate efficiency with operational, managerial, and environmental issues. This fact answers the problems faced by the plaster LPA industries in their supply chain.

Consequently, Key Performance Indicators (KPI) are needed to monitor the recovery of supply chain as they experience a development based on the application of lean manufacturing practices in the plastering industry (Mourtzis et al., 2017). However, due to resource limitations, industries fail to invest in all KPIs simultaneously. Therefore, there is a need to prioritize them.

The KPI prioritization in sustainable supply chains has been explored in the literature. Sufiyan et al. (2019) used a combination of two multi-criteria methods, Fuzzy Decision-Making Trial and Evaluation Laboratory (DEMATEL) and analytic Network Process (ANP), to prioritize KPIs for sustainable performance evaluation in Supply Chain. However, both methods present limitations well explored in the literature. The main one is regarding the high number of pairwise comparisons DMs make, which requires DMs much cognitive effort, and, consequently, may generate more inconsistencies in the decision-making process.

Neri et al. (2021) developed a set of generic KPIs based on a systematic literature review to assess the sustainable performance of industrial supply chains. However, they did not perform its validation in the plaster supply chain, nor was its prioritization performed to verify how many and which KPIs were most suitable for this supply chain.

Swarnakar et al. (2022) proposed a group decision model to prioritize KPIs to assess sustainability in different supply chains and used the Aggregate Uni-Criterion Ranking into One Ranking (AURORA) multi-criteria method. A limitation of this method is the use of criteria weights that only represent the relative importance of the criterion for the problem, losing preferential information from the decision-maker about the possible relevant tradeoffs to the problem.

Thus, this study proposes an approach to assist the managers of plaster LPA industries to develop, explore, and prioritize lean key performance indicators in the context of complex business environments. To successfully meet this purpose, an approach based on the combination of a Balanced Scorecard (BSC) and a multicriteria decision analysis (MCDA) method called Flexible and Interactive Tradeoff (FITradeoff) for the ranking problematic was proposed.

The contribution of BSC to the study hereof stands for a tool able to associate the long-term purposes of an organization in its daily operations, resulting in strategic control based on excellence, increased competitiveness, and productivity (Giannopoulos et al., 2013).

However, as the BSC features limits as to the comparison of the performance achieved by the company versus the estimated performance and fails to address the manager's value judgments in a structured manner, it is appropriate to use MCDA methods to aid their assessment (Huang et al., 2014).

In this respect, FITradeoff provides flexibility to the prioritization process. It requires less cognitive effort from the decision-maker (DM) as it evaluates strict preference relations between consequences and not indifference which is more difficult to assess. Consequently, the level of inconsistencies found in the process may be decreased when compared with the traditional Tradeoff method (Almeida et al., 2016). Simulations studies conducted by Mendes et al. (2020) using FITradeoff show that increasing the number of alternatives does not have an influence on the number of questions in FITradeoff., but when the number of criteria increases the number of questions will increase as well. Furthermore, FITradeoff includes software that features graphical tools to help the DM to check the process progress anytime.

This study is divided into 6 sections. The first one is the Introduction; Section 2 presents the literature review; Section 3 describes the proposed approach; Section 4 presents the case study used to validate the approach; Section 5 presents the discussions of the case study, and finally, Section 6 details the conclusions on the study.

2. Literature review

Over the years, studies have been developed focusing either on Balanced Scorecard and its deployments in MCDA methods field. The Balanced Scorecard was initially developed as a performance evaluation tool (Kaplan & Norton, 1992). However, over the years, the BSC is no longer used only for performance evaluation. In this respect, with the required changes, BSC can become a strategic management tool, as it takes into account four perspectives in which strategic objectives are defined. These strategic objectives must be aligned with the company's mission (Nudurupati et al., 2010; Hoque, 2014). Furthermore, these strategic objectives are linked as a map to represent the company's strategy (Leung et al. 2006).

BSC has also been already modeled by using many multi-criteria decision-analysis methods (MCDA) for several purposes. In this respect, Ravi et al. (2005) used an approach of the Analytic Network Process (ANP) with the BSC to evaluate alternatives, to carry out the reverse logistics of electronic waste. Despite the relevant effect, the authors noticed that the decision-maker showed bias in some of the criteria used, which may have reflected negatively on the results. In order to overcome this problem, the authors performed a series of consistency tests which might not be suitable for decision-making in the real world.

Moreover, Leung et al. (2006) put into practice the BSC, ANP and Analytic Hierarchical Process (AHP) to evaluate the performance of a company and included financial and non-financial performance indicators. The authors concluded that when this inclusion takes place, the BSC cannot only assess the company's current performance, but also provides the guidelines to evaluate the future performance. However, the authors stress that there are several ways of preparing the BSC, being required to evaluate the most appropriate way of preparing BSC to make the model more reliable.

Furthermore, Wu et al. (2009) suggested a hybrid model with multi-criteria optimization and compromise solution (VIKOR), Fuzzy AHP, and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) methods to assess banking performance based on the BSC's perspectives. The authors suggested that other methods can be used to deal with the interactive and relational nature among the studied indicators.

Moreover, Yuksel & Dağdeviren (2010) integrated BSC with the ANP to assess the performance level of business and compare it based on the performance set in its goals. The authors showed as a limitation of this study the failure of assessment of the interdependencies among the BSC perspectives and the indicators developed in each perspective.

Later, Barata et al. (2014) proposed a multi-criteria indicator based on Elimination and Choice Translating algorithm - TRI (ELECTRE-TRI) method to evaluate companies' maturity in terms of sustainability. The authors applied the approach in Brazilian petroleum companies to supplier selection considering Triple Bottom Line criteria and concluded that these companies have a low level of sustainability.

Additionally, Felice et al. (2015) suggested the tool called 'The Analytic Balanced Scorecard (A-BSC)' to analyze and to monitor the performance of activities which were outsourced in companies because they did not comprise their core competencies. According to the authors, A-BSC is a tool featuring the combination of BSC and the AHP method. However, the authors stress that aiming at real-world problems, AHP can be a limited method because it cannot deal with the complexities of relationships among the elements analyzed.

Saradhi et al. (2016) also used BSC and Fuzzy-TOPSIS to assess the performance of their suppliers. The authors suggested a new metric to calculate the distance in the TOPSIS method. However, the authors specified the current subjectivity for prioritizing factors as the main limits for this study, which lead to a lower performance of the method.

Freitas & Costa (2017) and Freitas et al. (2017) aimed to identify throughout systematic literature review criteria, factors or indicators that mapped the effects of lean philosophy in the organizational sustainability performance. Dinçer et al. (2017) aimed at evaluating the performance of European airlines. The authors used a methodology which joined the BSC, the methods Fuzzy Decision-making Trial and Evaluation Laboratory (DEMATEL), Fuzzy ANP, and Multi-Objective Optimization Method by Ratio Analysis (MOORA). However, the effectiveness of the methodology may have been reduced due to the restriction to include important indicators given the troubles in the acquisition of non-financial data.

Finally, Salimi & Khodaparast (2019) developed a model which combined BSC, Fuzzy AHP, and taxonomic analysis to assess the performance and classification of young sports players in Iran. In this respect, the complexity of the model and the amount of information required to use it, in addition to the various required evaluations can restrict the application of the model to real-world problems.

As one can notice, even with the combination of BSC and MCDA, most studies fall below the employment of the said approaches solely as a performance evaluation tool. In this respect, they did not use the potential for strategic planning, which is an issue detailed in the study hereof.

3. Proposed approach

The approach proposes the integration of two methodologies: Balanced Scorecard - a multi-perspective tool for performance evaluation and strategic planning, and FITradeoff for the ranking problematic - an MCDA that features a robust axiomatic structure while improving the elicitation process through the flexibility and interactivity which it depicts in the exploit of partial information required to prioritize key performance indicators (Almeida-Filho et al., 2017). The FITradeoff method arose from the need of having an elicitation process that employs partial information in a more structured and flexible way as the traditional methods entailed many inconsistencies in the process (Almeida et al., 2016). Moreover, FITradeoff showed did better than other MCDA methods while considering all problems related to the decision maker's cognitive effort and elicitation time (Camilo et al., 2020). Also, FITradeoff offers different forms of graphical visualization that improve de elicitation process (Roselli et al., 2019). Furthermore, the BSC also enables the inclusion of lean indicators in the four perspectives, a trend while thinking about the issue of sustainability (Kaplan & Norton, 1992; Leung et al., 2006; Almeida et al., 2016; Medel-González et al., 2016; Frej et al., 2019). Figure 1 briefly depicts the phases of the proposed approach. The approach's description is exhibited, as follows.

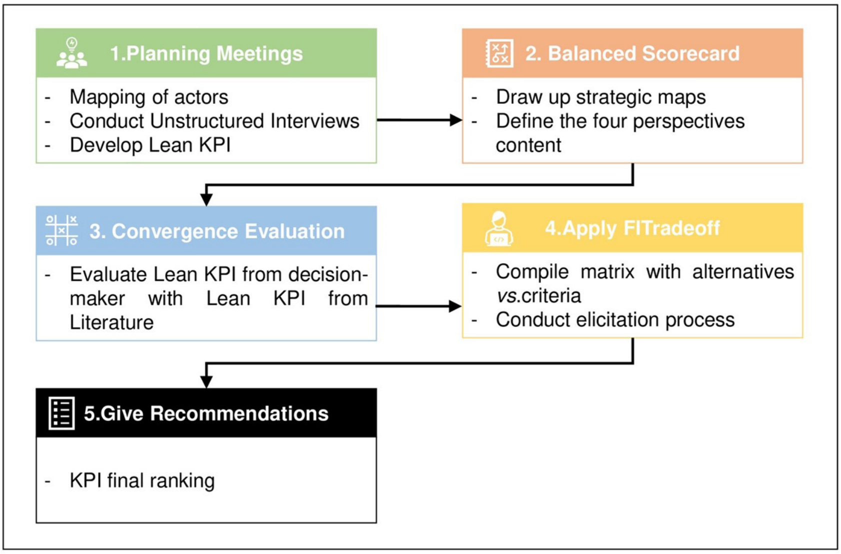

Figure 1. Proposed approach. Source: The Authors (2022).

Initially, planning meetings are held to identify the main actors in the study: the decision-maker (DM) and the analyst. The purpose of the study is then discussed with the decision-maker and the relevant information about the studied company are also collected. Similarly, DM rationality and problematic are assessed (Ackermann, 2012).

Afterward, the DM with the support of the analyst develops de first list of lean KPI. The development process begins with the DM being asked to develop a label to that represent the major issue in discussion. Then, the analyst asks about which are the DM objectives? How these objectives can be hierarchized? How these objectives relate to each other and how they can be measured using KPIs? (Silva et al., 2022). The outcome of this process is a first version of the KPIs.

Afterwards, the decision-maker prepares the Balanced Scorecard with the support of the analyst. According to Kaplan & Norton (1992), the Balanced Scorecard is a tool for performance assessment which manages to convert organization's intangible assets, as culture and knowledge, into tangible results. This conversion takes place through the definition of key performance indicators which are based on four perspectives: the financial, customer, internal processes, and learning and growth perspective.

In addition, Hansen & Schaltegger (2016) discuss the main questions about these perspectives, being noticeable its basic characteristics. Firstly, the financial perspective indicates how strategic transformation results in economic success. Next, the customer's perspective shows which organization practices can create value with customers. Then, the prospect of internal processes allows the organization to identify which processes meet the customer expectations. Finally, the perspective of learning and growth discusses the required infrastructure to meet the other perspectives. The preparation of a Balanced Scorecard requires that DM must draft a strategic map with the organization's purposes which encompass the four perspectives of the BSC, as follows; selection of the indicators to measure and to monitor the performance of the objectives; definition of goals, action plans, and initiatives (Kaplan & Norton, 1992; Hoque, 2014).

Later, a screening process in the literature is conducted to identify the lean key performance indicators mostly addressed in the papers of studies focused on this field. To do so, the steps suggested by Denyer & Tranfield (2009) must be carried out. In the first place, the definition of the research purpose is made set. Researchers must define the search area towards the review protocol establishment, which may be keywords to be searched; insertion of Boolean operators which aid the list of keywords in the search process; definition of the search fields; definition of exclusion criteria for studies which are not related to the studied topic; language; type of publication and time horizon. Next, researchers must identify the researched studies following the review protocol thus established. Then, as the studies were identified, researchers should select the studies which will compose the set of papers, by analyzing titles, abstracts, and keywords. Researchers must also analyze and synthesize the studies by detailing individual studies into constituent parts while describing how they are related one to another. Lastly, the results are exhibited as knowledge and information.

Furthermore, the convergences and divergences among the lean KPI identified in the literature and those resulting from the company's BSC will be evaluated. Consequently, in case there are differences, the decision-maker is asked about his contentment with lean indicators of the BSC. If the answer is negative, the decision-maker will list the literature KPI he/she wants to be included in the BSC. In case the decision-maker's answer is positive, the application of the approach is resumed (Silva & Fontana, 2020).

The lean KPI resulting from these previous steps will be taken into account as alternatives to the decision-making process. Thereafter, to settle the draft of the evaluation matrix, the decision-maker must submit those criteria which he/she considers as convenient for analysis. In addition, DM must evaluate the consequences of each criterion for each indicator.

Likewise, the FITradeoff method for ranking problematic is applied through his system available for free download from the website (fitradeoff.org). Flexible Interactive Tradeoff (FITradeoff) is an MCDA method developed by Almeida et al. (2016) which works on eliciting scale constants in a flexible and interactive way via the decision maker's preferences. This method uses partial information and features an axiomatic structure based on additive elicitation methods. FITradeoff application is based on a process of questions and answers about consequences, results in a global value for each alternative taken into account in the decision-making process (Keeney, 1992).

According to Kang et al. (2018) the FITradeoff procedure ponders compensatory rationality and was originally developed to deal with the choice problematic in which DM have to choose one single option out of a set of available alternatives.

Almeida et al. (2016) stated that the first step to apply FITradeoff elicitation procedure for the choice problematic is to obtain an order of the scaling constants (j) of the criteria used in the evaluation process. The scaling constants are referred here as weights for simplification purposes, and its order is obtained throughout questioning the decision-maker which criteria (Cr) he/she would level up for the best consequence (v_j) whether all the (j) criteria were placed in the worst consequence as can be seen in Figure 2.

Figure 3 represents the decision-maker answer to this question, which means that Cr1 was chosen.

This questioning occurs until (w_{j-1}) weight criteria are ordered. This process of questioning will result in the construction of a weigh space (ℓ) which will be explored in order to find the weights values as shown in Equation 1.

$$w \in \ell = \{(w_1, w_2, ..., w_j) \mid w \in R^n : \sum_{i=1}^{n} wj = 1, w_1 > w_2 > ... > w_j \quad (1)$$

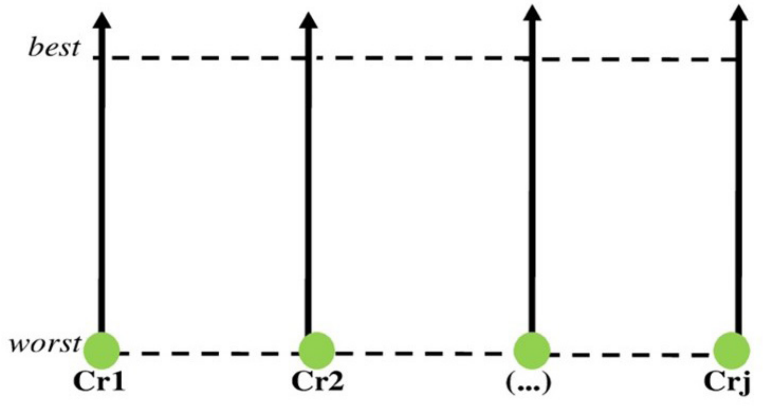

Figure 2. Weight criteria ordering – Initialization. Source: The Authors (2022).

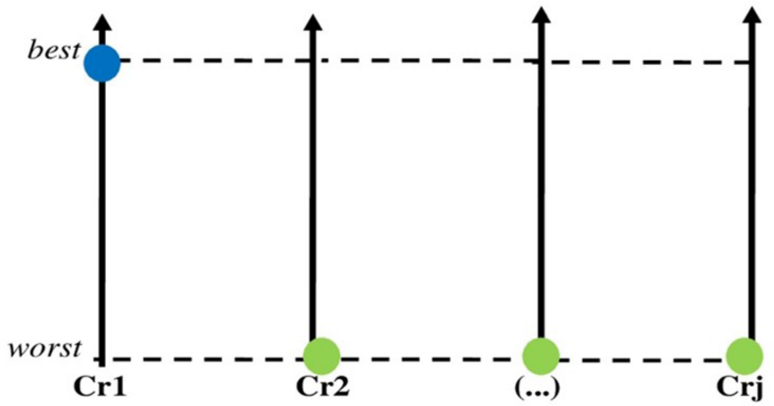

Figure 3. Weight criteria ordering – First cycle. Source: The Authors (2022)

After that, the elicitation of w_j will be performed by the decision-maker evaluating consequences with statements of strict preferences (*P*) which are less cognitively demanding to evaluate. Moreover, Figure 4 exemplifies the elicitation process of FITradeoff.

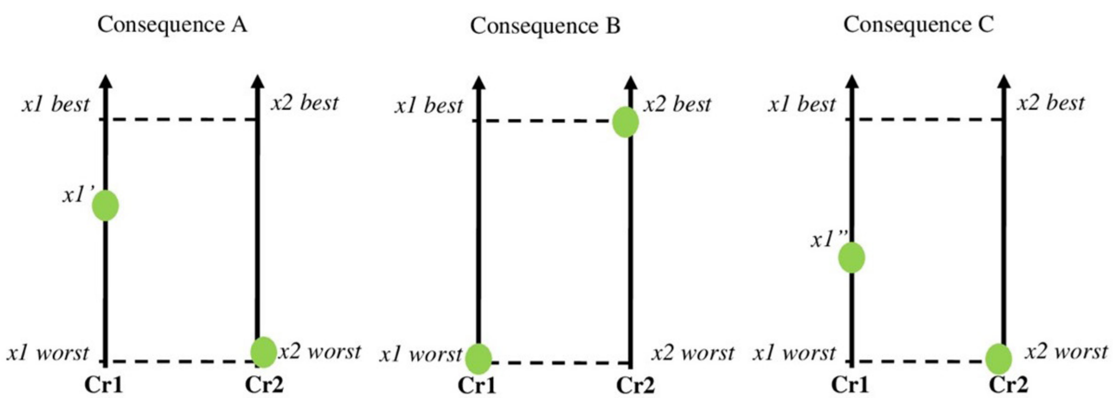

Figure 4. Consequence Evaluation. Source: Adapted from Almeida et al. (2016).

From Figure 4, let us assume that the decision-maker must evaluate the consequences A, B and C for criterion 1(Cr1) and criterion 2(Cr2). The worst result for Cr1 and the best result for Cr2 is in Consequence B. Furthermore, lets also assume that the decision-maker specified that the weight criteria order was ($w_1 > w_2$) and that decision-maker evaluated with strict preferences that Consequence A was better than Consequence B (A*P*B) and Consequence B was better than Consequence C (B*P*C). Consequently, this evaluation will result in a range between the consequences $x1$' to $x1$", and this range must contain the exact indifference point x1. Thus, instead of looking for exact points of indifference, the decision-maker finds ranges of values that contains these points of indifference through the evaluation of consequences using strict preference relations. Then, this range is explored with more consequences evaluations under the conditions of Eq.1 until we find the exact values of w_1 and w_2.

Later, the adaptation of FITradeoff to the ranking problematic, which consists of allocating alternatives in ascending order of preferences, according to Frej et al. (2019) is made through the search for dominance relations in the weight space. The authors state that these relations are obtained by the preferential information given by the DM during the elicitation process demonstrated in Figure 4. Also, the authors argue that the main difference in FITradeoff for ranking problematic when compared with the choice problematic stands for the linear programming problem (LPP) model in Equations 2-7. Differently from the FITradeoff for choice problematic where the objective function attempts to find out the global value of the alternatives, after every consequence evaluated by the decision-maker, the objective function in FITradeoff for ranking problematic in Equation 2 aims at maximizing the difference between the global values of two alternatives. By using this data, a pairwise comparison matrix is put up alongside the dominance relations.

$$\max d_{jz} = \sum_{j=1}^{m} w_j v_j(x_{ij}) - \sum_{j=1}^{m} w_j v_j(x_{iz}) \quad j = 1,\ldots,m; z = 1,\ldots,m; j \neq z \tag{2}$$

s.t.

$$w_1 > w_2 > \ldots > w_m \tag{3}$$

$$w_j v_j(x_i^{'}) > w_{j+1} \quad j = 1 \, to \, m-1 \tag{4}$$

$$w_j v_j(x_i^{''}) < w_{j+1} \quad j = 1 \, to \, m-1 \tag{5}$$

$$\sum_{i=1}^{m} w_j = 1 \tag{6}$$

$$w_j \geq 0, j = 1 \ldots m \tag{7}$$

The first step to apply FITradeoff for the ranking problematic is to order the criteria weights, wherever the consequence for one alternative i in criteria j as shown in Equation 3.

Furthermore, the next step is to find strict preference statements ($x_i' \, and \, x_i''$) which are the values around the indifference point (x_i) in Equations 4-5, where $v_j\left(x_i^{'}\right)$ is the lowest value of the consequence range for Cr*i* and $v_j(x_i^{''})$ is the upper value of the consequence range for the same criterion.

In Equation 6, the weight normalization is shown where the sum of the w_j riteria is equal to one. Equation 7 stands for the LPP models which run in the weight space until the ranking of the alternatives considered is found.

For the ranking process, the method employs a tool which is similar to the Hasse diagram that supports DMs to show the process progress.

Finally, the recommendations on prioritizing lean key performance indicators may be given to the decision-maker.

4. Case study

It is important to mention that to this study be put into practice the company manager have contacted the authors via e-mail to support in the problem resolution. Moreover, all the phases of the proposed approach were conducted with the support of one analyst who was one of the authors. The analyst collected the information regarding the company and the performances throughout the process of the proposed approach application using unstructured interviews. The results of the application of the proposed approach are presented in the next sections, as follows.

4.1. Planning Meetings

The planning meeting took place at the studied company site, which is located in Araripina-PE. This company has more than 20 years in the market and comprises the plaster LPA of Pernambuco, Brazil Northeast. The company also develops activities in the building sector, focused on the production of plaster and derivatives.

Its production process ranges from mining to the production of plaster products with greater added value, such as plaster ceramic, foundry plaster, land plaster, finishing masses, plaster glue, eco blocks, and dental plaster.

The manager responsible for the company's production process was the DM of the study. As the company's main objective is the production system improvement by putting into practice lean manufacturing practices in their operations. The company aims at reducing the waste generated in the process, plus reducing production costs to lower the prices of their products and looks forward to competing shoulder to shoulder with companies which work both in the black economy and legally in the market. One should stress that the analyst was also identified as a key stakeholder in the process.

The DM stated that the involved decision-making process was purely strategic and that she needed to define a priority order of a lean KPI which the company should put into practice to assess the performance of its operations and to develop the appropriate action plans. It was due to the fact the company lacked enough resources for their projects and was undergoing austerity measures as from the economic crisis of 2015.

This order priority emphasizes how urgently the KPI should be effected in the organization to meet its strategic objectives and goals. It was noticed, hence, that the DM was dealing with ranking problematic. Therefore, and still according to the DM, it would be interesting, in the case of the indicators which failed to achieve the performance for certain criteria, that they could be compensated by a better performance in other criteria. In this respect, it was identified that the DM rationality was compensatory. Consequently, the use of the FITradeoff method for ranking problematic to prioritize lean KPI was consistent in the scope thus exhibited.

Afterward, the DM defined his first list of KPIs with the support of the analyst through an interview. The first step was to define a label for the problem. The label defined was "LEAN MANUFACTURING PRACTICES TO IMPROVE COMPETITIVENESS AND SUSTAINABILITY". Later on, the analyst asked the DM what Lean KPI could support the improvement of competitiveness and sustainability in the company. The DM answered the KPI listed in Table 1.

Moreover, the preparation of BSC was put into practice.

Table 1. First list of lean KPI.

KPI	Description
% Profit on Revenue	Profit calculated on sales revenue
Loss of Gypsum on Calcination	[(Kg real gypsum in a month / Gypsum produced in a month) - (Kg real gypsum in a month / Theoretical value of monthly gypsum)]* 100
Loss of Plaster in Bagging	(Number of bags burst in the bagger)
% Block Sector Effectiveness (TEEP)	(Actual production time / Programmed production time) * 100
% NC Product by sector	(Product NC sector / Total production) * 100
Productivity by Sector	(Total production in a month / hours available for production)
Overall Equipment Efficiency (% OEE)	(% availability X% performance X% Quality)
Conforming Parts in a Time Period	(Number of batches produced in quality standards/ work shift)
% Integrated and Motivated Collaborator	(Number of satisfied employees / Total employees) * 100
% Training Hours per Year	(Number of hours trained per month / Hours worked per month) * 100
Water consumption per unit produced	(Water used in m^3 / m^2 Block produced per month)
Process Lead Time	(Actual production time / Programmed production time) * 100
Cycle time	Time needed to produce a product
Number of work accidents per hour worked	Number of accidents / hours worked
CO_2 Emission (Kg/month)	(Average monthly electricity consumption + Average monthly gas consumption / total number of employees)
Employee perception through internal research on the organization's maturity regarding Lean Manufacturing concepts	(Number of Lean practices implemented / Number of Lean practices planned) * 100

4.2. Balanced Scorecard

Later on, and with the support of the analyst, the DM prepared the Company's BSC. Initially, DM prepared the strategic map of BSC. As stated by Kaplan & Norton (1992) the strategic map is a graphical representation of the company's strategy. In this sense, to draw up the BSC strategic map, first, the DM must identify the strategic objectives of the company over the four perspectives of BSC. Moreover, when a perspective is put on the top of BSC, it means that the strategic objectives in this perspective are the most important to the company, and the objectives in the other perspectives below contribute to the top perspective happen. Afterward, the decision-maker links the objectives using arrows that represent relations of cause-effect in a bottom-up logic.

The BSC illustration is shown in Figure 5. For example, the most important strategic objective for the company studied was "Increase Profit" which is within the financial perspective on the top of the strategic map. In order to increase the profit of the company, one necessary objective that must happen is "Cost reduction" which is within the internal processes perspectives placed below the financial perspective. Thus, the arrow goes from the objective "Cost Reduction" in the direction of the objective "Increase Profit". The same reasoning was used to the other objectives and perspectives on the strategic map.

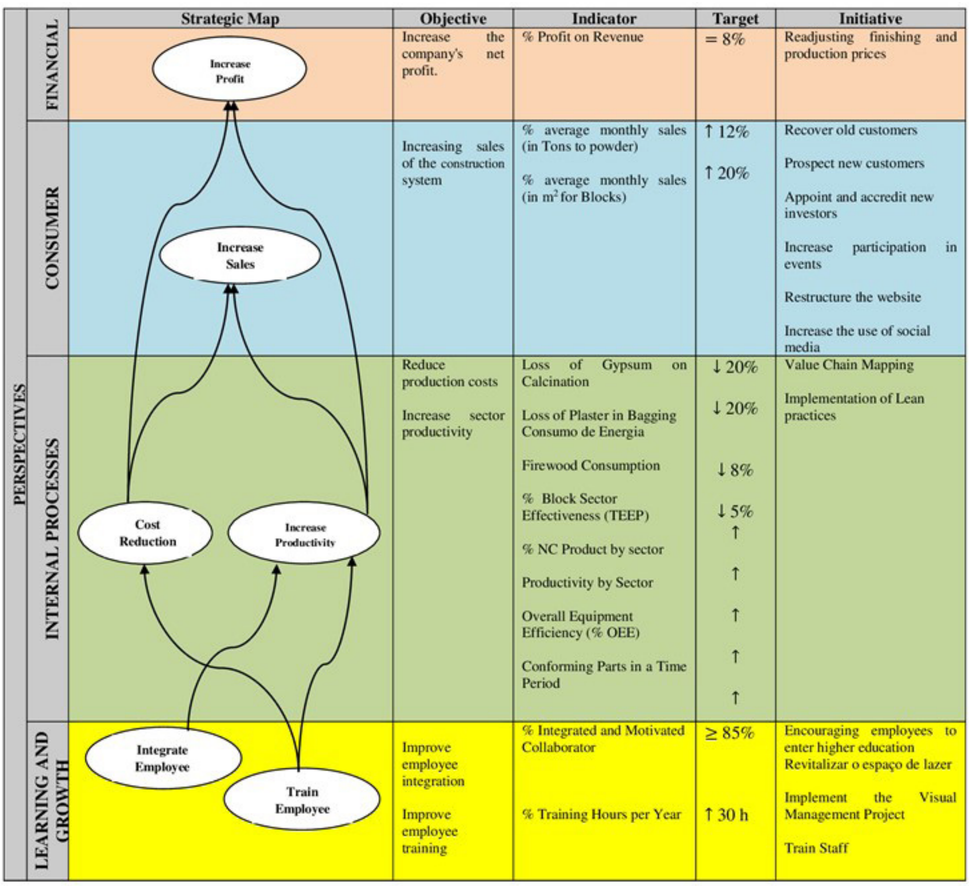

Figure 5. BSC illustration. Source: The Authors (2022).

After which the DM analyzed the strategic objectives and listed lean key performance indicators related to the objectives. At that point, DM identified the targets to be achieved in each one of the objectives upon their evaluation by KPIs. Finally, DM stated the measures to be effected, in order to achieve the strategic purposes. Furthermore, the analyst found that there was a divergence between the list of KPI in the review and the lists from the BSC. Thus, the DM expressed the need of including some of the conflicting KPI to the BSC for the final list of indicators.

During the preparation of BSC the DM felt the necessity of including more KPIs to monitor the objectives. Then, a convergence evaluation was conducted.

4.3. Convergence Evaluation

Subsequently, a screening process in the literature was conducted. The strings used for that purpose were “Key Performance Indicator*”, “Lean Manufacturing*”, “Plastering Industry*” and the Boolean operator “AND”. The review was performed in three databases: Web of Science, Science Direct, Emerald, and Scopus. The inclusion criteria were, as follows: papers from the last 12 years (2010-2022) and written in English. Papers in other languages, other databases, book chapters, undergraduate final projects, dissertations, and thesis were excluded. This first process harvested 15 papers. The papers were then selected, based upon the analysis of the titles, abstracts, and keywords to substantiate their alignment with the study hereof. At the end of the literature review process, five papers were obtained and their respective lean KPIs, which can be seen in Table 2.

Table 2. Lean KPI from screening process.

Perspective	Indicator	Reference
Financial	Operational Cost. Inventory Cost	
Consumer	Number of Social Responsibility Actions. Number of people impacted by Social Responsibility Actions promoted	
Internal Processes	Power Energy Consumption. Water Consumption. Waste Generated. Productivity. Unnecessary movements. Process Lead Time. Cycle time. Self-sufficiency of Water for the Production Process. Effluents Launched (m^3/month). CO_2 Emission (Kg/month)	Azevedo et al. (2012), Aguado et al. (2013); Pampanelli et al. (2014), Alves & Alves (2015), Verrier et al. (2016)
Learning and Growth	Number of work accidents per hour worked. % Training Hours per Year. % Employee satisfaction through internal research. Employee perception through internal research on the organization’s maturity regarding Lean Manufacturing concepts	

The lean KPI identified in the literature review were classified according to the four Balanced Scorecard perspectives to facilitate further analysis.

After that, the analyst compared the list of lean KPI generated by the DM and the lean KPI found in the screening process. Thus, the analyst observed some divergences in both the lists and asked if the DM were willing to include some other KPI in the final list. The DM analyzed the situation and included some other KPI. which are shown in the final list in Table 3. Then, FITradeoff was run.

4.4. Apply FITradeoff

As mentioned before, the final list with KPIs are the alternatives to be ranked in the process, as shown in Table 3.

After that, the DM submitted the evaluation criteria which can be found in Table 4.

To conclude, the DM prepared the evaluation matrix which is shown in Table 5.

The evaluation matrix was used as an input to the FITradeoff for ranking problematic software (FU_T1ONO_LF1 developed by Center for Decision Systems and Information Development – CDSID, free version) in which the elicitation process was carried out.

The DM was initially requested by the software as to provide the criteria weight ranking which was exhibited in descending order of preference: C1 > C3 > C5 > C2 > C4. With this information, the FITradeoff software promptly returned a partial result for the KPI ranking, but the DM still did not feel comfortable by accepting it.

Additionally, to proceed with the elicitation process, the DM was requested to compare fictional consequences on strict preferences relations, as can be seen in Figure 6. At each cycle of questions, the DM could check, via the available graphic tools, the process progress and could stop it anytime she would feel satisfied with the partial results of the elicitation process.

However, DM opted to proceed, and a total of 7 questions were made to the DM to rank the KPIs. Consequently, a partial ranking of the indicators shown in the Hasse diagram in Figure 7 was achieved as final result.

Table 3. Final list of alternatives.

ID	KPI	Description
A_1	% Profit on Revenue	Profit calculated on sales revenue
A_2	% sales monthly average (in Tons to powder)	(Sales Average per month of powder products / Total sales) * 100
A_3	% sales monthly average (in m^2 for Blocks)	(Sales Average per month of block products / Total sales) * 100
A_4	Loss of Gypsum on Calcination	[(Kg real gypsum in a month / Gypsum produced in a month) - (Kg real gypsum in a month / Theoretical value of monthly gypsum)]* 100
A_5	Loss of Plaster in Bagging	(Number of bags burst in the bagger)
A_6	Eletricity Consumption (in kWh/T)	(kWh/ ton produced per month per unit)
A_7	% Block Sector Effectiveness (TEEP)	(Actual production time / Programmed production time) * 100
A_8	% NC Product by sector	(Product NC sector / Total production) * 100
A_9	Productivity by Sector	(Total production in a month / hours available for production)
A_{10}	Overall Equipment Efficiency (% OEE)	(% availability X% performance X% Quality)
A_{11}	Conforming Parts in a Time Period	(Number of batches produced in quality standards/ work shift)
A_{12}	% Integrated and Motivated Collaborator	(Number of satisfied employees / Total employees) * 100
A_{13}	% Training Hours per Year	(Number of hours trained per month / Hours worked per month) * 100
A_{14}	Inventory Cost	(Ordering cost + Transport cost + Maintenance cost)
A_{15}	Number of Social Responsibility Actions	(Number of social responsibility actions implemented per year)
A_{16}	Number of people impacted by Social Responsibility Actions promoted	(Number of people impacted by annual social actions)
A_{17}	Water consumption per unit produced	(Water used in m^3 / m^2 Block produced per month)
A_{18}	Unnecessary movements	Chronoanalysis
A_{19}	Process Lead Time	(Actual production time / Programmed production time) * 100
A_{20}	Cycle time	Time needed to produce a product
A_{21}	Number of work accidents per hour worked	Number of accidents / hours worked
A_{22}	CO_2 Emission (Kg/month)	(Average monthly electricity consumption + Average monthly gas consumption / total number of employees)
A_{23}	Employee perception through internal research on the organization's maturity regarding Lean Manufacturing concepts	(Number of Lean practices implemented / Number of Lean practices planned) * 100

Table 4. List of evaluation criteria.

ID	Criterion	Description	Objective	Scale
C_1	Cost	Cost of implementing the indicator	Minimize	1-Very Low Cost to 5-Very High Cost
C_2	Time	Indicator put into practice time	Minimize	1 - Very Fast to 5- Very Slow
C_3	Urgency	The urgency of implementing the indicators	Maximize	1- Little urgent to 5- Very urgent
C_4	Amplitude	The impact generated by the indicator on internal and external customers	Maximize	1-Very Small to 5- Very Large
C_5	Operationalization	Difficulty in adapting the indicator to the company	Minimize	1 - Very easy to 5-Very Difficult

4.5. Give recommendations

These 17 positions found in the ranking shown in Figure 7 provide the order whereby the lean KPI should be put into practice. From Figure 7 the alternatives ranked in the same position and linked with non-direct grey arrows (---) show indifference relations as found in position 1 between A2 and A3. Moreover, straight arrows show dominance relations (→) as found between A13 and A20.

Moreover, before giving to the DM the recommendations a sensitivity analysis was conducted, and it is shown in Figure 8.

FITradeoff for the ranking problematic does not search for exact weight values either but can work with interval range of possible weight values. It shows how robust the ranking scores obtained are, as it does not change when taking into account the variations in weight ranges, as shown in Figure 8 (Frej et al., 2019).

Table 5. Evaluation matrix.

Alternative	Criterion				
	C_1	C_2	C_3	C_4	C_5
A_1	2	2	5	4	1
A_2	1	1	5	4	1
A_3	1	1	5	4	1
A_4	1	3	5	3	3
A_5	1	2	3	3	2
A_6	1	1	3	5	1
A_7	2	3	4	3	3
A_8	1	1	3	4	1
A_9	1	1	3	3	1
A_{10}	3	4	5	4	4
A_{11}	1	1	3	3	1
A_{12}	3	4	3	3	4
A_{13}	1	3	3	3	1
A_{14}	3	4	5	3	3
A_{15}	2	4	2	2	3
A_{16}	3	4	2	2	4
A_{17}	1	1	3	4	1
A_{18}	3	3	4	4	4
A_{19}	1	3	4	4	2
A_{20}	1	2	3	4	2
A_{21}	1	1	3	3	1
A_{22}	3	4	3	3	3
A_{23}	3	4	4	4	4

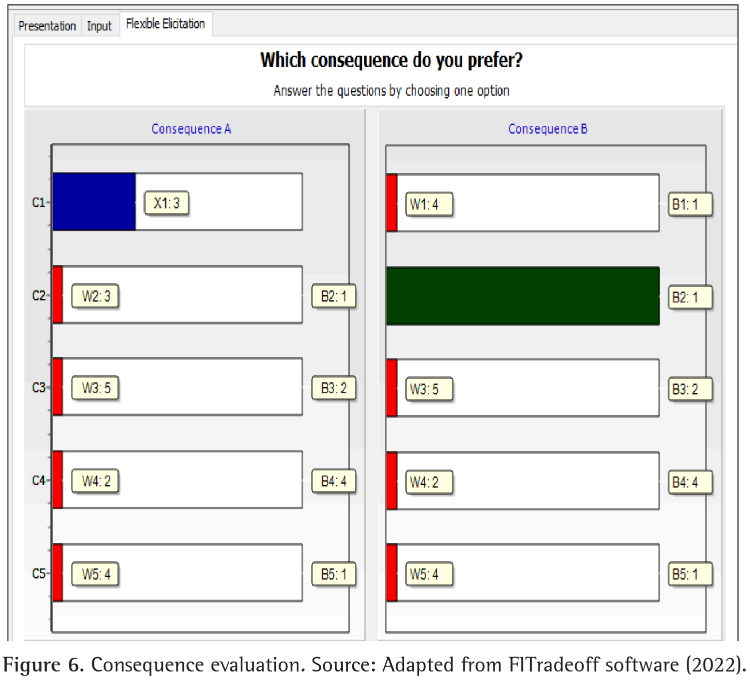

Figure 6. Consequence evaluation. Source: Adapted from FITradeoff software (2022).

More specifically, Figure 8 shows what are the minimum and maximum interval value range, their respective combinations with proper normalization, the weight of the criteria (C1-C5) can assume with no change in the final ranking obtained in Figure 7. Consequently, we may conclude that the final ranking obtained in Figure 7 is robust and does not change in the interval weight range shown in Figure 8 (Silva et al., 2022)

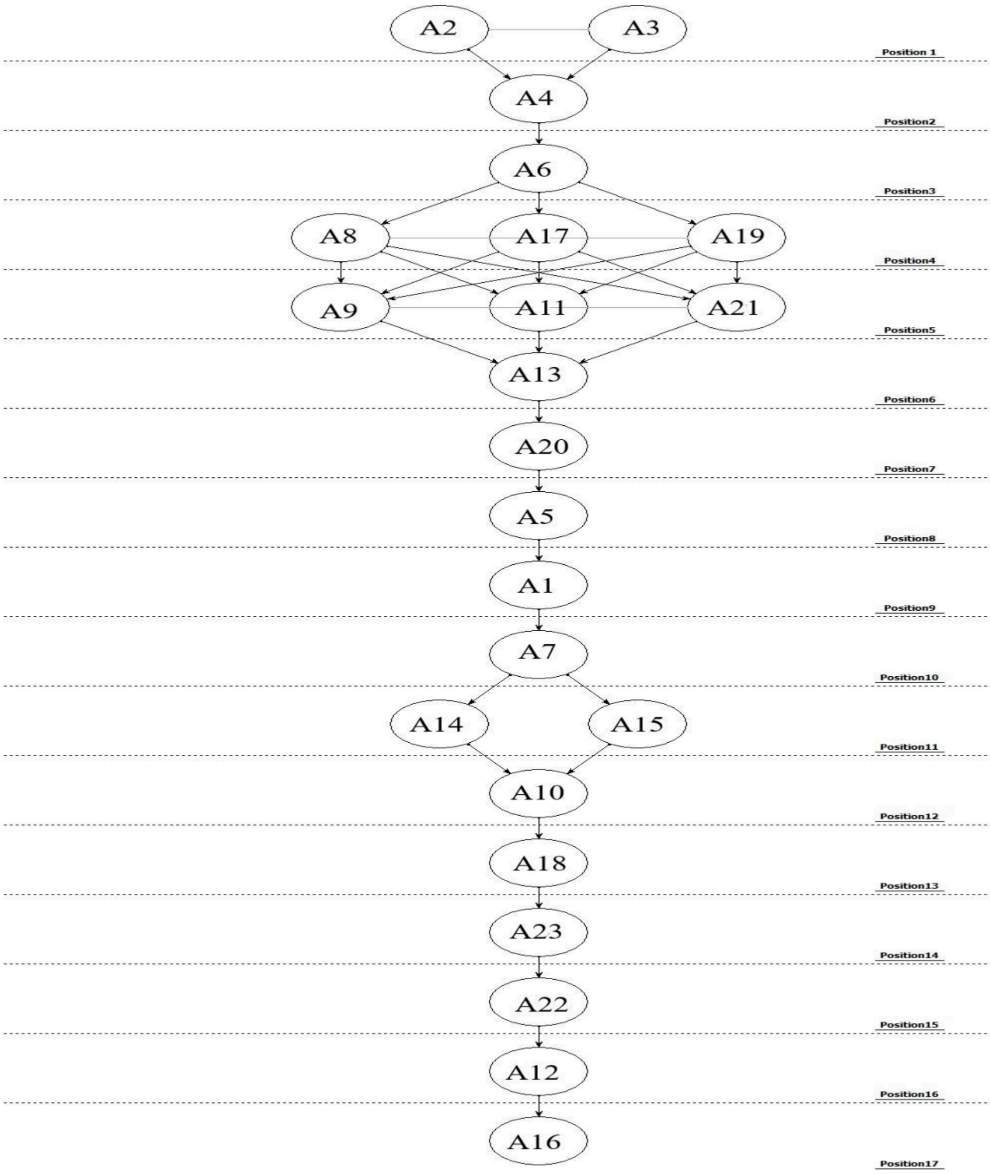

Figure 7. Hasse Diagram. Source: Adapted from FITradeoff software (2022).

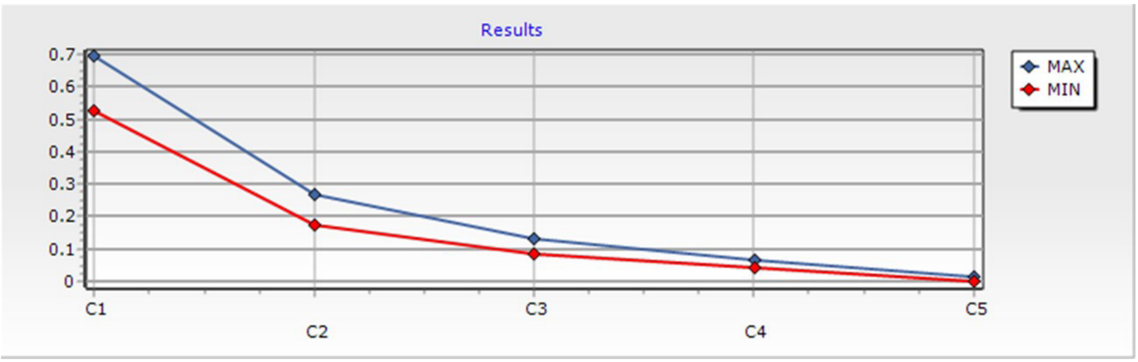

Figure 8. Sensitivity Analysis. Source: Adapted from FITradeoff software (2022).

As a final point, the recommendations were made to the DM who provided positive feedback as to the prioritization. When it comes to the results obtained in the indicators rank, the DM established a monthly plan for their application.

5. Discussions and managerial implications

The studied decision-making process entails more than performance evaluation, it provides the means whereupon DM can strategically plan the operations in order to be resilient in complex business environments. This is due to the approach offered which supports the DM in the attempt to find a feasible solution to her problem case, which did not impose a solution either, when compared with other methodologies (Muro & Jeffrey, 2008).

At first, the planning meetings were important to elucidate the DM purposes on the study and to analyze the information given to avoid some bias (Efremov et al., 2009). It also enabled to exhibit how the consequences of the study were important not only for the company but for the society as a whole (Barnaud et al., 2013).

The advantage of the literature review is also focused on the search strategy defined which showed evidences about the lean KPI studied over the years and its inclusion in BSC (Leal et al., 2019). Although the Scopus database was not considered, this fact did not introduce a bias in the research due the robustness of the other database used. To support this affirmation the results proved that it is possible to include KPI which features a sustainable basis in BSC as the lean KPI. It stands for beyond that, as the managers are prone to think about the cause-effect relationship between sustainable operations and the environmental impact (Singh et al., 2018).

As far as the BSC is concerned, the lean KPI of financial perspective replicated the DM's concern to compare the economic results which are to be obtained by effecting lean practices in the company with strategies and goals to keep the business profitable. In order to the organization's indicators and strategies to be prioritized to successfully meet the expectations of consumers and stakeholders, it is natural for companies to discern their finances and see how their capital can be invested (Modak et al., 2017).

From the consumer's perspective, the DM defined sales growth as a KPI, based on marketing and communication actions with simple tools, like social networks and massive participation in events in the area. DM stated that one of the issues with the greatest impact on the plaster market is the need to improve the way the company communication systems aid the trade of their products. If the company is able to effectively communicate with the type of customer to whom the company wants to sell the products, there will be also impacts on other perspectives. The indicators of this perspective are supported by the study of Fonseca et al. (2013).

In addition, from the perspective of the internal processes, DM asserted that there was a need to reduce costs while increasing the productivity. Upon using indicators which address issues as losses in the production process, consumption of natural resources and maintenance policies to adapt the machinery to the production system as a whole, the DM exhibited concerns regarding the sustainable issues which can add valued image of the company, therefore, adding value with its consumers (Sharma et al., 2015).

Subsequently, from the perspective of learning and growth, the studied indicators referred to the employee's training and willingness to learn. In this respect, the DM reinforces the need of scattering knowledge, expanding it throughout the company. According to the DM, the dominant organizational culture claims the company welcomes the participation of employees in order to identify and to suggest new ways of boosting and enhancing the operations which comprise the production process. The company is therefore willing to invest in employee skills to strengthen their enthusiasm so they can feel it as incorporated to them (Fouladgar et al., 2011).

When it comes to the application of FITradeoff for ranking problematic, the visualization tools were particularly employed in the decision-making process, as the DM could search for them at each questioning cycle to assess whether she was already satisfied with the partial results aimed at decreasing the time spent with the process (Frej et al., 2019).

Moreover, for $j = 5$ criteria, $3(j - 1) = 12$ questions would be required for elicitation in the traditional Tradeoff method. In the KPI prioritization, only 7 questions were required to rank the KPI. It was found that FITradeoff decreased questions by almost 42% when compared with the traditional tradeoff method, which means savings in time and effort for DM. This outcome reinforces that FITradeoff overperformes the traditional Tradeoff as to the number of questions matter (Almeida-Filho et al., 2017).

Another important matter stands for the fact that FITradeoff's 7 questions were on strict preference relations which are easier for the DM to assess. However, in the traditional Tradeoff method, 12 questions would be asked about precise points of indifference whose assessment is more difficulty. Furthermore, if the DM would find any question difficult to answer, she could move on to the next one, without losing information, which clearly depicts the flexibility of FITradeoff (Almeida et al., 2016).

The ranking obtained is also coherent with the DM's preferences on the strategic objectives approached in the BSC. As the company's main purpose was the growth of profit, more expensive indicators were ranked in positions farther from the first position, as it happens with A22 and A23.

Finally, the proposed approach differs from others identified in the literature in two major points. In first place, lean KPI were included in the four perspectives of BSC, which the alignment with sustainable trends to plan operations. Next, FITradeoff for ranking problematic requires cognitively easier information from DM for the decision-making process, and a lower volume of information which is crucial for real world applications.

6. Conclusions

The objective of identifying, exploring, and prioritizing lean KPI arising from an analysis process of the Balanced Scorecard was carried out through FITradeoff for the ranking problematic. In this respect, the company manager welcomed the recommendations of the proposed approach, emphasizing that the plan to effect the lean KPI arising out of the elicitation process would be followed.

In addition to the benefits aforementioned, the study hereof brought real managerial effects. For the company, the prioritization of indicators indirectly allowed for the prioritization of actions linked to these KPI, which made it possible to improve the entire production system when they were put into practice. It further leads to a reduction in the product prices while increasing the company's turnover, as the foremost objective approached in BSC. These results made the company more competitive, and, thus resilient at LPA plastering supply chain. Moreover, the corporate image was also enhanced with added value, as lean key performance indicators and their linked practices featured a sustainable positive impact, by reducing the waste generated in the process. Consequently, they preserved the environment.

Finally, this study limited its analysis to only one company so that future studies are required for the application of the proposed approach to more other companies of the LPA for comparative purposes so to successfully identify the best practices in this field.

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References

Abreu, M., Alves, A., & Moreira, F. (2017). Lean-green model for eco-efficient and sustainable production. *Energy*, *137*, 846-853. http://dx.doi.org/10.1016/j.energy.2017.04.016.

Ackermann, F. (2012). Problem structuring methods "in the dock": Arguing the case for Soft or. *European Journal of Operational Research*, *219*(3), 652-658. http://dx.doi.org/10.1016/j.ejor.2011.11.014.

Aguado, S., Alvarez, R., & Domingo, R. (2013). Model of efficient and sustainable improvements in a lean production system through processes of environmental innovation. *Journal of Cleaner Production*, *47*, 141-148. http://dx.doi.org/10.1016/j.jclepro.2012.11.048.

Almeida, A., Almeida, J., Costa, A., & Almeida-Filho, A. (2016). A new method for elicitation of criteria weights in additive models: flexible and Interactive Tradeoff. *European Journal of Operational Research*, *250*(1), 179-191. http://dx.doi.org/10.1016/j.ejor.2015.08.058.

Almeida-Filho, A., Almeida, A., & Costa, A. (2017). A flexible elicitation procedure for additive model scale constants. *Annals of Operations Research*, *259*(1-2), 65-83. http://dx.doi.org/10.1007/s10479-017-2519-y.

Alves, J., & Alves, J. (2015). Production Management model integrating the principles of lean manufacturing and sustainability supported by the cultural transformation of a company. *International Journal of Production Research*, *53*(17), 5320-5333. http://dx.doi.org/10.1080/00207543.2015.1033032.

Azevedo, S., Carvalho, H., Duarte, S., & Cruz-Machado, V. (2012). Influence of Green and lean upstream supply chain management practices on business sustainability. *IEE Transactions on Engineering Management*, *59*(4), 753-765. http://dx.doi.org/10.1109/TEM.2012.2189108.

Baines, T., Lightfoot, H., Evans, S., Neely, A., Greenough, R., & Peppard, J. (2007). State-of-art in product-service systems. *Proceedings of the Institution of Mechanical Engineers Part B: Journal of Engineering Manufacture*, *221*(10), 1543-1552. http://dx.doi.org/10.1243/09544054JEM858.

Barata, J., Quelhas, O., Costa, H., Gutierrez, R., Lameira, V. J., & Meiriño, M. (2014). Multi-criteria indicator for sustainability rating in suppliers of the oil and gas industries in Brazil. *Sustainability*, *6*(3), 1107-1128. http://dx.doi.org/10.3390/su6031107.

Barnaud, C., Le Page, C., Dumrongrojwatthana, P., & Trébuil, G. (2013). Spatial representations are not neutral: Lessons from a participatory agent-based modelling process in a land-use conflict. *Environmental Modelling & Software*, *45*, 150-159. http://dx.doi.org/10.1016/j.envsoft.2011.11.016.

Bui, T., Tsai, F., Tseng, M., Tan, R., Yu, K., & Lim, M. (2021). Sustainable supply chain management towards disruption and organizational ambidextery: a data driven analysis. *Sustainable Production and Consumption.*, *26*, 373-410. http://dx.doi.org/10.1016/j.spc.2020.09.017. PMid:33015266.

Camilo, D., Souza, R., Frazão, T., & Costa Junior, J. (2020). Multi-criteria analysis in the health area: selection of the most appropriate triage system for the emergency care units in natal. *BMC Medical Informatics and Decision Making*, *20*(1), 38. http://dx.doi.org/10.1186/s12911-020-1054-y. PMid:32085757.

Denyer, D., & Tranfield, D. (2009). Producing a systematic review. In D. A. Buchanan & A. Bryman (Eds.), *The SAGE handbook of organizational research methods* (pp. 671-689). Londres: Sage Publications.

Dinçer, H., Hacioglu, U., & Yuksel, S. (2017). Balanced scorecard-based performance measurement of European airlines using a hybrid multicriteria decision making approach under the fuzzy environment. *Journal of Air Transport Management*, *63*, 17-33. http://dx.doi.org/10.1016/j.jairtraman.2017.05.005.

Echegaray, F. (2021). What post-COVID-19 lifestyles may look like? Identifying scenarios and their implications for sustainability. *Sustainable Production and Consumption.*, *27*, 567-574. http://dx.doi.org/10.1016/j.spc.2021.01.025. PMid:34722841.

Efremov, R., Insua, D., & Lotov, A. (2009). A framework for participatory decision support using Pareto frontier visualization, goal identification and arbitration. *European Journal of Operational Research*, *199*(2), 459-467. http://dx.doi.org/10.1016/j.ejor.2008.10.034.

Esa, M., Halog, A., & Rigamonti, L. (2017). Strategies for minimizing construction demolition wastes in Malaysia. *Resources, Conservation and Recycling*, *120*, 219-229. http://dx.doi.org/10.1016/j.resconrec.2016.12.014.

Fagnani, E., & Guimarães, J. (2017). Waste management plan for higher education institutions in developing countries: the continuous improvement cycle model. *Journal of Cleaner Production*, *147*, 108-118. http://dx.doi.org/10.1016/j.jclepro.2017.01.080.

Felice, F., Petrillo, A., & Autorino, C. (2015). Development of a framework for sustainable outsourcing: Analytic Balanced Scorecard Method (A-BSC). *Sustainability*, *7*(7), 8399-8419. http://dx.doi.org/10.3390/su7078399.

Fonseca, A., McAllister, M., & Fitzpatrick, P. (2013). Measuring what? A comparative anatomy of five mining sustainability frameworks. *Minerals Engineering*, *46-47*, 180-186. http://dx.doi.org/10.1016/j.mineng.2013.04.008.

Fouladgar, M., Yazdani-Chamzini, A., & Zavadskas, E. (2011). An integrated model for prioritizing strategies of the Iranian mining sector. *Technological and Economic Development of Economy*, *17*(3), 459-483. http://dx.doi.org/10.3846/20294913.2011.603173.

Freitas, J., & Costa, H. (2017). Impacts of Lean Six Sigma over organizational sustainability: a systematic literature review on scopus base. *International Journal of Lean Six Sigma*, *8*(1), 89-108. http://dx.doi.org/10.1108/IJLSS-10-2015-0039.

Freitas, J., Costa, H., & Ferraz, F. (2017). Impacts of Lean Six Sigma over organizational sustainability: a survey study. *Journal of Cleaner Production*, *156*, 262-275. http://dx.doi.org/10.1016/j.jclepro.2017.04.054.

Frej, E., Almeida, A., & Costa, A. (2019). Using data visualization for ranking alternatives with partial information and interactive tradeoff elicitation. *Operations Research*, *19*(4), 909-931. http://dx.doi.org/10.1007/s12351-018-00444-2.

Giannopoulos, G., Holt, A., Khansalar, E., & Cleanthous, S. (2013). The use of the balanced scorecard in small companies. *International Journal of Business and Management*, *8*(14), 1-22. http://dx.doi.org/10.5539/ijbm.v8n14p1.

Hansen, E., & Schaltegger, S. (2016). The sustainability balanced scorecard: a systematic review of architectures. *Journal of Business Ethics*, *133*(2), 193-221. http://dx.doi.org/10.1007/s10551-014-2340-3.

Hoque, Z. (2014). 20 years of studies on the balanced scorecard: trends, accomplishments, gaps and opportunities for future research. *The British Accounting Review*, *46*(1), 33-59. http://dx.doi.org/10.1016/j.bar.2013.10.003.

Huang, T., Pepper, M., & Bowrey, G. (2014). Implementing a sustainability balanced scorecard to contribute to the process of organisational legitimacy assessment. *Journal of Business Finance & Accounting*, *8*, 15-34.

Instituto de Tecnologia de Pernambuco. (2019). *Centro Tecnológico do Gesso: pólo gesseiro do Araripe*. Recife: ITEP. Retrieved in 25 April 2022, from http://www.ipa.br/novo/arquivos/paginas/1-Relat%C3%B3rio%20apresenta%C3%A7%C3%B5es.pdf

Kang, T., Soares Junior, A., & Almeida, A. (2018). Evaluating electric power generation technologies: a multicriteria analysis based on the FITradeoff method. *Energy*, *165*, 10-20. http://dx.doi.org/10.1016/j.energy.2018.09.165.

Kaplan, R. S., & Norton, D. (1992). The balanced scorecard: measures that drive performance. *Harvard Business Review*, *70*(1), 71-79. PMid:10119714.

Keeney, R. (1992). *Value focused thinking.* Cambridge: Harvard University Press.

Klepa, R., Medeiros, M., Franco, M., Tamberg, E., Farias, T., Paschoalin Filho, J., Berssaneti, F., & Santana, J. (2019). Reuse of construction waste to produce thermoluminescent sensor for use in highway traffic control. *Journal of Cleaner Production*, *209*, 250-258. http://dx.doi.org/10.1016/j.jclepro.2018.10.225.

Leal, G. S. S., Guérdia, W., & Panetto, H. (2019). Interoperability assessment: a systematic literature review. *Computers in Industry*, *106*, 111-132. http://dx.doi.org/10.1016/j.compind.2019.01.002.

Leung, L., Lam, K., & Cao, D. (2006). Implementing the balanced scorecard using the analytic hierarchy process & the analytic network process. *The Journal of the Operational Research Society*, *57*(6), 682-691. http://dx.doi.org/10.1057/palgrave.jors.2602040.

Majumdar, A., Shaw, M., & Sinha, S. (2020). COVID-19 debunks the myth of socially sustainable supply chain: a case of the clothing industry in south asian countries. *Sustainable Production and Consumption*, *24*, 150-155. http://dx.doi.org/10.1016/j.spc.2020.07.001.

Medel-González, F., García-Ávila, L. F., Salomon, V. A. P., Marx-Gómez, J., & Hernández, C. T. (2016). Sustainability performance measurement with Analytic Network Process and balanced scorecard: Cuban practical case. *Production*, *26*(3), 527-539. http://dx.doi.org/10.1590/0103-6513.189315.

Mendes, J. A. J., Frej, E. A., Almeida, A. T., & Almeida, J. A. (2020). Evaluation offlexible and interactive tradeoff method based on numerical simulation experiments. *Pesquisa Operacional*, *40*, 1-25. http://dx.doi.org/10.1590/0101-7438.2020.040.00231191.

Modak, M., Pathak, K., & Ghosh, K. (2017). Performance evaluation of outsourcing decision using a BSC and Fuzzy AHP approach: a case of the Indian coal mining organization. *Resources Policy*, *52*, 181-191. http://dx.doi.org/10.1016/j.resourpol.2017.03.002.

Mourtzis, D., Fotia, S., & Vlachou, E. (2017). Lean rules extraction methodology for lean PSS design via key performance indicators monitoring. *Journal of Manufacturing Systems*, *42*, 233-243. http://dx.doi.org/10.1016/j.jmsy.2016.12.014.

Muro, M., & Jeffrey, P. (2008). A critical review of the theory and application of social learning in participatory natural resource management processes. *Journal of Environmental Planning and Management*, *51*(3), 325-344. http://dx.doi.org/10.1080/09640560801977190.

Neri, A., Cagno, E., Lepri, M., & Trianni, A. (2021). A triple bottom line balanced set of key performance indicators to measure the sustainability performance of industrial supply chains. *Sustainable Production and Consumption*, *26*, 648-691. http://dx.doi.org/10.1016/j.spc.2020.12.018.

Nooraie, V., Fathi, M., Narenji, M., Parast, M., Pardalos, P., & Stanfield, P. (2020). A multi-objective model for risk mitigating in supply chain design. *International Journal of Production Research*, *58*(5), 1338-1361. http://dx.doi.org/10.1080/00207543.2019.1633024.

Nudurupati, S., Bititci, U., Kumar, V., & Chan, F. T. S. (2010). State of the art literature review on performance measurement. *Computers & Industrial Engineering*, *60*(2), 279-290. http://dx.doi.org/10.1016/j.cie.2010.11.010.

Pampanelli, A., Found, P., & Bernardes, A. (2014). A lean & Green model for a production cell. *Journal of Cleaner Production*, *85*, 19-30. http://dx.doi.org/10.1016/j.jclepro.2013.06.014.

Ravi, V., Shankar, R., & Tiwari, M. (2005). Analyzing alternatives in reverse logistics for end-of-life computers: ANP and balanced scorecard approach. *Computers & Industrial Engineering*, *48*(2), 327-356. http://dx.doi.org/10.1016/j.cie.2005.01.017.

Rocha, C., & Sattler, M. (2009). A discussion on the reuse of building components in Brazil: an analysis of major social, economic and legal factors. *Resources, Conservation and Recycling*, *54*(2), 104-112. http://dx.doi.org/10.1016/j.resconrec.2009.07.004.

Roselli, L., Almeida, A., & Frej, E. (2019). Decision neuroscience for improving data visualization of decision support in the FITradeoff method. *Operations Research*, *19*(4), 933-953. http://dx.doi.org/10.1007/s12351-018-00445-1.

Salimi, M., & Khodaparast, M. (2019). Providing a combined model of fuzzy AHP and numerical taxonomy analysis for sport organizational ranking and performance appraisal. *International Journal of System Assurance Engineering and Management*, *10*(5), 1133-1144. http://dx.doi.org/10.1007/s13198-019-00843-4.

Saradhi, B. P., Shankar, N., & Suryanarayana, C. (2016). Novel distance measure in fuzzy TOPSIS for supply chain strategy based supplier selection. *Mathematical Problems in Engineering*, *2016*, 1-17. http://dx.doi.org/10.1155/2016/7183407.

Sharma, V., Dixit, A., & Qadri, M. (2015). Impact of lean practices on performance measures in context to Indian machine tool industry. *Journal of Manufacturing Technology Management*, *26*(8), 1218-1242. http://dx.doi.org/10.1108/JMTM-11-2014-0118.

Silva, W., & Fontana, M. (2020). Survey and analysis the critical success factors in the reverse flow inventory management process for returnable packaging. *Brazilian Journal of Operations & Production Management*, *17*, 1-14. http://dx.doi.org/10.14488/BJOPM.2020.040.

Silva, W., Morais, D., & Urtiga, M. (2022). An Integrative negotiation model to deal with conflicts toward water resources management: a case study in Brazil. *Environment, Development and Sustainability*, *24*(8), 10443-10469. http://dx.doi.org/10.1007/s10668-021-01866-3.

Singh, S., Olugu, E. U., Musa, S. N., & Mahat, A. B. (2018). Fuzzy-based sustainability evaluation method for manufacturing SMEs using balanced scorecard framework. *Journal of Intelligent Manufacturing*, *29*(1), 1-18. http://dx.doi.org/10.1007/s10845-015-1081-1.

Sufiyan, M., Haleem, A., Khan, S., & Khan, M. (2019). Evaluating food supply chain performance using hybrid fuzzy MCDM technique. *Sustainable Production and Consumption*, *20*, 40-57. http://dx.doi.org/10.1016/j.spc.2019.03.004.

Swarnakar, V., Singh, A., Antony, J., Jayaraman, R., Tiwari, A., Rathi, R., & Cudney, E. (2022). Prioritizing indicators for sustainability assessment in manufacturing process: an integrated approach. *Sustainability*, *14*(6), 3264. http://dx.doi.org/10.3390/su14063264.

Verrier, B., Rose, B., & Caillaud, E. (2016). Lean and Green strategy: the lean and Green house and maturity deployment model. *Journal of Cleaner Production*, *116*, 150-160. http://dx.doi.org/10.1016/j.jclepro.2015.12.022.

Wu, H., Tzeng, G., & Chen, Y. (2009). A fuzzy MCDM approach for evaluating banking performance based on Balanced Scorecard. *Expert Systems with Applications*, *36*(6), 10135-10147. http://dx.doi.org/10.1016/j.eswa.2009.01.005.

Yuksel, I., & Dağdeviren, M. (2010). Using the fuzzy analytic network process (ANP) for balanced scorecard (BSC): a case study for a manufacturing firm. *Expert Systems with Applications*, *37*(2), 1270-1278. http://dx.doi.org/10.1016/j.eswa.2009.06.002.