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Developing an Industrial Sustainability Strategy Model Through Exploratory Factor Analysis and DEMATEL

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A B S T R A C T

Corporate awareness of sustainability has increased significantly alongside growing stakeholder expectations for environmentally responsible practices. The industrial sector's GDP growth in 2023 was accompanied by higher CO_2 emissions, emphasizing the need for a managerial approach that integrates economic, social, and environmental dimensions. This study develops a strategy map based on the Sustainability Balanced Scorecard (SBSC) by identifying key sustainability performance indicators. Using Exploratory Factor Analysis (EFA), 18 indicators were obtained and grouped into four perspectives: Learning and Growth (3 indicators), Internal Business Processes (8), Stakeholders (3), and Financial (4). The Decision-Making Trial and Evaluation Laboratory (DEMATEL) method was then applied to examine causal relationships. Results highlight "green technology innovation," "energy efficiency and renewable energy practices," and "green corporate image" as the most influential indicators. The Internal Business Process perspective was identified as the primary driver of sustainability performance. These findings stress the importance of aligning strategies with operational improvements to achieve balanced economic and environmental outcomes.

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1. INTRODUCTION

The issue of sustainability has emerged as a strategic theme in the management of modern industries in the era of globalization. Over the past few decades, concerns surrounding sustainability have evolved beyond the realm of environmental advocacy and are now recognized as a critical determinant of long-term business success. The industrial sector—particularly manufacturing—has long been acknowledged as a key driver of national economic growth. However, it also significantly contributes to environmental degradation through increased carbon emissions, excessive energy consumption, water pollution, and industrial waste. This

situation presents a paradox between economic growth and environmental preservation, posing a tangible challenge to achieving sustainable development. In Indonesia, the manufacturing sector plays a vital economic role. Nonetheless, recent data indicates that its contribution to environmental problems cannot be overlooked. According to the World Bank (2023), Indonesia's carbon emissions rose by 23.8% between 2015 and 2023. Of the total recorded emissions, approximately 27% originated from industrial activities, with manufacturing and construction accounting for 21.46% (Ministry of Energy and Mineral Resources, 2024). These figures suggest that industrial operational practices are not yet fully aligned with sustainability principles. In other words, a gap persists between achieving productivity and economic efficiency and upholding social responsibility and environmental stewardship.
The push for improvement stems not only from government regulations but also from global market pressures, investor demands, consumer expectations, and the broader international community, all of which increasingly regard sustainability as a benchmark for organizational performance. Thus, transformation toward a more environmentally responsible, efficient, and socially accountable industrial landscape is becoming imperative. Within this context, a managerial approach is needed—one that facilitates the integration of business strategy with sustainability values. One such approach that has gained traction is the Sustainability Balanced Scorecard (SBSC).

The Sustainability Balanced Scorecard (SBSC) is an extension of the Balanced Scorecard (BSC), originally developed by Kaplan and Norton in the early 1990s. While the conventional BSC focuses on four main perspectives—financial, customer, internal business processes, and learning and growth—the SBSC expands this framework by incorporating environmental and social dimensions into organizational performance measurement systems. Hansen and Schaltegger (2016) emphasized that the inclusion of these two additional dimensions makes the SBSC a more holistic and relevant framework for addressing sustainability challenges in modern business practice. The SBSC enables organizations to move beyond short-term profitability and to consider long-term impacts on societal well-being and environmental preservation, consistent with the triple bottom line approach (Schaltegger & Lüdeke-Freund, 2011).However, the implementation of SBSC within Indonesia's manufacturing sector still faces several challenges. A study by Samiun and Damau (2024) reveals that most manufacturing firms in Indonesia have yet to develop a comprehensive understanding of the SBSC concept, particularly in integrating Environmental, Social, and Governance (ESG) indicators into their strategic performance measurement frameworks. Furthermore, many organizations struggle to operationalize sustainability indicators due to limited resources, methodological barriers, and a lack of standards adapted to the local industrial context.

These limitations are compounded by the scarcity of SBSC frameworks that are specifically tailored to particular sectors or subsectors. Existing references are predominantly generic and based on studies conducted in developed countries, making them less applicable to the Indonesian manufacturing sector, which faces its own set of complexities and challenges. For instance, Nurcahyo, Pustiwari, and Gabriel (2018) highlighted the importance of context-based approaches by developing an SBSC-driven strategy map for Indonesia's manufacturing sector. They also employed the DEMATEL method to identify key indicators such as resource efficiency and environmental compliance as strategic priorities. In this regard, the paper industry serves as a compelling example. Its production processes are resource-intensive, involving high consumption of energy, water, and chemicals, while also generating substantial solid and liquid waste that poses environmental risks. According to a UNIDO report (2021), the paper industry is classified as having a high environmental footprint, yet it also holds significant potential for sustainability transformation—through the use of recycled fibers, adoption of cleaner technologies, energy efficiency improvements, and the implementation of integrated waste management systems. However, realizing this potential requires a contextually relevant, strategically grounded, and practically applicable managerial framework such as the SBSC (Trisyulianti et al., 2024).

This study seeks to address these needs by developing a specific and applicable SBSC framework, using a case study of a paper manufacturing plant located in East Java. This site was purposively selected as it represents a large-scale manufacturing facility characterized by operational complexity and a demonstrated concern for both efficiency and environmental issues. Employing a qualitative and participatory research approach, the study involves identifying strategic objectives, formulating sustainability-based performance indicators, and designing causal linkages among SBSC perspectives that reflect real-world conditions.

The principal contribution of this research lies in constructing an SBSC framework that is not only theoretically sound but also practically implementable by corporate management to enhance competitiveness while simultaneously reducing ecological impact. It is hoped that the model developed in this study will serve as a reference for similar industries in Indonesia seeking to design measurable, adaptive, and positively impactful sustainability transformation strategies—economically, socially, and environmentally.

2. LITERATURE REVIEW

The concept of sustainability has become a central theme in global discourse, spanning academic scholarship, public policy, and business practice. The term gained widespread recognition following its introduction by the World Commission on Environment and Development (WCED) in 1987, which defined sustainable development as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." As awareness of the long-term impacts of human activity on the environment and society has grown, sustainability has evolved beyond being merely an environmental concern; it is now regarded as a fundamental principle in the governance of organizations and socio-economic systems at large.

Sadler (1990) emphasized that sustainability encompasses three interrelated dimensions that must be managed in a balanced manner: economic, social, and environmental. These dimensions were later popularized through the Triple Bottom Line (TBL) approach introduced by Elkington (1994), which asserts that organizational performance should not be assessed solely based on financial metrics, but also on its contributions to social well-being and environmental preservation. The economic dimension focuses on how organizations create financial value, maintain production efficiency, and ensure long-term business continuity through prudent resource management. The social dimension includes aspects such as social equity, human rights, occupational health and safety, and human capital development—all of which contribute to the formation of an inclusive and socially responsible organization. On the other hand, the environmental dimension highlights the importance of preserving ecological integrity through waste management, energy efficiency, and sustainable use of natural resources (Brown et al., 1987; Sadler, 1990; Shearman, 1990).

As a derivative of sustainable development, the notion of corporate sustainability has emerged in response to increasingly complex business challenges. Gladwin and Kennelly (1995) define corporate sustainability as a process of building organizations that are connected, equitable, inclusive, and secure. Bansal (2005) further argues that genuine sustainability can only be achieved when an organization simultaneously integrates economic, social, and environmental dimensions into its operations. In practice, corporate sustainability is not merely a form of social responsibility or regulatory compliance; it constitutes the foundation of a long-term, adaptive business strategy.

Moreover, well-managed sustainability initiatives have become a source of competitive advantage for companies. The adoption of the triple bottom line framework provides a strategic basis for navigating the complexities of modern market demands. Laurell et al. (2019) highlight that a sustainability-oriented strategic posture enables firms to create holistic value while enhancing their adaptability to external pressures. Failure to anticipate natural resource constraints, shifting social dynamics, and economic efficiency demands may jeopardize a company's long-term competitiveness. In this context, Lee et al.

(2022) demonstrate that integrating sustainability logic into marketing strategies not only strengthens corporate reputation but also fosters customer loyalty. Similarly, a study by Suroso et al. (2021) in Indonesia's palm oil industry shows that adherence to sustainability principles enhances corporate legitimacy and operational performance. Therefore, strategic approaches that harmonize economic objectives with social interests and environmental stewardship are becoming increasingly critical for firms aiming to thrive in a business environment that demands transparency, accountability, and long-term sustainability.

Balanced Scorecard and its Evolution Toward the Sustainability Balanced Scorecard

In today's increasingly dynamic business environment, relying solely on financial indicators to measure organizational performance is no longer sufficient. The need for a more comprehensive performance measurement system led to the development of the Balanced Scorecard (BSC), a managerial framework introduced by Kaplan and Norton (1996). The BSC was designed to help organizations evaluate performance more holistically through four key perspectives: financial, customer, internal business processes, and learning and growth. Thus, the BSC serves not only as a measurement tool, but also as a strategic framework that bridges long-term vision with day-to-day operational activities.

The financial perspective remains critical within the BSC framework, as it reflects the ultimate outcomes of implemented strategies. Indicators such as profit growth, cost efficiency, and shareholder value demonstrate how effectively an organization generates economic returns. The customer perspective, on the other hand, assesses the company's ability to understand and meet customer expectations—customer satisfaction being a key determinant of loyalty and, ultimately, long-term revenue. The internal business processes perspective directs attention to core activities that add value and drive competitive advantage. Finally, the learning and growth perspective emphasizes the importance of investing in human capital, information systems, and organizational culture as the foundation for sustainable development. These four perspectives are interlinked, enabling management to see the connections between strategy, actions, and results.

However, as awareness of sustainability issues has grown, researchers and practitioners have recognized that the conventional BSC does not fully capture the social and environmental impacts of business activities. This gap has given rise to the concept of the Sustainability Balanced Scorecard (SBSC), which integrates the core principles of the BSC with sustainability values. Figge et al. (2002) argue that the SBSC provides a coherent and strategic system that incorporates the three pillars of sustainability—economic, social, and environmental—into a unified performance measurement framework. The SBSC enables companies to pursue growth and profitability while also remaining accountable to society and the environment.

Several approaches have been proposed for embedding sustainability into the BSC framework. The first approach involves integrating social and environmental issues into the existing four perspectives without altering the BSC structure. In this model, sustainability is treated as a cross-cutting value that should be embedded across all organizational functions, including internal processes, customer service, and human resource development (Epstein, 1996). The second approach entails the addition of a new perspective—commonly referred to as the non-market or community perspective—which broadens the BSC's scope by incorporating the organization's relationships with non-business stakeholders such as local communities, regulators, and NGOs (Bieker & Waxenberg, 2002). A third approach involves creating a separate scorecard specifically dedicated to monitoring social and environmental dimensions. This additional scorecard serves as a complementary tool, allowing organizations to track their ecological and social impacts more systematically.

Through the SBSC, companies are encouraged to build strategies that are not only responsive to market pressures, but also proactive in generating long-term value for all stakeholders. Performance measurement is no longer confined to internal achievements but becomes a reflective tool for assessing a company's social and environmental responsibilities. In this way, the SBSC emerges as a highly relevant tool for addressing the challenges of business in the sustainability era, while simultaneously strengthening the organization's position in building competitive advantage that is ethical, adaptive, and future-oriented.

Green Industry as a Foundation for Sustainable Transformation in Performance Measurement

The green industry concept plays a vital role in steering national industrial transformation toward sustainable practices—environmentally, socially, and economically. This aligns with the mandate of Law No. 3 of 2014 on Industry, which states that one of the objectives of industrial development is the realization of environmentally conscious industrial growth. In this context, the green industry is not merely a technical effort to improve production efficiency, but a comprehensive strategy aimed at fostering sustainability-based competitiveness. In essence, it encourages organizations to shift from a narrow focus on cost efficiency or short-term growth to a broader commitment to resource preservation, environmental protection, and long-term social welfare.

To support this vision, the Ministry of Industry of Indonesia established the Green Industry Award as both a form of recognition and a motivational instrument for companies that adopt environmentally responsible practices in their operations. This award evaluates three key aspects: production processes, waste and emission management, and corporate governance. Each aspect encompasses sustainability-related indicators—ranging from energy and water efficiency, the use of alternative raw materials, to the implementation of environmental management systems and corporate social responsibility programs. In other words, the green industry assessment framework directly reflects a company's commitment to the three pillars of sustainable development: economic, social, and environmental.

The linkage between the green industry concept and strategic performance measurement becomes increasingly important as organizations are expected to embed sustainability values into their decision-making and management systems. This is where the Sustainability Balanced Scorecard (SBSC) emerges as a relevant tool. The SBSC not only enables companies to evaluate performance through the four conventional perspectives—financial, customer, internal business processes, and learning and growth—but also expands its scope by integrating environmental and social dimensions. The SBSC framework facilitates the incorporation of green industry indicators into a more holistic and strategic performance measurement system. For example, initiatives such as energy efficiency and carbon emission reduction, which are assessed in the green industry award, can be translated into performance indicators under the internal processes or environmental perspectives of the SBSC. Thus, the green industry approach serves not only as a technical guideline or environmental policy but also as a foundational basis for building a sustainability-driven performance measurement system. This is especially relevant to the aim of the present study, which is to develop a practical SBSC framework for the manufacturing sector, with a particular focus on the pulp and paper industry. By integrating green industry indicators into the SBSC, companies can not only monitor sustainability performance in a structured manner but also strengthen their strategic transformation toward a greener, more adaptive, and competitive industrial future.

3. RESEARCH METHODOLOGY

This section outlines the systematic stages and methods employed in this study, including the identification of relevant indicators and perspectives for the Sustainability Balanced Scorecard (SBSC), the development of survey instruments, and the sequential process of data analysis. Primary data were collected through two phases of questionnaire-based surveys. The collected data were then analyzed using a quantitative approach that combined Exploratory Factor Analysis (EFA) to identify underlying factor structures and Decision-Making Trial and Evaluation Laboratory (DEMATEL) to model causal relationships among the identified indicators.

Determination of SBSC Perspectives and Indicators

The following section outlines the process of determining the perspectives and corresponding indicators of the Sustainability Balanced Scorecard (SBSC) used in this study.

SBSC Perspectives

The Sustainability Balanced Scorecard (SBSC) is an extension of the conventional Balanced Scorecard, designed to incorporate sustainability as an integral component of organizational performance measurement. Several approaches have been proposed to embed economic, social, and environmental dimensions into the traditional BSC framework. Figge et al. (2002) outlined three primary integration models: (1) embedding sustainability issues within the existing four BSC perspectives, (2) adding a fifth perspective focused on non-market stakeholders, and (3) developing a separate scorecard specifically for sustainability.

This study adopts the first approach, as it is considered the most practical and widely applicable—namely, integrating sustainability issues directly into the four core perspectives. However, a key adjustment was made by substituting the "customer" perspective with a broader "stakeholder" perspective. This modification reflects the view that, in the context of sustainability, affected and interested parties extend beyond customers to include employees, local communities, regulators, and other relevant stakeholders (Munilla & Miles, 2005; Perrini & Tencati, 2006).

Indicators Within the SBSC Perspectives

After establishing the relevant perspectives, the next step was to identify performance indicators for each perspective in a systematic manner. Wang et al. (2022) proposed the integration of green operational objectives into the SBSC by introducing indicators such as energy efficiency, recycling, and waste management, aimed at enhancing the environmental sustainability of business operations. Gazi, Atan, and Kılıç (2022) identified key internal indicators—such as organizational culture, intrapreneurship, and the effectiveness of accounting information systems—that influence SBSC dimensions, particularly in the financial services sector. Meanwhile, Trisyulianti et al. (2024) clustered sustainability indicators based on a literature review and proposed a leveled indicator system to ensure local relevance and alignment with national sustainability policies. By combining these three approaches, the selected indicators in this study are not only grounded in previous empirical studies but also contextualized to align with Indonesia's Green Industry policy framework. This ensures that the developed SBSC model is both locally relevant and operationally applicable within the industrial landscape. The SBSC in this study adopts four standard perspectives: Learning and Growth (P), Internal Business Process (B), Stakeholder (K), and Financial (F). These labels are used consistently throughout the analysis to categorize indicators and interpret the causal structure of the SBSC model. All selected indicators were validated by two corporate social responsibility (CSR) experts from manufacturing firms. A summary of the indicators used in this study is presented in Table 1.

Table 1. Indicators across SBSC perspectives

Financial Perspective (F)		
F1	Profitability	Wang et al. (2022)
F2	Revenue from eco-friendly products	Akbar et al. (2022)
F3	Improvement in employee productivity	Epstein & Wisner (2001)
F4	Green corporate image	Lea et al. (2018)
Stakeholder Perspective (K)		
K1	Enhancement of corporate social responsibility (CSR)	Green Industry (2019)
K2	Corporate sustainability reporting	Green Industry (2019)
K3	Employee satisfaction	Baba et al. (2019)
K4	Anti-bribery policy enforcement	Hsu et al. (2011)
K5	Employee health and safety	Green Industry (2019)
K6	Sustainability awards and recognitions	Green Industry (2019)
K7	Adoption of ethical standards	Epstein & Wisner (2001)
Internal Business Process Perspective (B)		
B1	Product quality improvement	Akbar et al. (2022)
B2	Utilization of recycled materials	Green Industry (2019)
B3	Reduction of greenhouse gas emissions	Green Industry (2019)
B4	Environmentally friendly production	Green Industry (2019)

B5	Facilities for waste and emission management	Green Industry (2019)
B6	Environmental and social standard certifications	Green Industry (2019)
B7	Energy efficiency practices and use of renewable energy	Hsu et al. (2011)
B8	Green supply chain management system	Green Industry (2019)
B9	Workplace accident minimization	Wang et al. (2022)
Learning and Growth Perspective (P)		
P1	Improvement of employee education and skills	Green Industry (2019)
P2	Employee training and certification	Green Industry (2019)
P3	Enhancement of workplace comfort	Baba et al. (2019)
P4	Eco-innovation and green technology	Green Industry (2019)
P5	Environmental information systems	Green Industry (2019)

First-Stage Data Collection and Processing
This section describes the procedures for the initial stage of data collection and processing, which aimed to assess the validity and reliability of the Sustainability Balanced Scorecard (SBSC) indicators. The key steps involved the development of the survey instrument, data collection from respondents, and subsequent analysis using Exploratory Factor Analysis (EFA) to identify the most relevant and representative indicators.

Development of the Stage 1 Questionnaire
The first-stage survey was designed to test the validity and reliability of the proposed SBSC indicators. The primary method employed was Exploratory Factor Analysis (EFA), which facilitates the grouping of indicators and the elimination of less relevant items. Respondents were asked to evaluate the importance of each indicator using a five-point Likert scale, ranging from "strongly unimportant" (1) to "strongly important" (5).

Respondent Demographics – Stage 1
The respondents in this stage were professionals from various manufacturing companies. Most of them worked in departments related to Corporate Social Responsibility (CSR) and Human Resource Development (HRD). In terms of job positions, the majority were staff-level employees or supervisors, with work experience predominantly ranging from 0 to 3 years.

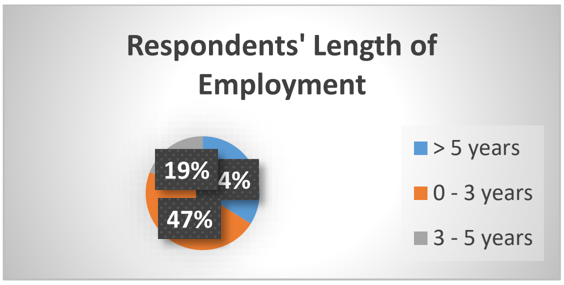

Figure 1. Respondent's length of employement

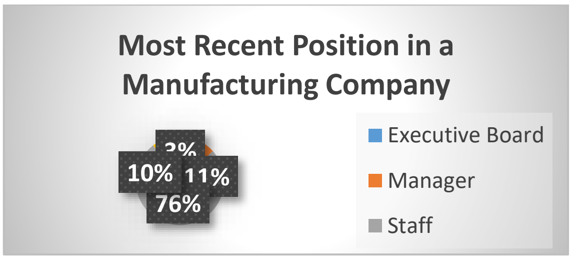

Figure 2. Most recent posititon in a manufacturing company

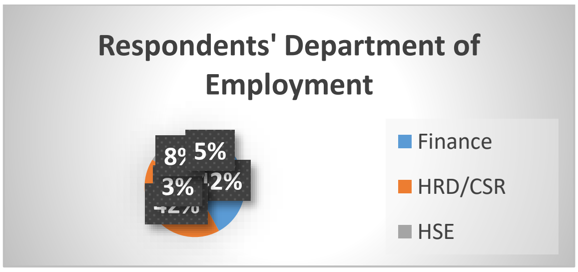

Figure 3. Most recent posititon in a manufacturing company

Reliability and Validity Testing
Reliability testing was conducted using Cronbach's Alpha, with a threshold value of ≥ 0.70 indicating acceptable internal consistency among the items. Validity was assessed using Pearson's correlation coefficient, where items with a correlation value greater than the critical value ($r > 0.376$) were considered valid. The results of the analysis confirmed that all items in the Stage 1 questionnaire met the criteria for both reliability and validity.

Table 2. Reliability test results of stage 1 questionnaire

Perspective	Cronbach's Alpha	Interpretation
F	0,827	Reliable
K	0,788	Reliable
B	0,851	Reliable
Pgrou	0,702	Reliable
Total		Reliable

Stage 1 Data Processing Using Exploratory Factor Analysis (EFA)
Data processing was carried out in stages using

Exploratory Factor Analysis (EFA) to examine the structural validity of the indicators. The analysis included the Kaiser-Meyer-Olkin (KMO) test, Bartlett's Test of Sphericity, cut-off values for factor loadings, composite reliability, and Average Variance Extracted (AVE). The evaluation criteria used in this EFA procedure are summarized in Table 3.

Table 3. EFA evaluation criteria

Assessment	Criteria	References
Bartlett's Test	p < 0,001	Field (2009); Hair et al. (2010);Tabachnick dan Fidell (2007)
KMO	> 0,6	Hair et al. (2010); Tabachnick dan Fidell (2007)
Anti-image correlation matrix	> 0,3	Hair et al. (2010); Pellegrini dan Long (2002); Tabachnick dan Fidell (2007)
Cut-off factor loading	> 0,5	Hair et al. (2010)
Cronbach's Alpha	> 0,7	Pellegrini dan Long (2002)
Average variance extracted	> 0,5	Pepler et al. (2006)
Composite reliability	> 0,8	Ando et al. (2005); Nunnally dan Bernstein (1994)

The total number of indicators analyzed in the SBSC framework was 25, consisting of 4 indicators for the financial perspective, 7 for the stakeholder perspective, 9 for internal business processes, and 5 for learning and growth.

These 25 indicators were processed using EFA, with iterations performed until all assessment criteria were satisfactorily met. The results of the initial EFA processing are presented in Table 4. The financial (F) perspective met all criteria without modification. For the stakeholder (K) perspective, indicator K5 was eliminated. In the internal business process (B) perspective, indicator B9 was removed. The most significant factor reduction occurred in the learning and growth (P) perspective, where indicators P1 and P3 were excluded from the final structure.

Table 4. Initial EFA results for each SBSC perspective

Perspective	Cronbach'sAlpha	KMO	Bartlett'sTest	Removed Item (s)
F	0,827	0,798	p<0.001	-
K	0,788	0,719	p<0.001	K5
B	0,851	0,680	p<0.001	B9
P	0,702	0,634	p<0.001	P1 and P3

Based on the results of the initial EFA, a total of 21 indicators were retained for further analysis. These indicators were then reprocessed through a second EFA to assess whether the revised set met all evaluation criteria. The results of this second round are presented in Table 5.

The results show that the Learning and Growth (P) and Financial (F) perspectives satisfied all required evaluation thresholds. However, the Stakeholder (K) perspective still did not fully meet the assessment criteria. Additionally, Kaplan and Norton (1996) recommend that each BSC perspective should ideally include no more than six objectives or indicators, as limiting the number helps organizations maintain focus on the most critical strategic priorities.

Table 5. Second EFA results for each SBSC perspective

Perspective	Cronbach's Alpha	KMO	Bartlett's Test	Removed Item (s)
F	0,827	0,798	p<0.001	-
K	0,748	0,719	p<0.001	K3 and K4
B	0,859	0,777	p<0.001	-
P	0,701	0.656	p<0.001	-

Following the second round of EFA, 19 indicators remained. However, the stakeholder perspective still failed to fully meet the evaluation criteria. As an additional consideration, Kaplan and Norton (1996) recommend that each BSC perspective contain no more than six indicators, to ensure focus on the most critical strategic objectives.

Table 6. Third EFA results for each SBSC perspective

Perspective	Cronbach's Alpha	KMO	Bartlett's Test	Removed Item (s)
F	0,827	0,798	p<0.001	-
K	0,787	0,745	p<0.001	K1
B	0,859	0,777	p<0.001	-
P	0,701	0.656	p<0.001	-

This third round of analysis resulted in a final set of 18 indicators, distributed as follows: 1 indicator for the learning and growth perspective, 8 indicators for internal business processes, 3 indicators for stakeholders, and 4 indicators for financial performance. These 18 indicators were subjected to a final round of EFA to verify full compliance with the evaluation criteria.

Table 7. Final EFA results for each SBSC perspective

Perspective	Cronbach's Alpha	KMO	Bartlett's Test
F	0,827	0,798	p<0.001
K	0,815	0,679	p<0.001
B	0,859	0,777	p<0.001
P	0,701	0.656	p<0.001

Table 8 presents the final selection of indicators derived through the Exploratory Factor Analysis (EFA) method. Out of the original 25 indicators, 18 indicators were retained based on their compliance with validity and reliability standards. These indicators are grouped under the four core perspectives of the Sustainability Balanced Scorecard (SBSC): Learning and Growth, Internal Business Process, Stakeholder, and Financial.

Within the Learning and Growth perspective, three indicators were selected, each emphasizing a critical organizational capability: enhancement of employee competencies, eco-innovation through sustainable technologies, and the development of environmental information systems. These indicators collectively support the organization's capacity to anticipate and respond to long-term sustainability challenges. The Internal Business Process perspective comprises eight indicators, highlighting the strategic importance of operational efficiency, effective waste and emission management, renewable energy adoption, and environmentally responsible production practices. The relatively high number of indicators in this perspective underscores the pivotal role that internal operations play in driving sustainability within the manufacturing sector.

Meanwhile, the Stakeholder perspective includes three indicators that reflect the organization's commitment to ethical standards, transparency through sustainability reporting, and external recognition via sustainability awards. These indicators signal the company's efforts to build trust and legitimacy among both market and non-market stakeholders.

Lastly, the Financial perspective contains four indicators that assess the extent to which sustainability initiatives contribute to economic performance. These include profitability, revenue from eco-friendly products, employee productivity, and corporate image. This combination of indicators offers a well-balanced representation of the economic, social, and environmental dimensions of sustainability. Furthermore, it provides a strong foundation for developing a sustainability-focused strategy map and conducting causal relationship analysis using the DEMATEL method in the next phase of this research.

Table 8. Final selected indicators across SBSC perspectives

Learning and Growth	Internal Business Process	Stakeholder	Financial
P2	B1	K2	F1
P4	B2	K6	F2
P5	B3	K7	F3
	B4		F4
	B5		
	B6		
	B7		
	B8		

Second-Stage Data Collection and Processing

The second phase of this research focused on deepening the analysis of causal relationships among the indicators and perspectives within the Sustainability Balanced Scorecard (SBSC) framework. Having identified the most relevant performance indicators in the previous stage, the next step was to explore the interdependencies among those indicators. The aim was to build a robust foundation for developing an SBSC strategy map that accurately reflects the causal logic between elements of the sustainability system. To achieve this objective, a questionnaire was developed and distributed to expert respondents in order to gather the necessary data. The collected data were then processed using the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method, which allows for a nuanced analysis of both direct and indirect influence among variables. The results of this analysis are expected to provide a comprehensive understanding of the roles and relative importance of each indicator in the system, thereby supporting the formulation of a sustainability strategy tailored to organizational needs.

Development of the Stage 2 Questionnaire

In the second stage of the study, the questionnaire was designed to identify and analyze cause-and-effect relationships among indicators and perspectives within the SBSC framework. The objective was to establish a logical foundation for constructing the SBSC strategy map by capturing the influence pathways among key elements. The analytical method employed was Decision-Making Trial and Evaluation Laboratory (DEMATEL), a structural analysis approach that reveals the direction and strength of interrelationships among complex variables. This method enables the identification of indicators that function as causal factors and those that are effect factors, along with the degree of their influence. During the survey process, respondents were asked to evaluate the strength of influence between pairs of indicators using a scale from 0 to 4, where 0 indicates no influence and 4 indicates a very strong influence. These evaluations were then processed to generate a causal relationship map that serves as the foundation for the strategy design phase of the SBSC.

The respondents selected for this second-stage survey were experts with more than seven years of professional experience and currently occupying managerial positions. After the questionnaire was distributed, responses were collected from a total of six experts.

Stage 2 Data Processing Using DEMATEL

The second stage of data processing was carried out using the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method. The process began with the construction of a direct-relation matrix (Z), which was derived from the average scores provided by expert respondents on the strength of influence between pairs of indicators. The next step was to normalize matrix Z into a standardized direct-relation matrix (X). This was done by summing the elements of each row and column to determine the maximum value, which served as the basis for normalization.

Once the X matrix was established, further computations were performed to generate the total-relation matrix (T). This matrix reflects the full scope of both direct and indirect relationships among the variables.

From matrix T, two key values were calculated:

- D (row sum): representing the degree of influence a variable exerts on others,
- R (column sum): representing the degree of influence a variable receives from others.
- The combination of these values yielded two essential analytical metrics:
- D + R, which measures the overall level of interactivity or connectivity of a variable, and
- D – R, which indicates the direction of influence, helping to distinguish between cause and effect variables.

These metrics were used to identify which indicators serve as drivers (causes) and which are outcomes (effects) in the system. They also formed the analytical foundation for the construction of the SBSC strategy map. The results of the analysis at the perspective level are presented in Table 9 and Table 10, while the detailed interrelationships among the 18 selected SBSC indicators are shown in Table 11. This data processing approach provides a comprehensive understanding of the role and interconnectedness of each indicator within the sustainability performance measurement system.

Table 9. Total-relation matrix (T) among SBSC perspectives

T	P	B	K	F
P	0,000	0,413	0,392	0,413
B	0,393	0,000	0,388	0,398
K	0,379	0,394	0,000	0,387
F	0,388	0,398	0,382	0,000

Table 10. Influence and relationship metrics among SBSC perspectives

	D	R	D+R	D-R
P	1,218	1,160	2,378	0,058
B	1,179	1,206	2,385	-0,027
K	1,161	1,163	2,323	-0,002
F	1,169	1,198	2,367	-0,029

Table 11. Influence and Relationship Metrics for 18 Selected Indicators

	D	R	D+R	D-R
P2	7,183	6,640	13,823	0,543
P4	7,526	7,354	14,879	0,172
P5	7,150	6,956	14,106	0,193
B1	7,268	7,056	14,324	0,212
B2	6,939	7,385	14,325	-0,446
B3	6,824	7,309	14,134	-0,485
B4	7,124	7,191	14,315	-0,067
B5	7,061	6,761	13,822	0,300
B6	7,162	7,263	14,425	-0,100
B7	7,273	7,605	14,878	-0,332
B8	7,154	6,893	14,047	0,261
K2	6,805	7,058	13,862	-0,253
K6	7,070	6,901	13,971	0,169
K7	6,937	6,766	13,703	0,171
F1	7,144	6,787	13,931	0,357
F2	6,910	7,080	13,990	-0,170
F3	6,856	7,276	14,132	-0,419
F4	7,193	7,300	14,493	-0,107

4. RESULT AND DISCUSSION

Selection of SBSC Indicators

In the first stage of data processing, an Exploratory Factor Analysis (EFA) was conducted to examine the structural validity of the indicators within each SBSC perspective. Reliability testing was performed to assess the internal consistency of each perspective, with Cronbach's Alpha (CA) values ranging from 0.701 to 0.859 (as shown in Table 7). All values exceeded the commonly accepted minimum threshold of 0.70, indicating strong and consistent reliability across the indicators within each perspective.

To complement the CA results, Composite Reliability (CR) values were also calculated. CR is considered a more robust alternative to Cronbach's Alpha, as it addresses several limitations associated with traditional reliability calculations (Chin, 1998). Additionally, Average Variance Extracted (AVE) was evaluated, using a threshold of 0.50 to determine whether each indicator explains more than half of the variance in the latent construct it represents, relative to the variance attributable to measurement error.

The decision to retain or remove an indicator was based on its factor loading, which was compared against a predefined cut-off value. Through four iterative rounds of EFA, indicators that failed to meet the required standards were progressively eliminated. Ultimately, 18 core SBSC indicators were retained, all of which met the validity and reliability criteria. These selected indicators served as the input for the next analytical stage, which involved identifying cause-and-effect relationships among the indicators using the DEMATEL approach.

SBSC Perspectives and Indicators

The DEMATEL method was chosen for this study due to its effectiveness in identifying cause–effect relationships among interconnected sustainability indicators and providing a structured basis for strategic decision-making. Unlike descriptive analyses, DEMATEL produces two essential metrics (D+R and D–R) that allow organizations to understand both the prominence and direction of influence of each indicator. These metrics form the analytical foundation for determining strategic priorities, sequencing initiatives, and allocating resources in sustainability management.

Based on the analysis of the four SBSC perspectives, the Internal Business Process (B) perspective exhibits the highest D+R score (2.385), indicating its central role within the sustainability system. However, because it has a negative D–R value, improvements in operational performance depend on progress made in other perspectives. In contrast, the Learning and Growth (P) perspective is the only one with a positive D–R value (0.058), identifying it as the primary causal domain that drives improvements across the entire system. This implies that strengthening human capital, technological innovation, and environmental information systems should precede efforts focused on internal process optimization, stakeholder engagement, or financial performance. Table 12 presents these relationships numerically.

Table 12. D + R and D – R values for SBSC perspectives

	D	R	D+R	D-R
P	1,218	1,160	2,378	0,058
B	1,179	1,206	2,385	-0,027
K	1,161	1,163	2,323	-0,002
F	1,169	1,198	2,367	-0,029

Interpretation of indicator-level results further refines these managerial insights. In the Learning and Growth perspective (Table 13), all three indicators (P2, P4, and P5) have positive D–R values, making them strong causal drivers. Among them, P4 (Innovation in environmentally friendly technology) has the highest D+R value, reinforcing the view that innovation capability is essential for long-term sustainability transformation.

Table 13. D + R and D – R for learning and growth perspective

	D	R	D+R	D-R
P2	7,183	6,640	13,823	0,543
P4	7,526	7,354	14,879	0,172
P5	7,150	6,956	14,106	0,193

In the Internal Business Process perspective (Table 14), B7 (Energy efficiency and renewable energy practices) emerges as the indicator with the highest D+R value, meaning it is highly interconnected with other indicators. However, because it has a negative D–R value, B7 is categorized as an effect indicator, influenced by other drivers in the system. Causal indicators such as B1, B5, and B8 should therefore be prioritized to create system-wide improvements. In particular, B5 (Waste and Emission Management Infrastructure), which has the highest positive D–R value in this perspective, should be treated as a key operational driver.

Table 14. D + R and D – R for internal business process perspective

	D	R	D+R	D-R
B1	7,268	7,056	14,324	0,212
B2	6,939	7,385	14,325	-0,446
B3	6,824	7,309	14,134	-0,485
B4	7,124	7,191	14,315	-0,067
B5	7,061	6,761	13,822	0,300
B6	7,162	7,263	14,425	-0,100
B7	7,273	7,605	14,878	-0,332
B8	7,154	6,893	14,047	0,261

Within the Stakeholder perspective (Table 15), K6 (Sustainability Awards) and K7 (Ethical Standards) function as causal indicators, while K2 (Sustainability Reporting) functions as an effect. This suggests that improvements in reporting accuracy and transparency are heavily dependent on advances in environmental and operational practices, especially those linked to B6 (Certification), B2 (Use of recycled materials), and B7 (Energy efficiency).

Table 15. D + R and D – R values for stakeholder perspective

	D	R	D+R	D-R
K2	6,805	7,058	13,862	-0,253
K6	7,070	6,901	13,971	0,169
K7	6,937	6,766	13,703	0,171

In the Financial perspective (Table 16), F4 (Green corporate image) has the highest D+R value but a negative D–R value, indicating that it is an outcome strongly influenced by upstream sustainability performance. Only F1 (Profit) serves as a causal indicator, meaning that improvements in profitability support other financial indicators but also reflect broader organizational performance.

Table 16. D + R and D – R values for financial perspective

	D	R	D+R	D-R
F1	7,144	6,787	13,931	0,357
F2	6,910	7,080	13,990	-0,170
F3	6,856	7,276	14,132	-0,419
F4	7,193	7,300	14,493	-0,107

To illustrate these findings, In Figure 4, the horizontal axis displays the 18 SBSC indicators, while the vertical axis represents their D+R scores, indicating the overall prominence of each indicator in the system. Higher bars reflect indicators that interact more strongly with others, making them strategically important to monitor. Although the figure does not involve quadrants or directional arrows, the consistent labeling using P, B, K, and F allows readers to easily identify the indicator's perspective and compare its relative importance within the SBSC structure.

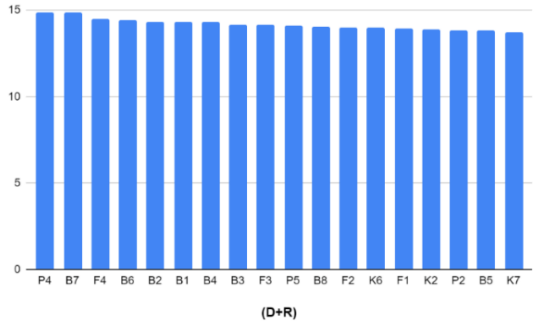

Figure 4. Importance level of SBSC indicators (D+R)

In Figure 5, the vertical axis represents the D–R values, which indicate whether an indicator acts as a cause (positive) or an effect (negative). Indicators positioned above the horizontal axis function as strategic drivers, meaning improvements made in these areas will influence multiple downstream indicators. Conversely, indicators below the axis are reactive outcomes that depend on progress in other domains. The consistent labeling of indicator codes facilitates comparison across perspectives and supports a clearer understanding of each indicator's causal role within the SBSC system.

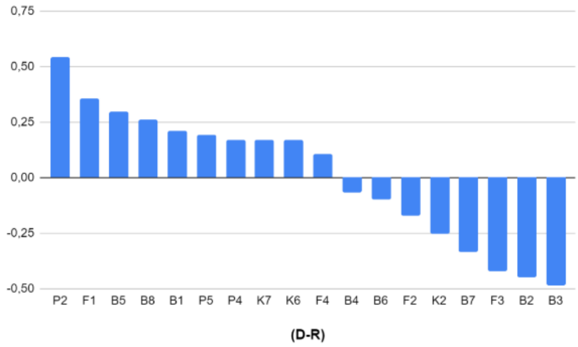

Figure 5. Causal Influence of SBSC indicators (D-R)

The mapping of relationships between perspectives and indicators within the SBSC framework was conducted using a two-dimensional coordinate system based on the D+R and D–R values. The horizontal axis (X) represents the D+R value, which indicates the overall importance or degree of involvement of an element within the system. The vertical axis (Y) represents the D–R value, which distinguishes whether an element functions as a causal (positive value) or reactive (negative value) factor. The resulting visualizations are presented in Figure 6 for the SBSC perspectives and Figure 7 for the 18 analyzed indicators.

In Figure 6, the horizontal axis (D+R) reflects the overall prominence of each perspective, while the vertical axis (D–R) indicates whether a perspective acts as a driver or an outcome. The placement of the Learning and Growth perspective in the positive D–R region confirms its role as the initial driver in the system. Meanwhile, the positions of the Internal Business Process, Stakeholder, and Financial perspectives in the negative D–R area show that they function as reactive components whose performance depends on developments in Learning and Growth. The use of consistent perspective labels (P, B, K, F) ensures clarity in interpretation and alignment with the broader SBSC framework.

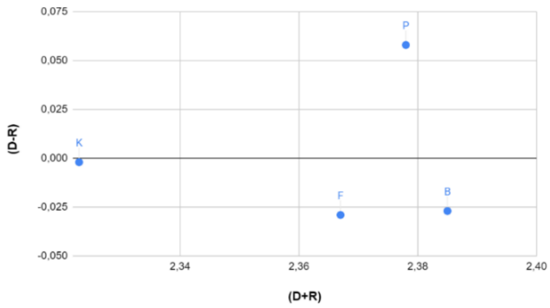

Figure 6. Mapping of (D+R, D–R) for SBSC perspectives

Similarly, in Figure 7, the horizontal axis represents the D+R values that show the overall prominence of each indicator, while the vertical axis displays the D–R values that distinguish causal indicators from reactive ones. The four-quadrant layout helps visualize strategic positioning: indicators in the upper-right quadrant act as strong drivers with high influence, those in the lower-right quadrant serve as important outcomes, and indicators in the left quadrants are comparatively less central. Consistent labeling using indicator codes (P, B, K, F) allows readers to easily identify each indicator's perspective and interpret its strategic role within the SBSC system.

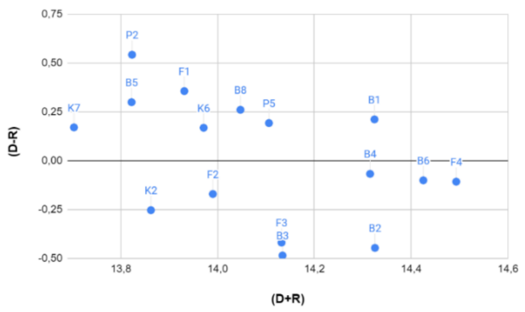

Figure 7. Mapping of (D+R, D–R) for 18 SBSC indicators

Further analysis of the 18 SBSC indicators, as depicted in Figure 7, reinforces these observations. Indicator F4 (Corporate image as an environmentally friendly company) holds the highest D+R value, identifying it as the most important or top-priority indicator. Nevertheless, its negative D–R value indicates that it is an outcome influenced by other indicators. Conversely, indicator P2 (Employee training and certification) records the highest positive D–R value, establishing it as the primary causal driver within the system. This emphasizes the critical role of human resource capacity building (particularly through training) as an essential first step in ensuring the successful implementation of sustainability initiatives. An organization's commitment to sustainability is highly dependent on how effectively employee knowledge and competencies are developed at the outset.

On the other hand, indicator B3 (Reduction of greenhouse gas emissions) registers the lowest D–R value, signifying its position as a terminal outcome shaped by the influence of other factors. Therefore, emission reduction efforts are likely to be effective only when preceded by improvements in causal indicators such as employee training, energy efficiency, and adequate waste management infrastructure.
Overall, the mapping diagrams illustrate that indicators located in the upper-right quadrant are proactive core indicators with substantial influence on the system, exemplified by indicator B1. In contrast, indicators in the lower-right quadrant, such as F4, are important core indicators but are primarily influenced by other factors. Indicators in the upper-left quadrant are causal but less dominant, whereas those in the lower-left quadrant tend to be passive and predominantly affected by external influences. This interpretation provides a robust basis for developing a targeted and sustainable SBSC strategy map.
From a managerial standpoint, the combination of D+R and D–R values provides a clear mechanism for prioritizing sustainability strategies. Indicators with high positive D–R values should be treated as primary strategic levers, meaning that investment in these causal indicators will generate the broadest system-wide impact. Conversely, indicators with high D+R but negative D–R values serve as outcome indicators that should be monitored as key performance results rather than targeted directly at the start of implementation. This causal hierarchy enables companies to sequence their initiatives logically, beginning with capability-building and process enablers, followed by operational improvements, and concluding with stakeholder and financial outcomesthereby ensuring efficient resource allocation and maximizing the effectiveness of sustainability interventions.

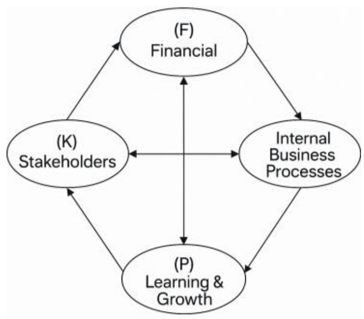

Figure 8. SBSC Perspective Strategy Map

Strategy Map

The DEMATEL method applies a threshold value (α) to filter significant relationships between variables from the total relation matrix (T-matrix), thereby facilitating the visualization of the influence relationship map (IRM). This threshold is typically determined as the average value of all elements in the T-matrix, which minimizes the potential for subjective bias from expert opinions and reduces the complexity of the relationship diagram (Nyimbili et al., 2023; Shooshtarian et al., 2024). Setting α based on the mean value is considered more objective than manual

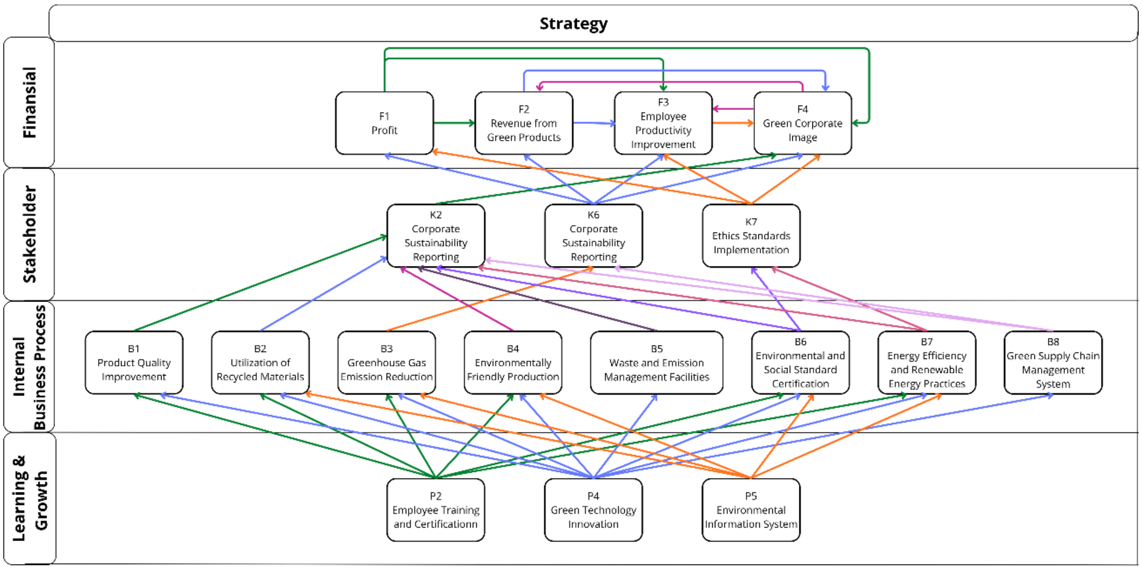

Figure 9. SBSC indicator strategy map

selection or reliance solely on expert judgment (Shooshtarian et al., 2024). In this study, the threshold was set at 0.394 for inter-perspective relationships and 0.3938 for inter-indicator relationships.

Based on this threshold, Figure 8 then visualizes the perspective-level strategy map. Arrows illustrate the directional influence between perspectives, confirming the hierarchical sequence: Learning and Growth drives Internal Processes; Internal Processes shape Stakeholder performance; Stakeholder performance ultimately affects Financial outcomes. This visual representation enables managers to identify which perspective requires early intervention and how improvements propagate through the organization.

In Figure 9, the directional arrows illustrate the specific cause–effect pathways among indicators, showing how improvements in foundational capabilities cascade toward higher-level outcomes. Indicators in the Learning and Growth perspective serve as initial drivers, sending influence upward to internal processes, which in turn shape stakeholder-related outcomes and ultimately affect financial performance. The color-coded arrows highlight different influence routes while maintaining consistent labeling across perspectives, making it easier to trace how each indicator contributes to the overall sustainability strategy. This visualization supports managers in identifying leverage points and sequencing initiatives in alignment with the SBSC's causal logic.

Sustainability Balanced Scorecard

Based on the strategy mapping results illustrated in Figure 10, a Sustainability Balanced Scorecard (SBSC) framework was developed. In line with the perspective of Figge et al. (2002), the SBSC enables the integration of the three pillars of sustainability (economic, social, and environmental) into a single comprehensive management system. This tool serves to identify sustainability-oriented strategic objectives, enhance transparency regarding the potential added value from social and ecological dimensions, and support the structured implementation of corporate strategies.

The SBSC was formulated through discussion sessions involving two key internal stakeholders: the Human Resources Division Manager and the Sustainability Division Manager. The outcome of this collaborative process is an SBSC that functions not only as a strategic guideline for the company but also as a communication instrument to convey its commitment to sustainability. The proposed SBSC is expected to serve as a practical recommendation for paper manufacturing companies in East Java, particularly in translating sustainability vision into operational policies. Moreover, it can be utilized to evaluate the extent to which green industry principles have been implemented within the company, thereby providing a benchmark for assessing sustainable performance.

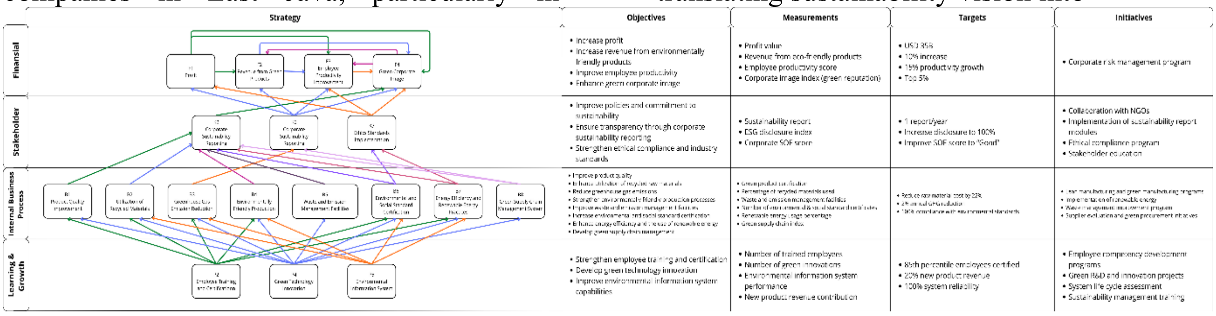

Figure 10. Sustainability balanced scorecard

Practical Applications and Strategic Initiatives

To ensure that the Sustainability Balanced Scorecard (SBSC) developed in the previous subsection can be translated into actionable managerial tools, it is essential to articulate how the strategic objectives, indicators, and causal linkages embedded within the SBSC framework evolve into concrete organizational programs. The SBSC presented in Figure 10 forms the structural basis from which operational initiatives are derived, particularly through its components of strategic objectives, performance indicators, targets, and sustainability-oriented initiatives. Building upon this structure, the present subsection elaborates the practical applications of the model and outlines a set of strategic initiatives that organizations may implement to strengthen sustainability performance in a systematic and measurable manner.

The operationalization of the SBSC is guided by two analytical foundations. First, the causal hierarchy derived from the DEMATEL results positions the Learning and Growth perspective as the principal driver of improvements across the system, providing insight into which areas must be prioritized in early-stage implementation. Second, the interactions among indicators act as a roadmap for sequencing interventions, signaling that improvements in internal processes, stakeholder engagement, and financial outcomes depend on prior reinforcement of enabling capabilities. This alignment ensures that strategic initiatives not only correspond to the analytical findings but also reflect the structure of the SBSC developed in this study.

Learning and Growth Initiatives

The Learning and Growth perspective consists of foundational indicators that enable organizational capacity to embed sustainability principles into daily operations. Programs within this perspective may include competency development initiatives for green skills, certification-based training related to environmental management, and investments in environmental information systems that support data accuracy and transparency. Additionally, fostering eco-innovation through the adoption or development of green technologies reinforces the organization's ability to meet long-term sustainability demands. These initiatives correspond directly to the strategic objectives and indicators identified in the SBSC, particularly those functioning as causal drivers (e.g., employee training, green technology innovation, and environmental information systems).

Internal Business Process Initiatives

Indicators in the Internal Business Process perspective represent the operational core of the SBSC framework. Strategic initiatives within this domain may focus on expanding the use of recycled materials, improving energy efficiency, transitioning toward renewable energy sources, and strengthening waste and emissions management infrastructure. Organizations may also pursue the implementation of environmental and social certifications to institutionalize their sustainability practices. Programs that enhance product quality and support the adoption of green supply chain management systems further align internal processes with sustainability objectives. These initiatives directly translate the SBSC's operational targets into structured action plans that reinforce the causal pathways identified in the strategy map.

Stakeholder-Oriented Initiatives

The Stakeholder perspective emphasizes the organization's need to build legitimacy and accountability among its internal and external constituencies. Practical programs may include the establishment of sustainability reporting mechanisms aligned with national and international frameworks, the institutionalization of ethical standards throughout the organization, and participation in sustainability award schemes. These initiatives mirror the SBSC components related to stakeholder engagement, ensuring that organizational actions contribute to increased transparency, strengthened ethical compliance, and enhanced societal recognition.

Financial Perspective Initiatives

Financial outcomes represent the culminating effects of strategic initiatives implemented across the preceding perspectives. Programs derived from this domain may include product portfolio diversification through eco-friendly innovations, cost-efficiency projects facilitated by energy reduction and process optimization, and corporate image enhancement campaigns emphasizing environmental responsibility. These initiatives ensure that sustainability contributes not only to ethical and operational performance but also to financial value creation, consistent with the SBSC's strategic objectives.

Implementation Roadmap

The practical application of the SBSC follows a structured roadmap that mirrors the methodological development of the model. Implementation begins with the identification of relevant indicators, validation of their construct reliability, and analysis of causal structures. These steps are followed by strategy map construction and the formulation of the SBSC table, which consolidates objectives, indicators, targets, and strategic initiatives. Organizations may then execute sustainability programs in accordance with the prioritization implied by causal indicators. This roadmap supports systematic integration of sustainability into managerial processes and promotes alignment across organizational functions.

Digital Operationalization Through SBSC Dashboard

To facilitate real-time monitoring and continuous evaluation, the SBSC model incorporates a digital dashboard that visualizes indicator performance through automated scoring calculations and color-coded status displays. This tool enhances managerial decision-making by providing timely insights into the achievement of sustainability targets, highlighting areas requiring further intervention, and enabling periodic assessment of perspective-level balance. As a complementary instrument to the SBSC table and strategy map, the dashboard reinforces the applicability of the model and supports organizations in maintaining continuous improvement in sustainability performance.

5. CONCLUSION

This study developed a Sustainability Balanced Scorecard (SBSC) model as an enhanced performance measurement framework that integrates environmental and social considerations into organizational strategic management. Using Exploratory Factor Analysis (EFA), eighteen validated indicators were identified and structured into four SBSC perspectives: Learning and Growth, Internal Business Processes, Stakeholders, and Financial. These indicators were further examined using the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method to determine their relative importance and causal–effect relationships.

The results highlight that "green technology innovation," "energy efficiency and renewable energy practices," and "green corporate image" are the most influential indicators in terms of overall importance (D+R). However, these indicators predominantly function as effect indicators, suggesting that improvements in sustainability performance must begin by reinforcing upstream drivers. The Learning and Growth perspective, characterized by a positive D–R value, emerges as the primary causal domain that supports system-wide improvement. This finding underscores the strategic importance of strengthening human resource capabilities, advancing eco-innovation, and developing robust environmental information systems as foundational inputs for achieving broader sustainability outcomes.

The strategy map derived from the DEMATEL analysis provides an integrated view of interdependencies across perspectives, enabling managers to identify leverage points and prioritize interventions more effectively. When translated into practical initiatives, as outlined in the SBSC and accompanying implementation framework, the model facilitates the alignment of short-term operational improvements with long-term sustainability goals. These applications, ranging from internal process optimization to stakeholder engagement and financial value creation, demonstrate the model's potential as both a strategic guide and an operational tool for advancing sustainability performance in the manufacturing sector. Overall, the SBSC model produced in this study offers a structured, empirically grounded, and practically applicable approach that can support organizations in designing and executing sustainability-oriented strategies. Its adaptability also enables replication across various industrial contexts, providing a valuable foundation for broader sustainability transformation efforts.

Limitations and Future Research

This study is subject to several methodological limitations that should be considered when interpreting the findings. First, the DEMATEL analysis relied on evaluations from six expert respondents. Although these individuals possessed substantial managerial experience, the limited number of experts increases the potential for subjective bias and restricts the generalizability of the causal structure obtained. Second, DEMATEL inherently captures perceived influence rather than empirically measured interactions, making the results sensitive to expert judgment. Future studies may address these limitations by employing larger and more diverse expert panels or by validating the causal relationships through quantitative approaches such as structural equation modeling (SEM), partial least squares (PLS), or longitudinal performance tracking. Additionally, applying the SBSC framework to other industrial sectors and conducting cross-sector comparisons would enhance the external validity of the model and allow the identification of context-specific sustainability drivers.

Recommendations

This study makes a tangible contribution by systematically and visually developing a Sustainability Balanced Scorecard (SBSC) framework, complete with a causal–effect relationship analysis among indicators. Nevertheless, given that each organization has distinct characteristics, the structure and content of an SBSC may vary depending on the internal conditions of the respective company. Therefore, the SBSC produced in this study can serve as an initial reference, particularly for paper mills or manufacturing companies with comparable operational profiles.

For future development, it is recommended that similar research be conducted across other industrial sectors to broaden the diversity of SBSC models and enhance their relevance to the specific needs of each sector. Furthermore, integrating quantitative approaches with qualitative insights from key stakeholders presents an opportunity to strengthen the validity and applicability of the sustainability strategy framework.

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