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Novel ergonomics indicator-based approach for evaluating a supplier organization's sustainable process performance

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ABSTRACT

Ergonomics principles can be crucial in supplier audits by providing an effective framework and continuum ratings, moving beyond check-sheet based dichotomous rating. In contemporary supply chain management practices focal firms –which govern supply chains– are held accountable for product sourcing and transportation deficiencies. This study proposes a novel method for assessing the supplier organization's sustainability performance by integrating twenty-five ergonomics indicators (EIs) across economic, ecological, and social dimensions. Data from 38 Pakistani supplier organizations exporting products to Western firms were analyzed to develop an interval-scale-based evaluation scheme, and aggregated to form an organization's composite sustainable performance score. The results showed that the economic dimension was more frequently measured by the organizations compared to the ecological and social dimensions. Moreover, mapping these EIs onto Sustainable Development Goals (SDGs) demonstrates their relevance to SDGs broadly. A performance scorecard was also designed to assess suppliers' sustainability practices within the ergonomics paradigm, enabling organization-to-organization comparisons through visual representation. This approach supports focal firms in incorporating sustainable and resilient process performance into their supplier evaluations.

1. Introduction

Today's sustainability-focused world pressures supply chains to meet economic objectives without compromising ecological or social standards. Focal firms, which lead or govern supply chains (Frostenson and Prenkert, 2015), are accountable for their suppliers' actions (Vidal et al., 2022) and face growing regulatory challenges. For example, the EU's corporate sustainability due diligence directive holds firms responsible for human rights and environmental issues across their supply chain (Schilling-Vacaflor and Gustafsson, 2024). Consequently, focal firms pressure their suppliers to comply with corporate social responsibility standards (Picasso et al., 2021), while building resilient supply chains and establishing long-term partnerships through careful supplier assessments (Wang et al., 2024), and enforcing more stringent sustainability requirements (Memari et al., 2019; Wilhelm and Villena, 2021). Many suppliers have integrated sustainable practices into their business models to meet these demands. For example, they must implement fair labor policies, promote social welfare initiatives, and reduce their environmental footprint (Villena et al., 2021). However, the extent of these practices can only be reliably determined through audits.

According to Rogala et al. (2024) audits have been progressively utilized to assess an organization's sustainability performance and compliance, often guided by ISO 19011:2018 standards which include both supplier auditing and organizational certification. Yet, the credibility of audit results is a major concern, as the problem of inadequate supplier audits is becoming more prominent in the manufacturing industry, impacting the credibility of multinational supply chains to achieve their sustainability goals (Erhun et al., 2021; Zink, 2014). Significant strides have been taken to address the impact of supplier practices on the environment, for example, flue gas capture (Zhang et al., 2020), water treatment (Karchiyappan et al., 2024), green manufacturing (Sarker and Bartok, 2024), and measuring suppliers'

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environmental performance using key performance indicators (Marrucci et al., 2024). However, the same cannot be said from a social sustainability perspective.

The role of corporate social responsibility has been investigated in the supply chain management discipline (Falcone and Ridge, 2024; Tao et al., 2023), but research on the adoption of social sustainability practices by suppliers is limited (Ahram et al., 2023; Pimenta et al., 2021). Although the check-sheet approach to audits is often inadequate for overall supplier assessment, it is particularly ineffective in evaluating suppliers' social sustainability aspects. Ergonomics can be crucial in addressing human and social aspects of sustainable supply chains (Cao et al., 2024) and ergonomics considerations across supply chains fit precisely with the goals that Thatcher et al. (2018) proposed as important for ergonomics in addressing global challenges because of the focus on systemic issues. Manufacturing organizations can inculcate the ergonomics discipline to augment the workforce's well-being and rights, thus influencing socially sustainable supply chains (Kumari and Singh, 2023). Furthermore, incorporating ergonomics-based metric systems can substantially reduce the health and safety risks posed to workers (Greig et al., 2023). Therefore, leveraging ergonomics principles and structured audits, such as those outlined by Dempsey et al. (2017, 2005), Drury and Dempsey (2021), and Lowe et al. (2019), can serve as a bridge between a human-centric approach and developing socially responsible supply chains.

Various supplier assessment criteria have been reported in the literature such as delivery (Kao, 2022), service (Büyüközkan, 2012), quality (Shaik and Abdul-Kader, 2011; Sheu, 2016), cost (Genovese et al., 2014), pollution regulations (Song et al., 2024), green products (Awasthi et al., 2010; Lee et al., 2009), strategic alliances (Taubeneder et al., 2024), and environmental management (Diebel et al., 2024). While these constructs provide general insights, they may not reveal the specific operational capabilities required for supplier assessment (Nokelainen et al., 2017). Furthermore, Nokelainen et al. (2017) proposed using ergonomics in the supplier evaluation process. Ergonomics has been used in various supply chain related areas such as healthcare (Azadeh et al., 2016), courier deliveries (Van Lopik et al., 2020), distribution systems (Kapur and Kaswan, 2020), material supply systems (Neumann and Medbo, 2010), and pharmaceuticals (Salehi et al., 2020). The International Labor Organization (ILO) estimates that 2.78 million workers die each year from work-related accidents and occupational diseases (UN Global Compact and ILO, 2021). Conversely, lost workdays are estimated to account for about 4 % of the gross world product, reaching 6 % or more in some countries (Hämäläinen et al., 2017). These statistics highlight the need for reliable and effective indicators in the pursuit of sustainable process performance. While literature identifies several reporting mechanisms, such as the '*Global Reporting Initiative*' (GRI, 2011), the '*Environmental Performance Index*' (Block et al., 2024), and the '*Environmental Performance Evaluation standard – ISO 14031*' (ISO, 2021a), these address sustainability assessments at a high level (Joung et al., 2013). The GRI is widely used for sustainability assessments, but questions have been raised about its adequacy in reporting social and environmental issues (Zharfpeykan and Akroyd, 2023). Hazelton et al. (2022) also found significant gaps in disclosure requirements within GRI standards related to labor and corporate interactions in developing countries. Therefore, operational indicators are required for sustainable process performance rather than higher-level ones. This objective can be achieved using ergonomics to provide operational indicators for sustainable process performance (Munck-Ulfsfält et al., 2003; Neves et al., 2023; Törnström et al., 2008; Village et al., 2015; Yazdani et al., 2015).

Thus, the aim of this study is to propose an ergonomics-inspired evaluation scheme to calculate an organization's composite sustainable performance score and to design a comparative scorecard. Our approach integrates three sustainability dimensions (economic, ecological, and social) with ergonomics indicators (EIs) aligned with the fundamental elements of ergonomics (system performance, human well-being, and working conditions) to create a more effective supplier auditing mechanism. The resulting scorecard is particularly valuable for focal firms assessing suppliers in labor-intensive industrially developing countries.

This research offers significant contributions to society, academia, and management practices. Applying the ergonomics-based performance scorecard approach can help achieve supply chain sustainability by modifying the nature of supplier audits. The proposed approach can complement the dominant check-sheet (subjective) approach with a comprehensive quantitative approach, which can help in not only supplier selection but also supplier development by clearly identifying sustainable ergonomics areas for improvement. In addition, the mapping of EIs onto the United Nations Sustainable Development Goals (SDGs) promotes their relevance for organizations and fits with Bolis et al.'s (2023) and Sigahi et al.'s (2024) call for concretizing the links between ergonomics and the SDGs. The SDGs are a set of 17 global goals adopted by the UN in 2015 (replacing the Millennium Development Goals) as a universal commitment to sustainable development. Notably, some of the SDGs, such as "SDG 3: Good Health and Well-being", "SDG 8: Decent Work and Economic Growth", and "SDG 12: Responsible Consumption and Production" are directly related to Human Factors and Ergonomics principles. Mapping these indicators with the SDGs provides a valuable tool for suppliers to monitor their processes in terms of their impact on the 2030 sustainability agenda (UN, 2015).

2. Methodology

This study presents a comprehensive ergonomics framework for evaluating manufacturing organizations' sustainable process performance. Several theoretical frameworks have been proposed in the ergonomics literature for an organization's sustainability related evaluation. For instance, Zarte et al. (2019) suggested indicators for sustainable production planning and control. Lin et al. (2019) evaluated sustainable product manufacturing while Karuppiah et al. (2020) examined small and medium enterprises in the leather-based garment industry. Similarly, Lin et al. (2021) addressed workplace sustainability in Indonesia. Nonetheless, these frameworks are theoretical in nature and tailored to specific industries. Rodríguez-Gámez et al. (2022) similarly highlight the fragmented and inconsistent use of safety and ergonomics indicators across supply chains. The sustainability dimension-specific limitation of previous frameworks was addressed by Sarbat and Ozmehmet Tasan (2022), who, after reviewing 77 different studies, selected the twenty-five most pertinent EIs for assessing sustainable process performance. Sarbat and Ozmehmet Tasan's (2022) framework is yet to be empirically tested as the EIs used to measure economic, ecological, and social dimensions vary in units of measurement. This study overcomes this limitation by proposing a methodology to normalize the EIs and construct a performance scorecard, allowing organization-to-organization comparisons. Fig. 1 presents the hierarchical framework originally proposed by Sarbat and Ozmehmet Tasan (2022, 2020), which categorizes three main dimensions—economic, ecological, and social—into sub-dimensions to facilitate detailed analysis and calculation. The economic sub-dimensions encompass loss and investment, the ecological sub-dimensions include conditions and contribution, and the social sub-dimensions focus on self-development and satisfaction. Twenty-five individual EIs correspond to these sub-dimensions.

This framework was used to develop a performance scorecard using a four-step methodology, as explained below and shown in Fig. 2.

(i) The data were collected from a sample of suppliers using the formulas of twenty-five EIs presented in Sarbat and Ozmehmet Tasan (2022) to measure distinct features of organizational sustainable process performance (Section 2.1).

Fig. 1. Hierarchical construction of indicators affecting processes performance of an organizations (modified from Sarbat and Ozmehmet Tasan (2022)).

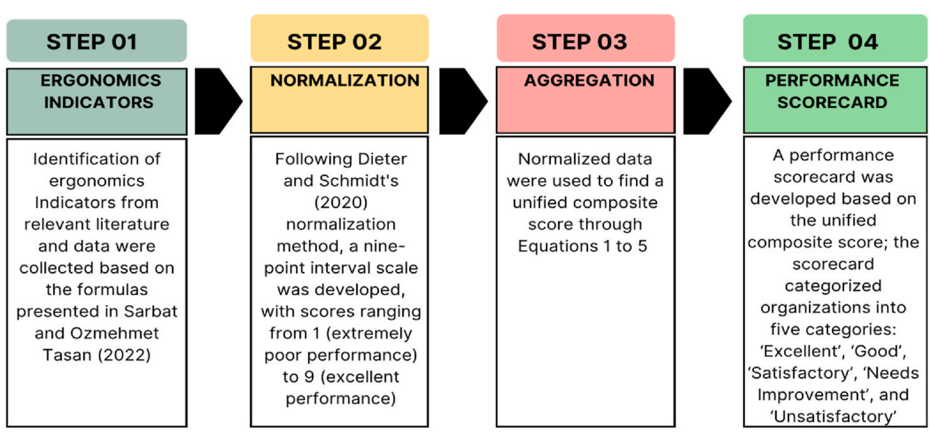

Fig. 2. Performance scorecard evaluation methodology.

(ii) Data scaling and normalization techniques were employed to transform the measured data into dimensionless scores (Section 2.2).

(iii) The dimensionless scores corresponding to the economic, ecological, and social aspects were aggregated into a unified composite score showing the overall sustainable process performance of the organization (Section 2.3).

(iv) For benchmarking purposes, a performance scorecard was developed for organization-to-organization comparison (Section 2.4).

2.1. Data collection and quantification of EIs

A vital requirement of this study was to collect data from representative manufacturing organizations to create a benchmark interval scale evaluation scheme, enabling future evaluations. To ensure that the accuracy of the interval scale, the manufacturing organizations were selected on the following criteria: (i) must be an exporter of goods to a Western focal firm; (ii) must have undergone an audit from the Western focal firm within the past year; (iii) must be an internationally certified organization holding either ISO 9001:2015, or ISO 14001:2015, or ISO 45001:2024 certifications; and (iv) must have a workforce of more than 500 employees.

A purposive sampling (Patton, 2002) technique was used and human resource departments of manufacturing organizations were involved in the data collection. Only those organizations who showed a willingness to complete the questionnaire with respondents meeting the following selection criteria were targeted: (i) respondents were either a middle/senior level manager or ergonomists or occupational health and safety (OHS) specialist; (ii) respondents worked for the current organization for at least three years; and (iii) respondents were part of a team that supervised the audit from the focal firm. After applying the above conditions, the sample frame consisted of 50 possible manufacturing organizations in Pakistan. All the short-listed organizations were approached to collect data via their human resource department. Thirty-eight organizations in the sample frame responded, of which 21 were discrete part manufacturers and 17 were process-based organizations. These organizations represent a diverse range of industries, producing textiles, knitwear, garments, shoes, apparel, chemicals, leather goods, and engineering products for export to Western buyers, including the United States, United Kingdom, Netherlands, Germany, and Spain. This diversity enables a comprehensive examination of ergonomics across various contexts.

2.2. Normalization

Integrating various EIs into a comprehensive evaluation posed challenges due to varying units of measurement. To overcome this, data scaling and normalization techniques were employed to convert the measured data into dimensionless scores. Following Dieter and Schmidt's (2020) normalization method, a 9-points interval scale was developed, with values ranging from 1 (extremely poor performance) to 9 (excellent performance). These values are derived from 9-points Likert scale. The scale allowed for capturing dispersion in the data set, thereby creating clear classifications among manufacturing organizations.

2.3. Data aggregation

The normalized data were used to find a unified composite score through Equations (1)–(5) below. Equation (1) calculates the score for each sub-dimension (SD_n) by taking the mean of all normalized ($EI - i$) scores within that sub-dimension. Here, m represents the total number of indicators in a given sub-dimension. The Ec, Eco, So was the score of each main dimension, namely *Economic*, *Ecological*, and *Social*, computed by aggregating the sub-dimension (Fig. 1) scores relevant to those main dimensions (Equations (2)–(4)). The unified composite score was calculated by averaging each dimension score (i.e., Ec, Eco, So), as shown in Equation (5).

$$Sub-dimension\ score\ (SD_n) = \frac{\sum_{i=1}^{m} EI - i}{m} \quad \forall n = 1 \ldots 6 \tag{1}$$

$$Economic\ dimension\ score\ (Ec) = \frac{SD_1 + SD_2}{2} \tag{2}$$

$$Ecological\ dimension\ score\ (Eco) = \frac{SD_3 + SD_4}{2} \tag{3}$$

$$Social\ dimension\ score\ (So) = \frac{SD_5 + SD_6}{2} \tag{4}$$

$$Unified\ composite\ score = \frac{1}{3}\ (Ec + Eco + So) \tag{5}$$

2.4. Performance scorecard

A performance scorecard was developed to ascertain an organization's overall sustainable process performance, allowing for organization-to-organization benchmarking. The calculated unified composite score and each sustainability dimensions' score for each participated organizations are plotted based on five categories: 'Excellent', 'Good', 'Satisfactory', 'Needs Improvement', and 'Unsatisfactory', which are equally ranged. The details of each performance scorecard categories are explained in Table 1. This visualization helps the focal firms benchmark their supplier organizations based on the EIs assessment.

3. Results

3.1. Presenting EIs sample data

This section presents a case study conducted in 38 manufacturing organizations to empirically test the applicability of the Sarbat and Ozmehmet Tasan's (2022, 2020) framework, which forms the basis of the methodology constructed in Section 2. All prospective participants received a questionnaire accompanied by a cover letter, which comprehensively explained two key points: First, participation in the survey was voluntary, and second, the survey results would be exclusively employed for rigorous scientific research in relevant publications. A digital survey was used to collect the data. The questionnaire used in this study consisted of four sections. The first section, titled "General Information" collected data on respondents' details, including job title, educational background, years of employment with the current organization, and organizational characteristics (e.g., product type and ISO certifications), as shown in Table 2.

The remaining three sections focused on gathering economic, ecological, and social data using twenty-five individual EIs, illustrated in Fig. 1. These questions were designed to align with the EIs presented in

Table 1
Performance scorecard categories.

Score	Categories	Interpretation
7.41–9.00	Excellent (E)	An excellent score in this range indicates that the supplier sustainable process performance in ergonomics is outstanding. They have likely implemented effective ergonomics practices that promote the health and well-being of their employees.
5.81–7.40	Good (G)	A good score in this range suggests the supplier sustainable process performance in ergonomics is commendable. They are likely taking appropriate measures to ensure their employees a comfortable and safe work environment.
4.21–5.80	Satisfactory (S)	A satisfactory score implies that the supplier sustainable process performance in ergonomics meets the basic requirements. Although there is room for improvement, they are on the right track in addressing ergonomics concerns.
2.61–4.20	Needs Improvement (N)	A score in this range indicates that supplier sustainable process performance in ergonomics needs significant improvements. There are likely issues or deficiencies in their ergonomics practices that should be addressed to create a healthier workplace.
1.00–2.60	Unsatisfactory (U)	An unsatisfactory score suggests that supplier sustainable process performance in ergonomics is very poor. They are likely failing to meet essential ergonomics standards, and urgent corrective actions are necessary to improve workplace conditions.

Table 2
General information of sample data set.

		Number	Percentage (%)
Organizations type	Discrete	21	55
	Process	17	45
ISO certifications	ISO 9001, ISO 14001, ISO 45001	25	66
	ISO 9001, ISO 14001	13	34
Products type	Textile	7	18
	Engineering goods	7	18
	Chemicals	5	13
	Textile – Yarn	4	11
	Garments	3	8
	Knitwear	3	8
	Apparel	2	5
	Hosiery	2	5
	Leather goods	2	5
	Shoes	1	3
	Sugar Industry	1	3
	Socks	1	3
Respondent qualification	Industrial Engineering	12	32
	Industrial Engineering and Management	11	29
	Mechanical Engineering	7	18
	Electrical Engineering	2	5
	Chemical Engineering	2	5
	Operations and Supply Chain Management	1	3
	Metallurgy and Materials Engineering	1	3
	Industrial Engineering and NEBOSH IGC Certified	1	3
	Environmental Engineering	1	3
Respondent position	Manager	22	58
	OHS manager	7	18
	Ergonomists/safety manger	9	24
Number of years employed by the current organization	5	18	47
	6	7	18
	7	2	5
	8	2	5
	9	5	13
	10	2	5
	13	1	3
	24	1	3

Sarbat and Ozmehmet Tasan (2022). Table 3 summarizes the information collected from the sample organizations, presenting the mean, standard deviation (SD), and maximum and minimum values for each of the EIs.

The maximum score for respective EIs presented in Table 3 was used as a benchmark to generate nine ranges on the interval scale. Table 4 presents the detailed evaluation scheme for scoring, which provides a clear framework for assessing the sustainable process performance of participating manufacturing organizations. Table 4 shows information regarding trends, units of measurement (days, percentage, monetary value in US $ and number count), and ranges of interval scale. The trend for each EI was indicated as either "Higher is Better" (HB) or "Lower is Better" (LB), which influenced how the score ranges were defined. For example, EI-1 (accident-free days) had an HB trend, meaning higher values indicated better performance, while EI-4 (expenditure on medical treatments) had an LB trend, meaning lower values were preferred. Thus, for HB, the minimum value starts at a score of 1 and the maximum value at a score of 9, while for LB, scores were reversed. It is important to note that for EI-4, EI-6, EI-7, EI-8, and EI-9, the monetary value was calculated based on US $ per capita (i.e., the number of employees working in the organization) in a financial year. This helped make more standardized comparisons between different organizations. If an organization did not record an EI, it was assigned the lowest score of 1.

3.2. Representing the normalized scores

Table 5 presents the normalized scores for all 38 participating manufacturing organizations. It is structured with each organization represented by a unique code (O1–O38). The second column lists the types of products exported by each organization. The subsequent columns (EIs 1–25) display the normalized scores for each EI. A special notation '1*' represents an EI not measured by the organization. As per the methodology, the lowest score is assigned, i.e., 1. The last column represents the frequency and percentage of 'EIs measured by the respective organizations' (the percentage is calculated by dividing the row count by the total number of EIs, i.e., 25). The last row 'number of organizations measuring the EI' represents the frequency and percentage of each EI measured across all participating organizations (the percentage is determined by dividing the column count by the total number of participating organizations, i.e., 38). For example, O8 measured only four indicators (EI-1, EI-2, EI-16, EI-17), therefore all other indicators are given the lowest score and for differentiation purposes represented as '1*'. As the number count is 4, the total number of EIs measured by the organization O8 comes to 16%. Conversely, organization O24 measures 22 EIs, accounting for 88% coverage across indicators. Table 5 also shows that EI-13 is measured by only 16% of organizations (i.e., only by 6 participating organizations) while EI-6 is measured by 82% (i.e., 31) of organizations.

3.3. Evaluating EIs with SDGs based on their measurability

Based on the measurement of EIs in the participating organizations, Fig. 3 shows these measurements in three color-coded bars: Blue color bars indicate measurement by less than 50% of the organizations (nine in total); yellow color bars indicate measurement by between 50% and 70% of the organizations (eight in total); and green color bars indicate measurement by more than 70% of the organizations (eight in total). It is evident from Fig. 3 that while there is diversity in the types of EIs measured, no single indicator is wholly ignored. Moreover, Fig. 3 demonstrates a one-to-one mapping of each EI with the SDGs and their targets, illustrating how improvements in specific EIs can be directly linked to the SDGs. Most EIs were aligned with SDG 8 ("decent work and economic growth"), specifically targets 8.8, 8.5, and 8.2. Additionally, some EIs were linked to other SDGs, including targets 3.8, 4.4, 9.1, 9.5, 11.6, and 12.5. Therefore, these EIs are valuable for evaluating manufacturing organizations and supporting the 2030 sustainability agenda.

The results further demonstrate a strong emphasis on measuring the economic dimension of EIs. Notably, 62% of the EIs related to the economic dimension were actively being measured by these organizations. In contrast, the measurement for EIs in the ecological and social dimensions was lower, with 53% and 48% of the relevant indicators being tracked by manufacturing organizations, respectively. These results are supported by literature confirming that in industry, the economic dimension takes precedence over ecological and social dimensions (Nguyen et al., 2023). Thus, the EIs used to construct the performance scorecard were well-positioned and could help assess the sustainable process performance of manufacturing organizations.

3.4. Proposing performance scorecards through calculated EIs' scores

To facilitate understanding of how a unified composite score is calculated, manufacturing organization 'O15' is used as an example. Table 6 shows the EI-1 to EI-25, answers received in the questionnaire, the normalized dimensionless scores as per the evaluation scheme, corresponding sub-dimensions, and aggregated sub-dimension values. For instance, the 'Loss' sub-dimension is calculated according to Equation (1), as $\frac{[6+6+9+9+9]}{5} = 7.80$. Other sub-dimension values were similarly calculated. The main dimensions (economic, ecological, social)

Table 3
Summarized calculated values for each EI based on 38 participating manufacturing organizations.

EIs	EIs Description (modified from Sarbat and Ozmehmet Tasan, 2022)	Units	Mean	SD	Max	Min
1	Accident-free days per annum	Days/year	272	55	365	212
2	Injury-free days per annum	Days/year	267	55	365	217
3	Annual percentage of work hours lost due to accidents and injuries relative to total hours worked	% of lost time/year	0.36	0.71	2.30	0.00
4	Annual expenditure on medical treatments for accidents, injuries, and occupational diseases	Total expenditure in US $/year	3612	8209	36,750	11
5	Annual number of occupational disease cases reported within an organization	# occupational diseases/year	67	143	600	0
6	Annual investment cost for Environment, Health, and Safety (EHS) issues and ergonomics interventions	Total investment in US $/year	5293	11,083	52,500	0
7	Annual cost of EHS training for employees within an organization	Total training cost in US $/year	4204	8557	36,750	0
8	Annual expenditure on employee development due to their personal skills and work-related skills development	Total expenditure in US $/year	3312	6044	33,250	0
9	Annual expenditure on research and development (R&D), technology, and innovation to enhance ergonomically and environmentally friendly design processes	Total expenditure in US $/year	119,923	270,603	1,050,000	0
10	Annual number of employee complaints related to physical conditions	# of complaints/year	368	970	5045	10
11	Annual number of complaints received from community (e.g., distributors, customers, government) related to an organization	# of complaints/year	43	48	150	1
12	Annual number of days with unfavourable physical conditions (e.g., dust, odour, noise, temperature)	Days/year	65	64	210	0
13	Employees facing physical and mental health problems due to working in unfavourable conditions per year	% of employees working in unfavourable conditions/year	5	11	29	0
14	Annual number of activities (e.g., meeting, audits, reports, assessments) undertaken to improve working conditions within an organization	# of activities/year	80	168	930	3
15	Charitable contributions towards EHS issues made by volunteers per year	# of charitable contributions/year	223	328	1000	5
16	Annual use of recycled products or raw materials in ergonomic design processes	% of recycled products/year	2	6	30	0
17	Annual incentives and promotions made by the organization to encouraging the contributions of stakeholders towards ergonomically and environmentally friendly design processes	% of incentives and promotion/year	14	33	100	0
18	Employees receiving EHS training per year	% of employee training/year	12	27	100	0
19	Total work hours devoted to EHS training per year	% of total time spent for EHS training/year	10	18	68	0
20	Suggested improvements made by employees per year	# of improvements/year	27	31	120	0
21	Annual activities (e.g., reports, meetings) performed in the organization for successful implementation of EHS issues and ergonomics interventions	# of activities/year	62	145	700	1
22	Turnover rate of employees per annum	% of employee turnover/year	11	14	60	0
23	Satisfaction of employees with their work per year	% of employee satisfaction/year	55	37	98	0
24	Complaints received related to working conditions which are not included in the decent work agenda per year	# of complaints/year	105	82	292	0
25	Employees contributing into the managerial decisions related to EHS issues and ergonomics interventions per year	% of employee participation/year	5	9	30	0

were derived by averaging sub-dimension scores (Equations (2)–(4)). Finally, using Equation (5), the unified composite score for sustainable process performance was calculated as $\frac{1}{3}[5.15+1.97+3.13]=3.41$ on a scale of 9.

As discussed in the methodology, a performance scorecard was used to benchmark and compare the performance of participating organizations based on their scores. Fig. 4 (a, b, c, d) presents the unified composite scores and main dimension scores for all participating organizations. A five-tier color-coded scheme was used to easily visualize the scorecard: Red for 'Unsatisfactory', Light red for 'Needs Improvement', Yellow for 'Satisfactory', Light green for 'Good', and Dark green for 'Excellent'. It can be observed from Fig. 4a that the organization 'O20' attained the highest unified composite score (4.5 out of 9), which lies under the 'Satisfactory' category and falls under the yellow range. No other organization fell under the 'Satisfactory' category. For the rest of the organizations surveyed, the performance for 20 organizations was 'Unsatisfactory' and for 17 organizations was 'Needs Improvement'. It is important to note that no organization scored in the 'Good' or 'Excellent' categories, showing a lack of good ergonomics practices in these organizations.

Fig. 4b, 4c, and 4d present the performance of all the participating organizations on economic, ecological, and social dimensions, respectively. It can be observed that economic scores were generally higher than ecological and social scores. In the economic dimension, the performance of 7 organizations was deemed 'Satisfactory', while 16 organizations 'Needs Improvement', and 15 organizations were 'Unsatisfactory'. For the ecological dimension the breakdown was 2 organizations were 'Satisfactory', 12 'Needs Improvement,' and 24 'Unsatisfactory'. Lastly, for the social dimension, the performance of 2 organizations was 'Satisfactory', 8 organizations were 'Needs Improvement', and 28 organizations were 'Unsatisfactory'.

The results show that each organization must improve performance across all three criteria. Generally, organizations' social and ecological performance was poor compared to economic performance. However, for O20, the ecological, social, and economic scores were 5.6, 5.1, and 2.6, respectively, resulting in a unified composite score of 4.5. Overall, the poor performance demonstrates the need for manufacturing organizations in Pakistan to adopt more sustainable health and safety practices, including ergonomics.

4. Discussion

In a sustainability-focused world, suppliers face increased audits from focal firms to ensure that they are complying with sustainable supply chain requirements (Cui et al., 2024). While auditing practices are widely used (Berg and Swanemar, 2022), their check-sheet nature can be inexpedient due to their subjective nature (Hutchinson et al., 2024). Moreover, these audits overlook social aspects, focusing more on economic and ecological aspects (Gualandris et al., 2024; Wilhelm et al., 2024). Thatcher and Yeow (2016) have proposed that this issue can be resolved using a sustainable systems-based approach. Thus, this study proposes a novel method to assess supplier's sustainable process performance, offering a more robust evaluation than traditional audits. In this proposed methodology, focal firms are able to assess their supplier's

Table 4
Evaluation scheme for EIs normalization.

EIs	Trend	Units	Max obtained value	Cut-off points[a] based on 9-points interval scale								
				1	2	3	4	5	6	7	8	9
1, 2	HB	Days	365	0–40	41–80	81–121	122–161	162–202	203–242	243–283	284–323	324–365
3	LB	%	2.30	≥ 2.04	1.79–2.03	1.53–1.78	1.28–1.52	1.02–1.27	0.77–1.01	0.51–0.76	0.26–0.50	0.00–0.25
4[b]	LB	US $	67	≥ 60	52–59	45–51	37–44	30–36	22–29	15–21	7–14	0–6
5	LB	#	600	≥ 533	467–532	400–466	333–399	267–332	200–266	133–199	67–132	0–66
6[b], 7 [b]	HB	US $	67	0–6	7–14	15–21	22–29	30–36	37–44	45–51	52–59	≥ 60
8[b]	HB	US $	18	0–1	2–3	4–5	6–7	8–9	10–11	12–13	14–15	≥ 16
9[b]	HB	US $	700	0–77	78–155	156–232	233–310	311–388	389–466	467–543	544–621	≥ 622
10	LB	#	5045	≥ 4484	3924–4483	3363–3923	2803–3362	2242–2802	1682–2241	1121–1681	561–1120	0–560
11	LB	#	150	≥ 133	117–132	100–116	83–99	67–82	50–66	33–49	17–32	0–16
12	LB	Days	365	324–365	284–323	243–283	203–242	162–202	122–161	81–121	41–80	0–40
13	LB	%	29.41	≥ 26.14	22.88–26.13	19.61–22.87	16.34–19.60	13.07–16.33	9.80–13.06	6.54–9.79	3.27–6.53	0.00–3.26
14	HB	#	930	0–102	103–206	207–309	310–412	413–516	517–619	620–722	723–826	≥ 827
15	HB	#	1000	0–110	111–221	222–332	333–443	444–555	556–666	667–777	778–888	≥ 889
16	HB	%	30.00	0.00–3.32	3.33–6.66	6.67–9.00	10.00–13.32	13.33–16.66	16.67–19.99	20.00–23.32	23.33–26.66	≥ 26.67
17, 18	HB	%	100	0.00–11.10	11.11–22.21	22.22–33.32	33.33–44.43	44.44–55.55	55.56–66.66	66.67–77.77	77.78–88.88	≥ 88.89
19	HB	%	68.49	0.00–7.60	7.61–15.21	15.22–22.82	22.83–30.43	30.44–38.04	38.05–45.65	45.66–53.26	53.27–60.87	≥ 60.88
20	HB	#	120	0–12	13–26	27–39	40–52	53–66	67–79	80–92	93–106	≥ 107
21	HB	#	700	0–77	78–155	156–232	233–310	311–388	389–466	467–543	544–621	≥ 622
22	LB	%	60.00	≥ 53.33	46.67–53.32	40.00–46.66	33.33–39.99	26.67–33.32	20.00–26.66	13.33–19.99	6.67–13.32	0.00–6.66
23	HB	%	98.00	0.00–10.88	10.89–21.77	21.78–32.66	32.67–43.55	43.56–54.43	54.44–65.32	65.33–76.21	76.22–87.10	≥ 87.11
24	LB	#	292	≥ 260	227–259	195–226	162–194	130–161	97–129	65–96	32–64	0–31
25	HB	%	30.00	0.00–3.32	3.33–6.66	6.67–9.99	10.00–13.32	13.33–16.66	16.67–19.99	20.00–23.32	23.33–26.66	≥ 26.67

Note.
[a] The cut-off points mentioned above is purely based on the manufacturing organization's EIs value. It was derived from the maximum obtained values of the collected data.
[b] For EI-4, EI-6, EI-7, EI-8, and EI-9 the monetary value is computed based on US $ per capita (i.e., the number of employees working in the organization. This will assist in creating a scoring range and understanding the interval scale more easily.

Table 5
Normalized score of all 38 manufacturing organizations for each EI.

Code	Prod Exp	MD ▶	Economic									Ecological								Social								# of EIs M by the O	
		SD ▶	Loss					Investment				Conditions					Contribution			Self-development				Satisfaction				Count	%
		EI ▶	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25		
O1	Shoes		1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	1*	1	1	2	1*	1*	1	1*	9	1*	1*	6	24
O2	Garments		1*	1*	1*	1*	1*	3	1	2	1	1	1*	8	1*	1*	1*	1	9	5	1*	1	1*	1*	1*	1*	1*	10	40
O3	Garments		6	1*	1*	1*	9	1*	1*	1*	1*	9	1*	1*	1*	1	1*	1	1	1	1*	1*	1*	8	1*	1*	1*	8	32
O4	Textile - Yarn		6	6	1	9	1	1	1	1	1	9	1*	9	1*	1	1*	2	1*	1	2	5	1	9	9	9	1	21	84
O5	Leather goods		7	1*	1*	9	1*	1	1	3	1*	9	1*	1*	1*	1*	1*	1	1	9	3	1*	1*	1*	1*	1*	1*	10	40
O6	Engineering goods		1*	6	1*	9	1*	2	1	5	1	9	9	9	1*	1	1	1	1	1*	1*	6	1	7	1*	1*	1*	16	64
O7	Chemicals		6	7	9	9	9	1*	1*	1*	1*	9	9	1*	9	1*	1	1	1	1*	1*	1*	1	7	1	1	1	16	64
O8	Apparel		8	6	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	9	1*	1*	1*	1*	1*	1*	1*	1*	4	16
O9	Engineering goods		1*	6	1*	1*	9	1*	1	1*	1*	9	5	1*	1	1	1*	1	1	1	1	1*	1*	1*	7	1*	1*	12	48
O10	Knitwear		1*	6	9	9	1*	1	1*	1	1	9	1*	4	9	1	8	1	7	1	1	2	1	9	9	1*	1*	19	76
O11	Socks		9	9	1*	9	1*	1	1	1	1	9	9	9	9	1	1*	1*	1	1	1	1	1	9	1*	9	1*	19	76
O12	Knitwear		1*	1*	1*	9	1*	1*	1*	1*	1*	9	9	9	1*	1	1	1	1	1	1	1*	1	5	1*	9	1	14	56
O13	Garments		1*	1*	1*	1*	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	9	1	1*	1*	1*	1*	1*	1*	1*	1*	3	12
O14	Engineering goods		1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	1*	1	1	1	1*	1*	1*	9	1*	1*	1*	5	20
O15	Chemicals		6	6	9	9	9	2	2	5	1	1*	1*	9	1*	1	2	1	1	1	1*	1	2	9	1*	1*	9	19	76
O16	Textile - Yarn		7	7	1*	1	9	9	9	4	2	9	1*	1*	9	1	1*	1*	1	1	1	1*	1*	8	1*	1*	1	16	64
O17	Textile - Yarn		9	9	9	9	9	1	1	1	1	1*	1*	1*	1*	2	1*	1	1*	5	2	3	1	9	1*	1*	1*	16	64
O18	Engineering goods		7	7	8	9	1*	1	1	2	9	1*	1*	1*	1*	1	7	3	9	1	1	1	1	1*	1*	1*	1	17	68
O19	Textile		1*	1*	1*	1*	1*	1	1	4	1	8	1*	5	1*	2	1*	1	1	1	1	2	1	5	1*	1*	1*	14	56
O20	Knitwear		1*	1*	1*	9	9	1	1	1	1	9	5	9	1*	9	9	1	1	1	9	9	9	9	1*	6	1*	19	76
O21	Engineering goods		8	8	1*	9	1*	1	1	1	1*	9	1*	1*	1*	1*	2	1	1	1	1	1	1*	5	2	1*	1*	15	60
O22	Textile - Yarn		6	7	1*	9	8	1	1	2	1	9	1	5	1*	1	1	1*	1*	1*	1*	1	1	9	1*	5	1*	17	68
O23	Hosiery		6	7	1*	9	9	1	1	1	1	9	9	9	1*	2	1*	1	1*	1	1	1*	1	1	1*	3	1	19	76
O24	Chemicals		6	6	1*	9	8	1	1	1	1	8	1*	7	9	1	1	1*	1	1	1	2	1	8	3	5	1	22	88
O25	Textile		9	9	9	1*	1*	1	1	1	1*	1*	1*	1*	1*	1	1*	1	1	1	1*	1*	1	9	1*	1*	1*	12	48
O26	Apparel		6	6	7	9	9	1	1	1	1	1*	1*	1*	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	10	40
O27	Engineering goods		6	6	1*	9	9	2	1	1	1*	9	6	8	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	10	40
O28	Leather goods		9	9	1*	9	9	1	2	3	3	9	1*	8	1*	1	1*	1	1	1	1*	8	1	9	1	6	1*	19	76
O29	Chemicals		9	9	9	7	1*	2	3	9	1	1*	1*	1*	1*	1	1*	1*	1	9	6	3	1	1*	9	1*	1*	15	60
O30	Textile		1*	1*	1*	1*	1*	1	1	1	1	1*	1*	1*	1*	3	1*	1	1	1*	1*	4	1*	1*	1*	1*	1	9	36
O31	Textile		1*	1*	1*	9	1*	1	1	1*	1	9	1*	7	1*	1	1	1	1*	1*	1*	1	1*	8	1*	6	1*	12	48
O32	Hosiery		9	9	1*	9	1*	1	1	1	1	9	1*	9	1*	1	1*	1	1	1	1*	2	1*	9	1*	1*	1*	15	60
O33	Textile		1*	1*	1*	9	1*	1	1	2	1*	9	1*	8	1*	1	1*	1	1	1	2	1	1	1*	1*	1*	1*	13	52
O34	Textile		6	6	1*	9	1*	1	1	1	1	9	1*	1*	1*	1	1	1*	1*	1	1*	2	1	1*	6	5	1*	15	60
O35	Sugar Industry		6	6	1*	9	9	2	1	1	1	9	9	7	1*	1	1	1*	1*	1	1	1	1*	9	1*	9	1*	18	72
O36	Engineering goods		6	6	1*	9	8	1	1	1	1	9	4	7	1*	1	1	1	1*	1	1*	1	1	1*	1*	7	1*	18	72
O37	Textile		1*	1*	1*	1*	1*	2	2	6	1*	1*	1*	1*	1*	1*	1*	1*	1	1*	1*	1*	1*	1*	1*	1*	4	5	20
O38	Chemicals		1*	1*	1*	9	1*	1	2	4	1	1*	1*	1*	1*	1	1*	1	1	1	1	1	1*	1*	5	1*	1*	12	48
# of O MEI	**Count**		23	24	9	27	16	31	30	29	24	25	11	19	6	30	14	28	28	28	18	23	21	22	11	13	10		
	%		61	63	24	71	42	82	79	76	63	66	29	50	16	79	37	74	74	74	47	61	55	58	29	34	26		

Note.
Prod Exp – Product exported, MD – main dimension, SD – sub-dimension, EI – ergonomics indicator. O1: word 'O' is representing the organization and 1 is the number count. # of EIs M by the O – Number of EIs measured by the Organization, # of O MEI – Number of organizations measuring the EI, % – Percentage.
The type of product exported by each organization is mentioned in the second column. Symbol '1*' represents an EI that is not measured by the organization. Hence, as per the methodology it is given the lowest score.

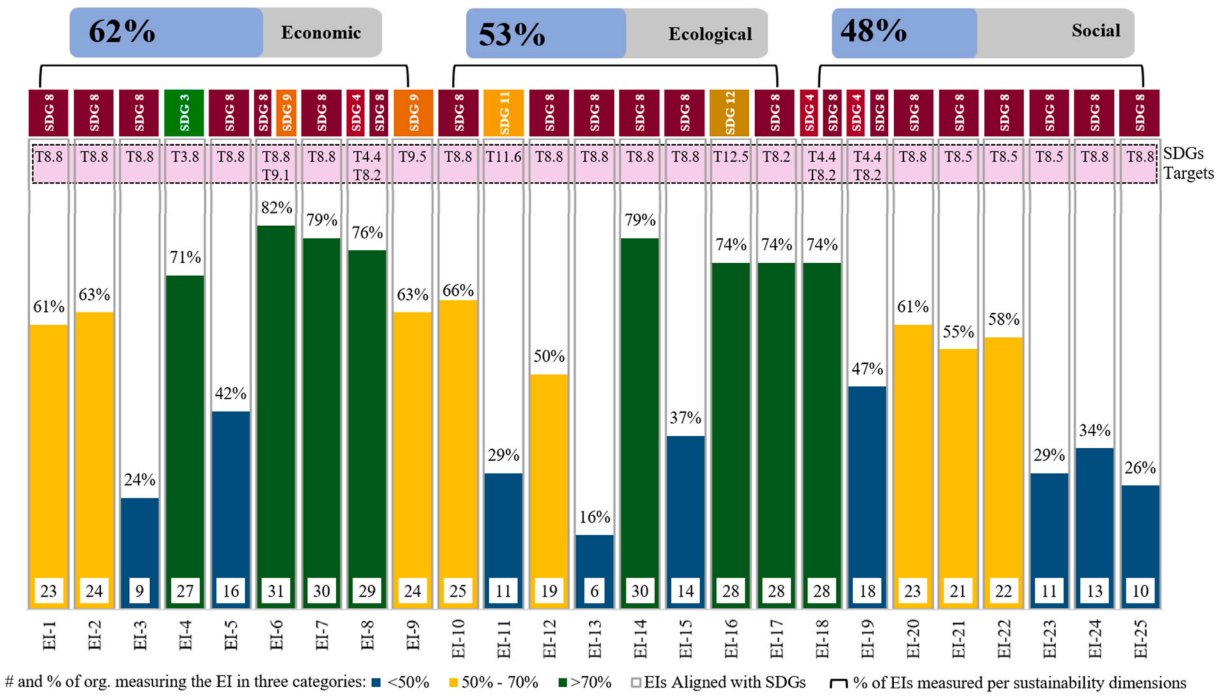

Fig. 3. Results of EIs from the sample organizations and their mapping with SDGs.

Table 6
Procedure for calculating the unified composite score from questionnaire results for manufacturing organization 'O15'.

EIs	Questionnaire Result	Normalize value	Sub Dimensions	Value	Main Dimensions	Value	Unified Composite Score (Out of 9)
1	227 days	6	Loss	7.80	Economic	5.15	**3.41**
2	227 days	6					
3	0.054%	9					
4	US $ 1/employee	9					
5	1 # count	9					
6	US $ 7/employee	2	Investment	2.5			
7	US $ 7/employee	2					
8	US $ 9/employee	5					
9	US $ 70/employee	1					
10	Not measured	1	Conditions	2.6	Ecological	1.97	
11	Not measured	1					
12	8 days	9					
13	Not measured	1					
14	50 # count	1					
15	200 # count	2	Contribution	1.33			
16	0.000%	1					
17	6.670 %	1					
18	1.000%	1	Self-Development	1.25	Social	3.13	
19	Not measured	1					
20	5 # count	1					
21	100 # count	2					
22	2.400%	9	Satisfaction	5			
23	Not measured	1					
24	Not measured	1					
25	30.000%	9					

sustainable process performance not only as a unified composite score, but also individually measure each sustainability dimension - economic, ecological, and social. This allows focal firms to identify areas of improvement for their suppliers and ensure long-term collaborations.

The results showed that no organization scored in the 'Good' or 'Excellent' categories, indicating a lack of good ergonomics practices. Economic scores were generally higher than ecological and social scores. The study highlights the need for manufacturing organizations in Pakistan to adopt more sustainable process practices in ergonomics and improve their performance across all three dimensions. These findings regarding unsatisfactory sustainability practices by manufacturing organizations in Pakistan were reported by previous literature (Alam and Tariq, 2023; Batool et al., 2022).

4.1. Theoretical implications

This study advances theoretical knowledge by integrating ergonomics-based indicators into supplier selection. While previous research has explored social sustainability in supplier selection (Rajesh and Aljabhan, 2024), no studies have, to our knowledge, incorporated operational factors such as employee conditions, health and safety, training, and welfare into the assessment of sustainable process performance from an ergonomics perspective. Even in the domain of ergonomics, frameworks have been proposed to assess sustainability via EIs

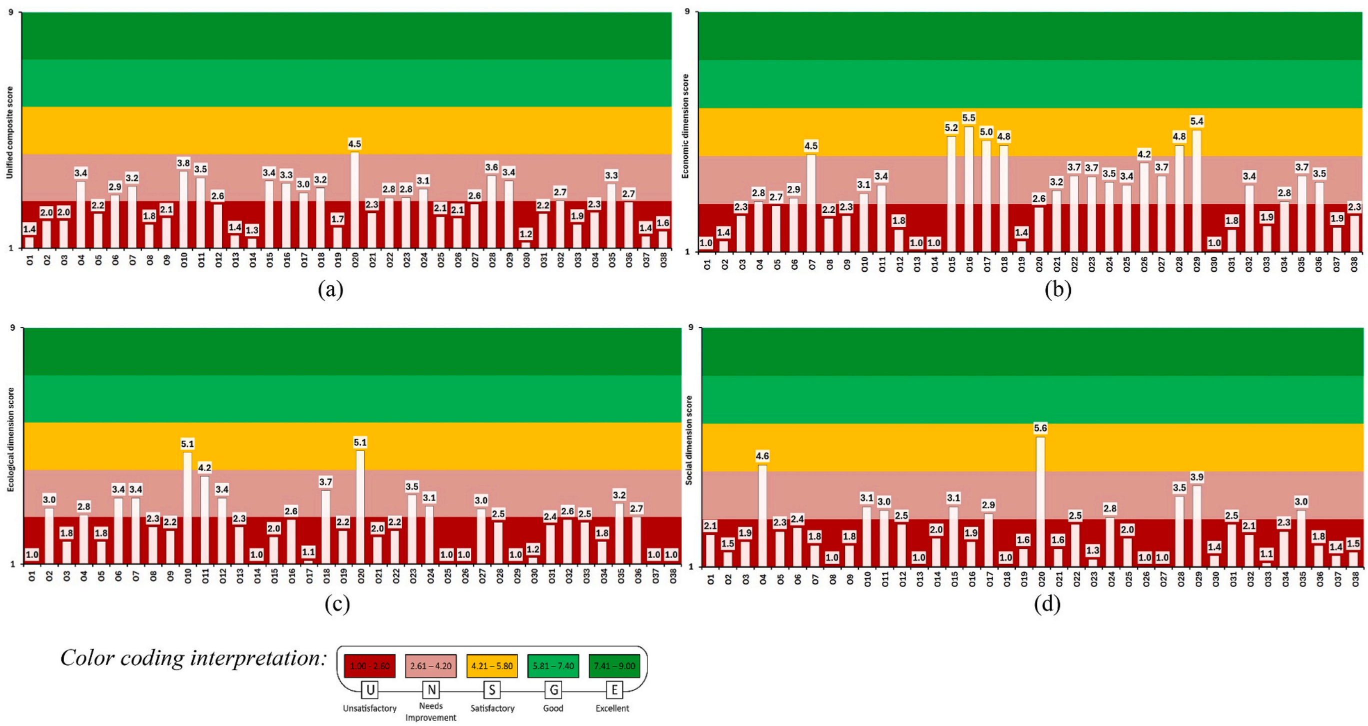

Fig. 4. Performance scorecard for benchmarking organization-to-organization: (a) unified composite score, (b) economic dimension score, (c) ecological dimension score, and (d) social dimension score.

(Sarbat and Ozmehmet Tasan, 2022), but they have not been empirically tested due to the varying nature of units of measurement. This study addresses this gap by proposing an interval-based evaluation scheme to normalize data and empirically collect data from suppliers, thereby developing a mechanism for assessing supplier performance.

4.2. Managerial implications

This study offers several practical applications for managers. The proposed methodology is easy to integrate into daily routines, with the 1–9 interval scale serving as a simple and effective benchmarking tool for assessing organizational performance. Unlike more complex multi-criteria decision-making methods such as TOPSIS, ELECTRE, VIKOR, PROMETHEE, and their fuzzy versions, which are often seen as impractical (Ionaşcu et al., 2024; Karsak and Dursun, 2015), this approach is simpler for a decision maker.

The EIs in this study focus on operational performance, making them more relevant and likely to be measured by industry. The findings (Fig. 3) show that 16 out of 25 indicators are measured by more than 50% of manufacturing organizations. This indicates that organizations are more likely to measure these EIs than other reporting mechanisms (GRI), which are considered more complex (Hazelton et al., 2022). Moreover, in developing countries, GRI has been reported to have an insignificant impact on increasing social responsibility (Tauringana, 2020) and is not adequately measured by organizations (Alam and Tariq, 2023).

Finally, the performance scorecard can be used not only for audits but also for supplier development through its practicality in assessing the organization's sustainable process performance. It allows for making informed decisions for the quantitative monitoring of suppliers' sustainable performance and signifies the importance of EIs in an organization's performance, addressing the limitations of traditional qualitative audits. By identifying weaknesses in economic, ecological, and social aspects, focal firms can set clear improvement targets for suppliers, fostering long-term development and sustainability.

4.3. Societal implications

This study makes a significant societal contribution, particularly as many suppliers to focal firms are in low-to mid-income countries. Despite efforts by the focal firms, the processes of suppliers do not always conform to best sustainable practices from a social (or ecological) perspective. Gains have been made in overcoming serious issues like child labor (Gold et al., 2015), human rights (Rodríguez et al., 2016), community development (Yawar and Kauppi, 2018), codes of conduct (Reinecke and Donaghey, 2021), and labor practices (Bubicz et al., 2019), but challenges remain in improving working conditions, health and safety, and employee development (Uttam et al., 2024). Applying ergonomics can improve working conditions, promote worker well-being, and reduce health risks (Brunoro et al., 2020). The concept of decent work, encompassing ideal conditions, justice, personal development, and equity (ILO, 2024), aligns with the vision of ergonomics, which aims to enhance both organizational performance and worker well-being (IEA, 2023). The scorecard proposed in this study offers a clear framework for assessing the impact of working conditions on production processes, helping focal firms ensure no compromises are made on the social dimension.

4.4. Limitations and future research

While this study significantly contributes by proposing the use of EIs for supplier assessment and thereby making audits more quantitative, it is not without its limitations. Firstly, while the evaluation scheme in Table 4 is a valuable tool for assessing sustainable process performance basically, the cut-off points in the evaluation scheme might need to be recalibrated with a larger sample of organizations or if the nature of organizations differ significantly. In our study, the cut-off points were used as an illustrative tool to categorize the performance of this sample of manufacturing organizations based on their composite scores. These cut-off ranges help in quantifying what can be considered relatively good, average, or poor performance with respect to ergonomics indicators through a generic/basic approach. This study proposes an introductory methodology for developing a fundamental scorecard framework that can be further customized and refined. These cut-off points are not fixed; rather, they are context-dependent and can vary depending on regional, industrial, or organizational practices. Our approach provides a flexible and fundamental framework where these cut-off points can be adapted by practitioners. While doing this, the proportion of ergonomists or engineers with a background in Human Factors and Ergonomics among all respondents can be increased. Secondly, the EIs and their sub-dimensions should be further explored using different classifications and proposals, including ergonomics principles from the ISO 6385:2016 standard to broaden their application in sustainable supply chains.

All EIs in this study were given equal weighting, though focal firms may prioritize some EIs over others. Future research could explore varying EI weights using multi-criteria decision-making approaches. This study serves as a basic exploration as being pioneer for the studies in this research field, requiring further empirical validation across diverse manufacturing contexts. Such research would strengthen our evaluation scheme and offer key insights into sustainable supplier selection within the ergonomics field.

Certain EIs - economic (EI-3, EI-5), ecological (EI-11, EI-13, EI-15), and social (EI-19, EI-23, EI-24, EI-25) - were less frequently assessed by manufacturing organizations. Future research should investigate why. Are these EIs seen as irrelevant, too costly to measure, or unnecessary due to minimal requirements from focal firms? Addressing these questions could guide future studies, expand on our findings and enhance the understanding of sustainable supply chain practices.

5. Conclusion

This study introduces an innovative performance scorecard for evaluating the sustainable process performance of manufacturing organizations from an ergonomics perspective, particularly those supplying to focal firms in the West. The EIs used in this study provides a comprehensive framework for assessing supplier process performance. By normalizing diverse measurement units on a 9-point scale, the unified composite score methodology—grounded in EIs from Sarbat and Ozmehmet Tasan (2022)—provides a comprehensive and effective framework for benchmarking supplier process performance. It addresses the key limitations of traditional auditing practices, which often overlook the social dimension.

The present study addresses a significant research gap by integrating ergonomic principles into supplier evaluation, thereby providing managers with a comprehensive tool for informed decision-making and enhanced working conditions. Empirical evidence from 38 Pakistani manufacturing organizations substantiates the practical implementation of this methodology, which culminates in sustainable process performance evaluation within the context of supply chain ergonomics. This contributes to the development of more stable and socially responsible supply chains.

CRediT authorship contribution statement

Asim Amjad: Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Mujtaba Hassan Agha:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Shahid Ikramullah Butt:** Writing – original draft, Validation, Supervision, Methodology, Conceptualization. **Andrew Thatcher:** Writing – review & editing, Writing – original draft, Validation, Investigation, Formal analysis, Conceptualization. **Irem Sarbat:** Writing – review & editing, Writing – original draft, Validation, Investigation, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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