Paper

Balanced Scorecard Based on a Sustainable Approach for Maintenance Management in the Plastic Industry

Cuadro de mando integral para gestión del mantenimiento con enfoque sostenible en industrias del plástico

MSc. Márian Pérez Pérez[1*] https://doi.org/0000-0002-4358-6801
Dr. Ángel Tomás Pérez Rodríguez[2], https://doi.org/0000-0001-8508-2225
Dr. Estrella María de la Paz Martínez[3], https://doi.org/0000-0003-0819-9555

[1]Department of Industrial Engineering, Faculty of Entrepreneurial Sciences and Management, University of Holguin, Cuba
[2]Department of Chemistry, Faculty of Natural and Agricultural Sciences, University of Holguin, Cuba
[3]Department of Postgraduate Education, *Marta Abreu* Central University of Las Villas, Santa Clara, Cuba

*Corresponding author: marian.perez@uho.edu.cu

ABSTRACT

Aim: To achieve strategic alignment and continuous improvement of maintenance management based on a sustainable approach by designing balanced scorecards in the Cuban plastic industry.

Methods and techniques: Theoretical methods: analysis and synthesis of the concepts of maintenance management based on a sustainable approach; the functional structural systemic method was used to deal with the qualities of this type of management. Empirical methods: document review of definitions analyzed, surveys, and interviews. Mathematical method: Analytical hierarchical process was used to design an indicator that enables measurement of maintenance sustainability.

Main results: A procedure was designed, and an indicator was suggested for evaluation of maintenance sustainability; it was based on the analytical hierarchical process for this type of industry.

Conclusions: The need to design a procedure that enables stakeholders to match the objectives of maintenance management, using a balanced scorecard with a sustainable approach, to those of the organization was demonstrated for the plastic industry. It ensures effective evaluation of sustainability of this type of management, and its impact on groups of interest and society.

Key words: balanced scorecard, sustainable approach, maintenance management, plastic industry, procedure, analytical hierarchical process.

RESUMEN

Objetivo: Lograr el alineamiento estratégico y la mejora continua de la gestión del mantenimiento con enfoque sostenible a través del desarrollo de un cuadro de mando integral en la industria del plástico en Cuba.

Métodos y técnicas: Métodos teóricos: análisis y síntesis de los conceptos sobre gestión de mantenimiento con enfoque sostenible y el sistémico estructural funcional, para abordar las cualidades de este tipo de gestión. Métodos empíricos: revisión documental de las definiciones analizadas, encuestas y entrevistas. Método matemático: proceso de análisis jerárquico para el diseño del indicador que permita medir la sostenibilidad del mantenimiento.

Principales resultados: Se realizó el diseño de un procedimiento y se propuso un indicador para evaluar la sostenibilidad del mantenimiento basado en el proceso analítico jerárquico para este tipo de industria.

Conclusiones: Se demostró la necesidad del diseño de un procedimiento para la industria del plástico que permita alinear los objetivos de la gestión del mantenimiento con enfoque sostenible, con la de la organización a través de un cuadro de mando integral. Permite evaluar de forma efectiva la sostenibilidad de este tipo de gestión y su impacto en los grupos de interés y la sociedad.

Palabras clave: cuadro de mando integral, enfoque sostenible, gestión del mantenimiento, industria del plástico, procedimiento, proceso analítico jerárquico.

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INTRODUCTION

The term sustainable development is defined as development which meets the needs of the current society, without compromising the capacity of future generations to satisfy their needs (World Commission on Environment and Development [WCED], 1987). In recent years, the interest of the scientific community over the study of sustainability has expanded as a result of the growing awareness of the need of development that does not compromise the existence of future generations (Plasencia, 2018). In that sense, maintenance is fundamental for proper operation of companies, and the fulfillment of company goals. Adequate planning, organization, and implementation are essential aspects to reach satisfactory results, since this activity ensures proper functioning of fixed assets, minimizing stoppage times and related costs. Proper maintenance management using a sustainable approach allows for an increase of production, therefore improving the environment, in concert with the development of society. Accordingly, the study of this aspect, and the development of associated research in terms of implementation are critical.

The plastic industry is one of the industries that is largely affecting the environment, and consequently, sustainability. The main problem of plastics is non-biodegradability, so its reintegration to nature takes decades. The world initiative of the United Nations Organization on the environment, known as *Clean Seas Campaign* to reduce ocean trash, has pointed out that more than eight million tons of plastic are dumped into the ocean every year. This study found that, in 2018, between 20 000 and 40 000 tons of plastic were inappropriately managed in Cuba (ONU, 2018).

Currently, the demand of objects, parts, and assembling pieces in Cuba has increased, which has originated the growing need of creating different entities for the transformation of these materials. The newly-created plastics industry in Cuba comprises 38 factories, of which, 24 manufacture containers and packages, and 14 are engaged in the production of hoses, pipes, and hygiene products. Inappropriate handling of wastes from the plastic transformation industry due to technical and management problems is the cause of environmental damages. Hence, the development of this industry will depend largely on the implementation of maintenance management performance with a sustainable approach that will permit to alignment of established objectives with their goals.

One of the most commonly used tool to measure and control performance and strategic management is balanced scorecard (BSC), which includes the application of indicators, measurement, comparison, and adjustment (Lueg & Carvalho, 2013). It was developed by Robert Kaplan and David Norton, in 1992, in order to translate the vision and strategy of organizations into objectives, to which the company's operational and strategic results are integrated by means of a model based on financial and non-financial management indicators with four perspectives: financial, customer, internal operational processes, and learning and growing (Gutiérrez, Santis, Martínez, and Villamizar, 2019; Kaplan and Norton, 2016).

Additionally, organizations need decision-making based on justifiable value judgment, so quantitative assessment using the multi-criteria analysis technique, such as the analytical hierarchy process, will help determine a solution in accordance with the expected objective, placing the priority on key management indicators to evaluate maintenance management processes with a sustainable approach based on BSC.

However, there are still problems in the organization of industrial maintenance. Today, several entities lack a well-defined maintenance policy for their assets and facilities, as corroborated in the diagnostic conducted by the Ministry of Industry in 2013, which concluded that only 15.5% of issues identified were related to the resource availability, and the lack of funding; whereas 84.5% were associated to planning, organization, maintenance management, training, and management (Castro, 2016). According to Cárdenas and Hernández (2018), and studies done by the authors of this research, embracing sustainability by organizations has brought about shortages, particularly in maintenance management and control. Accordingly, the aim of this paper is to achieve strategic alignment and continuous improvement of sustainable-based maintenance management in the plastic industry, using a balanced scorecard with a sustainable approach.

DEVELOPMENT

Maintenance with a sustainable approach

Maintenance with a sustainable approach emerges as a new challenge to companies seeking the creation of economic value without harming the environment, and considering the social aspects. It is defined as the maintenance actions or tasks that foster a balance of all the dimensions of sustainability, and not only focuses on financial terms such as costs of repair and materials used, but also on environmental aspects, like greenhouse gas emissions, and power consumption, considering social aspects related to the safety and health of workers, and stakeholder satisfaction (Jasiulewicz-Kaczmarek and Żywica, 2018). Research done by Amrina, Yulianto, and Kamil (2019), Franciosi, Voisin, Miranda, Riemma & Iung 2020, Jasiulewicz-Kaczmarek and ŻywicA (2018), Nezami and Yildirim (2011), and Sari, Shaharoun, Ma'aram & Yazid (2015), shows the concept of maintenance with a sustainable approach; however, the approach to social and environmental aspects is not dealt with thoroughly. A first glimpse on the concept by Sari *et al*. (2015) shows the definition of sustainability-based maintenance management as the set of necessary processes to ensure an acceptable condition to assets, by removing the negative environmental impact, optimizing resource use, and creating concern about the safety of employees and stakeholders, so that, at the same time, it can be economically viable.

To measure, control, and improve this management appropriately, an adequate measuring framework should be implemented. Some authors have developed measuring frameworks (Sénéchal, 2018; Franciosi *et al*., 2020), but most have focused on the functional or machine level, disregarding their relation with the company's goals. In that sense, so that maintenance actions can encourage a balance of the dimensions of sustainability, this concept should be seen as part of the strategy of maintenance, in alignment with the organization, which can ensure better control of costs of maintenance, higher good and service quality, a reduction of environmental impacts derived from maintenance actions to contribute to economic wellbeing, health, safety, and education of employees (Hennequin & Ramírez, 2016). BSC is a tool that ensures a balanced approach, since it considers financial and non-financial aspects in terms of stakeholders, internal processes, learning, and same-level growth.

Maintenance performance using a balanced scorecard approach

Part of the bibliographic review was done to find the prospects commonly used for assets maintenance management and facilities of manufacturing companies. According to Sari *et al*. (2015), the outcome and value created during maintenance should be measured, controlled, and improved using an adequate performance measurement system.

Sustainability problems affect every aspect of operation and maintenance management of organizations, so this approach should be integrated to the system of performance measurement. By anticipating this emerging problem, several authors (Galar, Parida, Kumar, Stenström, & Berges, 2011; Jasiulewicz-Kaczmarek and Żywica, 2018; Sari *et al*., 2015) have adopted the economic, environmental, and social sustainability dimensions, instead of only considering the balanced scorecard approach. Other suggest that in addition to considering the four perspectives of BSC alone, the technical dimension should be included. Some studies (Galar *et al*., 2011; Hami *et al*., 2020; Ighravwe & Oke, 2017; Sénéchal, 2018) are only focused on the technical dimension or the economic dimension (also called lean maintenance, which emphasizes on the reduction of maintenance costs, and the elimination of residues, with less attention to the social and environmental dimensions. The ecological dimension deals mainly with economic and environmental aspects, whereas the social dimension is related to safety, satisfaction, and communication to maintenance stakeholder groups.

Generally, the literature rarely considers the four dimensions of maintenance performance with a sustainable approach as a whole: economic, technical, environmental, and social dimensions. Stenico & Tadeu (2019) noted that few companies adopt sustainable-based maintenance because they have no information about this topic and its benefits. Similarly, Jasiulewicz-Kaczmarek (2018) pointed out that studies in this area are still in an early stage. Consequently, it is necessary to study sustainable-based maintenance and its four dimensions: technical, economic, environmental, and social.

Procedures for the selection of key indicators of sustainable-based maintenance management

It was deemed necessary to study the existing procedures. First, a study of sustainable-based maintenance was done to assess the selection of key indicators of performance, and their alignment with the strategic objectives of the organization, using a BSC approach. The procedures suggested by these authors were analyzed: Amrina *et al.* (2019), Franciosi *et al.* (2020), Kumar, Galar, Parida, Stenström & Berges (2013), Sari *et al*. (2015), Sénéchal (2018), Jasiulewicz-Kaczmarek and Żywica, (2018). All of them embraced sustainable-based maintenance performance management indicators; however, some shortcomings were observed during homogenization. For instance, availability can be seen in different ways, and bring about confusion: instant, average, constant, inherent and achieved availability, or operational availability. Another bias has been introduced by the temporary horizon of economic performance considered. It is fundamental to compare this evolution with the value provided by the team, in terms of goods or services produced, and their market value, in order to conduct actual monitoring of economic performance of maintenance actions.

The authors mentioned above suggest more than seventy indicators at three different levels: technical, economic, and organizational. These papers only consider the economic and technical dimensions of sustainability for manufacturing companies explicitly, except Sari *et al*. (2015) and Sénéchal (2018). The social dimension is considered indirectly through worker safety in terms of the number of personal injuries as a result of maintenance. The environmental dimension is considered generally through the concept of environmental damage. In a review of state-of-the-art maintenance performance indicators, Kumar *et al.* (2013) found that in order for maintenance to contribute to a company's strategic objectives, these indicators should include the following challenges (coinciding with the authors of this research): reaching maximum productive capacities of companies, and maximizing equipment availability at lower costs. Besides, the perspectives to consider in the balanced scorecard for proper sustainable-based maintenance performance in the plastic industry are financial, customer and stakeholder satisfaction, internal maintenance, and learning and growth. Sustainability comprises four dimensions: economic, social, environmental, and technical.

Procedure for the implementation of BSC for sustainable-based maintenance performance management in the plastic industry

Procedure design (Fig. 1). It relies on several previously analyzed methodological approaches. It embodies four phases, thirteen steps, and eight tasks; its goal is to match the objectives of sustainable-based maintenance management to those of the organization. It embraces a process-based approach, and the PDVA cycle (planning, doing, verifying, acting), with a proven effectiveness and cost-effectiveness that facilitate the project. It has been conceived for implementation in any organization, regardless of the maturity of management systems in place.

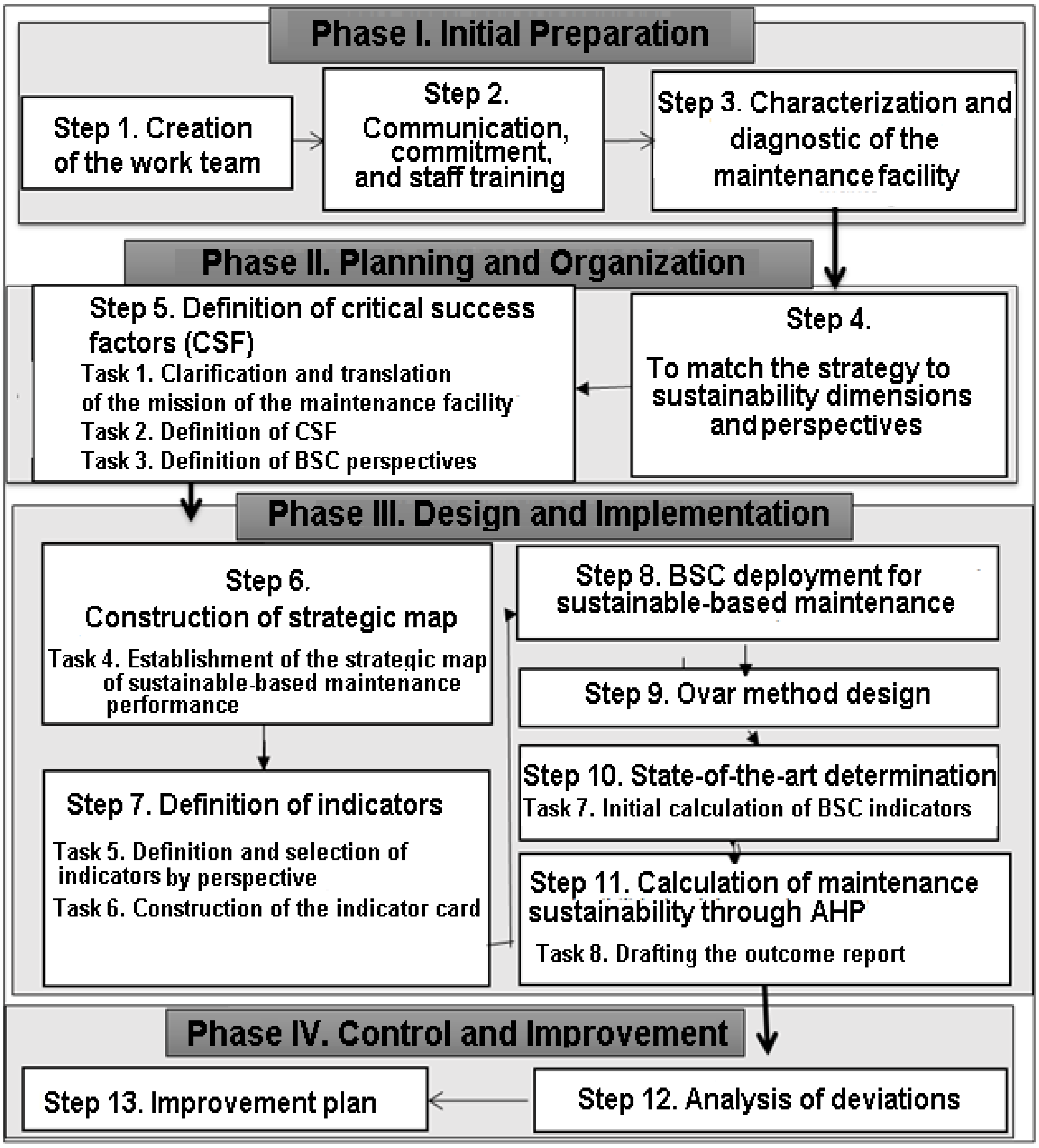

Fig 1. Procedure for BSC implementation in sustainable-based maintenance performance management in plastic transformation factories.

Source: Made by the authors

Phase I: Initial preparation

The objective of the first phase is to create the conditions needed for implementation of the procedure, and the participation and commitment of all the executives and actors involved.

Step 1. Creation of the work team

Specialists with overall and specific knowledge of this topic must be selected. If necessary, experts will receive training on the techniques and methods used.

Step 2. Communication, commitment, and staff training

All the institutional communications channels will be used to keep every party updated. To achieve adequate training, the work team must act in coordination to know the characteristics of the procedure, and learn its advantages.

Step 3. Characterization and diagnostic of the maintenance facility

This step should include the mission, objectives, organizational structure, limitations of the department, staff members, responsibilities assigned, policies used, and management of spare parts, suppliers, and competitors, along with classification as a process of the organization. This characterization must include the equipment name and model, manufacturing year, origin, function, technical status, and years of operation. Moreover, a SWOT matrix must be used to perform a general diagnostic; the groundwork for the design or redesign of the maintenance strategy will be established according to the confluence of strengths, weaknesses, opportunities, and threats. Accordingly, the following must be clearly stated:

1. The strategy at the maintenance facility, so that it uses a sustainable approach in plastic transformation factories.
2. The objectives to be fulfilled, and their relation to the dimensions of sustainability.
3. Stakeholder groups related to sustainable-based maintenance performance.
4. A review of quality policies, environment, vision, and mission of the maintenance facility.

Phase II. Planning and organization

The purpose of this stage is to define the perspectives, dimensions, objectives, and critical factors of BSC success, in terms of sustainable-based maintenance performance, starting with a clarification and translation of the maintenance strategy.

Step 4. To match the strategy to the sustainability dimensions and perspectives.

Accordingly, the alignment matrix between the sustainability strategy and the balanced scorecard is used to accomplish alignment. It consists in the association of objectives that make up BSC perspectives with the pillars of sustainability. Table 1 shows the matrix; each resulting cell from the intersection of a sustainability pillar with a perspective should have at least one objective, and each objective would need, at least, an indicator for measurement and management.

Table 1. BSC perspective alignment with the dimensions of sustainability

	Balanced scorecard perspective			
Dimensions of sustainability	Financial	Customer and stakeholder satisfaction	Internal maintenance process	Learning and growth
Economic	Objective 1	Objective 2	Objective 3	Objective 4
Social	Objective 5	Objective 6	Objective 7	Objective 8
Environmental	Objective 9	Objective 10	Objective 11	Objective 12
Technical	Objective 13	Objective 14	Objective 15	Objective 16

Source: Made by the authors

Step 5 Definition of critical success factors

Task 1. Clarification and translation of the mission of the maintenance facility.

This step defines, in the first place, the mission of the facility (plant or workshop); then, the end and guidelines of the maintenance department are unfold. It permits to establish the metrics, which after fulfilled, act in concert with the strengthening of the competitiveness of the organization.

Task 2. Definition of critical success factors (CSF)

The selection of CSF is critical when identifying the aspects that lead to success or failure of a strategy, and to develop performance indicators in them. They are defined according to strategic goals.

Task 3. Definition of BSC perspectives

Kaplan and Norton (2016) suggest four perspectives in their BSC, which altogether, engulf the financial organization, customers, internal processes, and learning and growth. The possibility of other different perspectives is suggested if the work team deems it necessary. The customer perspective is suggested to be presented to maintenance performance stakeholders.

Phase III: Design and implementation

Step 6. Construction of the strategic map

Task 4. Establishment of the strategic map of sustainable-based maintenance performance

The strategic map offers a simple, coherent, and uniform way of describing a company's strategy. Accordingly, it becomes the missing link between a strategy design and its implementation. The link between perspectives and CSF allows the top executives to analyze the strategy of the company, contributing to improvements in the decision-making processes.

Step 7. Definition of indicators

Task 5. Definition and selection of indicators by perspective

A literature review provided clues to identify the main performance indicators for evaluation of sustainable-based maintenance in the plastic transforming industry. A survey was made, in which experts were asked to select up to 25 indicators that meet the requirement of choosing at least one indicator per objective stated in Phase II. Then, indicators for evaluation of sustainable-based maintenance performance were suggested, according to the dimensions of sustainability

Economic dimension

Indicators: costs of spare parts, the loss of production due to failures, external training, materials used, energy used in the process of production, maintenance of machinery, quality of maintenance tasks (re-work), maintenance budget, staff salary.

Social dimension

Indicators: stakeholder satisfaction, number of work accidents, investment in protection equipment, number of innovations to improve sustainable-based maintenance performance, improvement of labor competencies, safe work environment, communication with stakeholders, employee absence percent.

Environmental dimension

Indicators: energy efficiency, amount of wastes generated, number of fines as a result of violation of environmental laws, total spare parts used (original, recycled or rebuilt), total lubricant used (original, synthetic or from plants), total consumption of treated water, greenhouse gas emissions (CO_2), management of dangerous substances.

Technical dimension

Mean repair time, mean time between failures, general equipment efficiency, stoppages (%), time for corrective action (%), time for preventive actions (%), availability, line efficiency, mean time between maintenance response and intervention, maintainability, and reliability.

According to the design of the survey, each expert must grant a score between 1-5 points (Likert scale) in order to select the level of importance of every indicator: 1 means little important, and 5 means very important. When the score is given to every indicator, the relative importance index (RII) is calculated (Hasan & Beshara, 2020), using the

$$RII = \frac{W}{A*N} = \frac{\sum_{i=1}^{5} \text{frequency of indicator} * i}{A*N}$$

(1) ratio.

Where W is the total indicator weight; i is equal to each indicator's weight by frequency; A is the greatest weight equal to 5; and N is the total surveyed individuals or experts.

After obtaining the RII, the indicators are classified into three ranges: if RII ≥ 0.8, very important; if 0.8 ≥ 0.6, mean; and if RII < 0.6, little important.

Then 5-6 indicators are selected by perspective, making sure that at least one indicator is present in every cell of Table 1. Thus, an adequate mix of performance and result indicators is obtained, considering the existence of a 50% balance in their numbers. The work group checks the selection of final indicators, seeing that no omissions are made of the ones directly related to the compliance of compelling standards.

Task 6. Construction of the indicator card

The creation of the methodological indicator sheet must include name definition, short description, threshold values, calculation formula, person in charge of measurements, measure unit, measurement frequency, and classification.

Step 8. BSC deployment for sustainable-based maintenance

The balanced scorecards are deployed using the previous information, thus allowing for a connection of the strategic direction of the organization to all its process management. They are broken down into cascades throughout the structure of the organization, from the top executives to the physical levels or operational core.

Step 9 Ovar method design

To carry on with this step, a managing technique known as the ovar method was used (objectives, action variables, responsibility), which enables the deployment of strategic objectives in every task of the organization, then they are translated into concrete tasks to be developed. Responsibilities must be defined (Pérez, 2005).

Step 10. State of the art determination

Task 7. Initial calculation of BSC indicators

In this step, the status of BSC indicators are determined; their results help determine the performance of the efficiency and efficacy indicators.

Step 11. Calculation of maintenance sustainability through AHP

AHP comprises three main principles on which decision-making rests: development of hierarchies, assignment of priorities using pair-wise comparison matrices, and the assurance of logical coherence of criteria. The calculation of the maintenance sustainability indicator (MSI) is based on these four steps:

1. Construction of Saaty's analytic hierarchy (1994). A hierarchy of the four dimensions of sustainability is built on established dependence relations, using i indicators, n declared objectives, and multicriteria function (Fig. 2). To determine the weight of each dimension of sustainability, experts must pair-wise compare the objectives based on the Saaty's scale, where 1 means equally preferred; 3, more moderately preferred; 5, more powerfully preferred; 7, very more powerfully preferred; 9, extremely more preferred; and 2, 4, 6, and 8 correspond to mid values used when particularizing is needed, and to build the Saaty's matrix (Table 2). In all the cases, inconsistency has to be under 10%, so expert judgment can be accepted; otherwise further judgment is required.

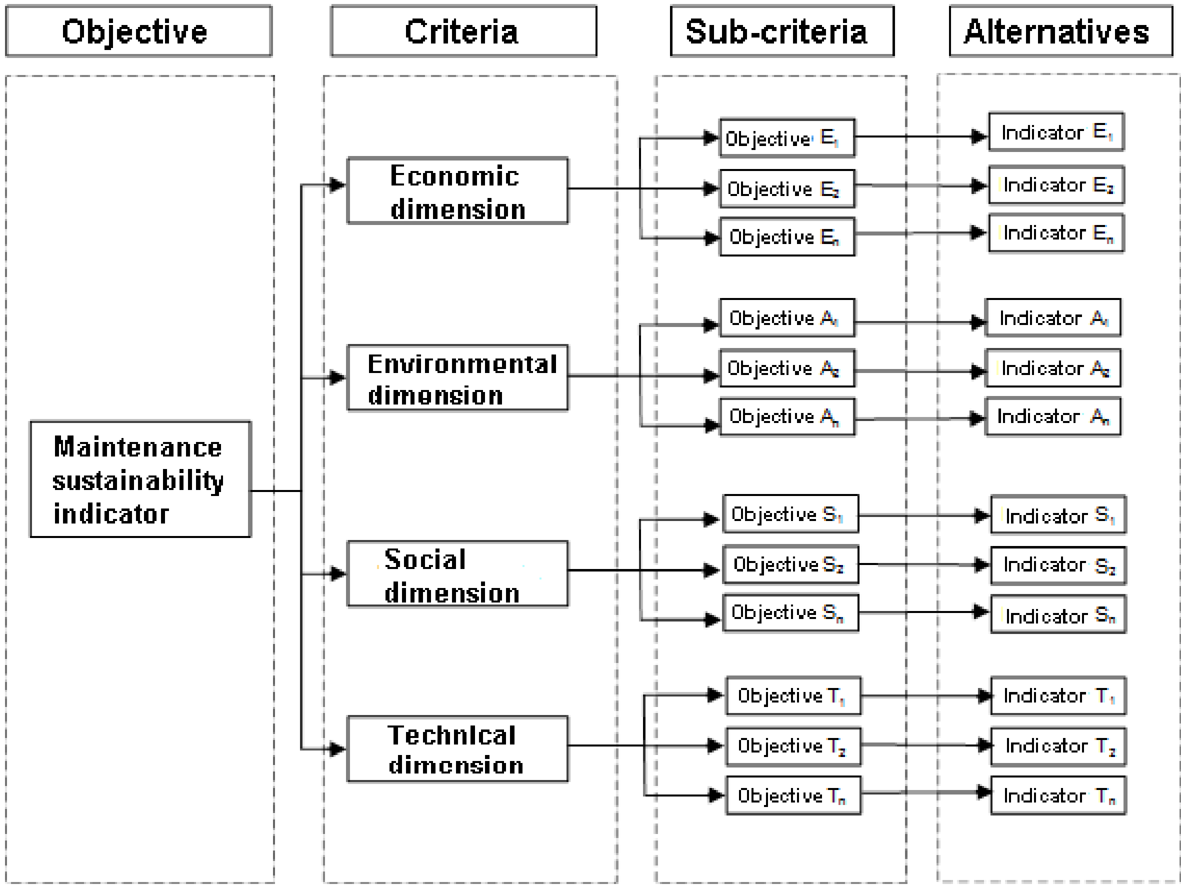

Fig. 2. Saaty's hierarchy to calculate maintenance sustainability

Source: Made by the authors

Table 2. Objective relation matrix

Dimensions of sustainability	**Economic**	**Environmental**	**Social**	**Technical**	**Wn**
Economic	1	x_{12}	x_{13}	x_{14}	w_1
Environmental	x_{21}	1	x_{23}	x_{24}	w_2
Social	x_{31}	x_{32}	1	x_{34}	w_3
Technical	x_{41}	x_{42}	x_{43}	1	w_4
Total					1

Source: Made by the authors

Legend Wn: dimension weight; Xij: value based on Saaty's scale

2. To determine the weight of every objective by dimension. The process of dimension-related objective was performed using a logic similar to the previous. The number of analyses equals the number of objectives developed.

3. To determine the weight of every indicator by objective. The process is made for indicators related to every objective. The number of analyses equals the number of objectives developed. The indicators included are part of the same objective, considering that their relevance to other objectives is null.

4. Analysis of consistency. The analysis of consistency should be done to reduce the effect of subjectivity of preferences from individuals during pair-wise comparison. Hence, it must be calculated according to equations (2) and (3):

$IC = (_{max} - n) / (n - 1)$ (2)

Where, $_{max}$ denotes the maximum own vector, and n represents the dimensions of the matrix and index of consistency (IC).

$RC = IC / RI$ (3) Where RI denotes the random index related to the size of the matrix.

Where RC is the consistency ratio, and RI is the consistency index of a random matrix. Because the RC value must be higher than 0.10, the judgment matrix is thought to be reasonably inconsistent. Otherwise, experts must conduct reevaluation.

5. To determine the overall weight of each indicator. Calculations are made to determine the final weights of indicators (ω_m) using the formula:

$\text{Combined weight of each indicator (\%)} = W_x * W_y * W_z$ (4)

Where:

W_x is the weight of sustainability dimensions.

W_y is the weight of dimensions by objective.

W_z is the weight of dimensions by indicator.

Upon finalizing the Saaty's AHP method, the general indicator is determined; the formula to perform the calculation is $ISM = \sum_{i=1}^{m} (\omega_m \cdot Cu_m)$, where Cu_m shows the completion of indicator m determined by the work team. This variable is binary, it takes value 0 if the result of the indicator does not correspond to the desired state (does not fit the measure criteria), otherwise.

Task 8. Drafting of the outcome report

A report containing the results of each indicator (fulfillment or lack of fulfillment), is made.

Phase IV: Control and improvement

Step 12. Analysis of deviations

The importance, impact, frequency, and occurrence of deviations must be analyzed.

Step 13. Improvement plan

After the analysis of deviations, proactive, preventive, and corrective actions must be taken and implemented effectively. The content of the action, staff in charge of implementing and running them, as well as dates and deadlines of implementation and control must be considered along with the materials to be utilized.

CONCLUSIONS

This research showed that the proposal of indicators to measure sustainable-based maintenance management relies on technical and economic aspects, without considering the social and environmental dimensions.

A procedure made of four phases, thirteen steps, and eight tasks was designed. Its purpose was to match the objectives of sustainable-based maintenance performance management to those of the organization. It comprises the process-based approach, and the PHVA cycle; it was conceived for implementation at any plastic transformation company, regardless of the maturity level it may have in terms of management systems.

Saaty's hierarchy was built for calculation of maintenance performance sustainability indicator, based on the analytical-hierarchical process. Indicators were suggested according to the four dimensions of sustainability in the plastic industry.

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Conflicts of interest and conflict of ethics statement

The authors declare that this manuscript is original, and it has not been submitted to another journal. The authors are responsible for the contents of this article, adding that it contains no plagiarism, conflicts of interest or conflicts of ethics.

Author contribution statement

Márian Pérez Pérez. Procedure design, redaction of the manuscript (equal participation), formal analysis.

Ángel Tomás Pérez Rodríguez. Redaction-original draft (equal participation), systematic bibliographic review.

Estrella María de la Paz Martínez. Redaction-original draft (equal participation), analysis of results, and conculsions.