Original scientific paper

UDC: 338:502.131.1(497.11)

Received: February 11, 2025.
Revised: April 30, 2026.
Accepted: May 05, 2026.

10.23947/2334-8496-2026-14-1-001-010

Check for updates

Social and Technological Drivers of Sustainable Manufacturing Performance: A Cognitive-Organizational Perspective

Stana Vasić[1], Kristina Ristić[1], Nebojša Brkljač[1], Daria Vidović[1], Srđan Vulanović[1]*

[1]Faculty of Technical Sciences, University of Novi Sad, Department of Industrial Engineering and Management, Novi Sad, Serbia, e-mail: vasic.stana@uns.ac.rs, kristina.ristic@uns.ac.rs, n.brkljac@uns.ac.rs, daria.vidovic98@uns.ac.rs, srdjanv@uns.ac.rs

Abstract: Sustainable manufacturing has become a strategic priority for organizations seeking to balance competitiveness with environmental and social responsibility. However, the successful implementation of sustainability initiatives depends not only on technological and economic factors but also on workforce competencies, organizational learning, and human-centered drivers. This study examines the cognitive and organizational determinants of sustainable manufacturing performance through the analysis of social, economic, environmental, and quality drivers in manufacturing organizations in the Republic of Serbia. Data were collected using a structured questionnaire administered to 153 employees in production-related positions. The research model integrates human, technological, and managerial dimensions of sustainability and evaluates their influence on six performance outcomes: environmental, social, economic, process, innovation, and stakeholder performance. Multiple regression analyses were applied to test the proposed relationships. The findings indicate that environmental and economic drivers exert the strongest positive effects on performance outcomes, while social drivers - reflecting employee engagement, training, and organizational culture - demonstrate moderate but significant influence. Quality drivers show mixed effects across performance domains. The results highlight the critical role of workforce involvement, knowledge development, and sustainability-oriented competencies in supporting organizational transformation toward sustainable manufacturing. This study contributes to the emerging cognitive-organizational perspective on sustainability by integrating human and technological drivers within a single empirical framework and providing evidence from a transition economy context.

Keywords: *sustainable manufacturing, cognitive-organizational drivers, organizational performance, workforce competencies, technological drivers, human factors.*

Introduction

Sustainable manufacturing is evolving as organizations adopt strategies to reduce waste, enhance efficiency, and align competitiveness with environmental and social responsibility (Karuppiah et al., 2024; Scharmer et al., 2024). The concept of sustainable manufacturing encompasses the integration of environmental management, social responsibility, and operational excellence into production processes to achieve long-term viability (Scharmer et al., 2024). However, despite theoretical advances, the empirical evidence on which drivers are crucial in the process of implementing sustainable manufacturing, especially in transitional economies, remains limited. Companies are increasingly under pressure to align competitiveness with responsibility toward the environment, employees, and society. Beyond technological investments and environmental initiatives, sustainable manufacturing increasingly depends on human and cognitive factors embedded within organizational systems. Employee competencies, sustainability awareness, continuous learning, and knowledge sharing practices shape the extent to which sustainability principles are adopted and operationalized in production environments. From this perspective, manufacturing transformation is not solely a technical process but also a cognitive and educational one, requir-

*Corresponding author: vasic.stana@uns.ac.rs

ing the development of workforce capabilities aligned with sustainable and digital industrial paradigms. In transition economies, the pressure rises, as traditional industrial models must adapt to the requirements of sustainability and digital transformation (Karuppiah et al., 2024). Manufacturing organizations are, therefore, expected to integrate sustainability principles not only to meet regulatory demands but also to improve resilience, innovation capacity, and market reputation (Scharmer et al., 2024). Identifying drivers of sustainable manufacturing provides both theoretical and practical insights into how manufacturing organizations can align economic efficiency with environmental and social objectives (Karuppiah et al., 2024). Thus, this research aims to identify and analyze the key drivers that influence the implementation of sustainable manufacturing practices in production-oriented organizations, with a specific focus on the Republic of Serbia. Based on a comprehensive literature review, a list of factors that stimulate the adoption of sustainable practices in industrial systems has been developed. The research provides insights into the current state of sustainable manufacturing implementation within the Serbian manufacturing sector. Drivers influence the degree to which sustainable manufacturing practices are adopted, which in turn affects performance. Higher levels of drivers are expected to lead to stronger implementation and thus better outcomes across performance dimensions. The model allows for cross-domain effects, anticipating positive relationships across driver-performance pairs. While many explore drivers of sustainable practices in developed economies, fewer empirical investigations focus on transition economies or on multiple driver types simultaneously. This research examines social, economic, environmental, and quality drivers simultaneously in relation to multiple dimensions of organizational performance (social, economic, environmental, process, innovation, and stakeholder). This research addresses the gap by surveying manufacturing organizations in Serbia, encompassing operational, managerial, and supportive roles. This approach provides novel empirical evidence from a transitional economy. Thus, this research contributes by: (a) empirically validating a framework of sustainable manufacturing adoption; (b) testing the relative influence of distinct drivers on multiple performance outcomes; and (c) providing evidence from a country with limited prior research in this domain. Considering the research subject, objectives, and existing literature, the following research question has been formulated: “How do social, economic, environmental, and quality (technological) drivers influence sustainable manufacturing performance, from a cognitive-organizational perspective?”

Literature review

Achieving sustainability-oriented performance improvement requires a multidimensional approach that integrates organizational, technological, and human factors (Rosen and Kishawy, 2012). The idea has evolved in recent years from being solely ecological to encompassing environmental management in relation to innovation and operational excellence (Andronie et al., 2021). Manufacturing businesses are increasingly recognizing that sustainability is not just a moral or environmental requirement; it is also a business imperative. Resilience and long-term competitiveness are fueled by sustainability (Andronie et al., 2021). The internal and external factors that are essential for organizations to implement socially and environmentally responsible practices are represented by drivers in this framework. These drivers are typically divided into four groups based on a summary of earlier research: social, economic, environmental, and quality drivers. Each of these groups influences sustainability outcomes through specific mechanisms. These factors frequently work together to produce synergies that increase the overall impact on the organization. Social drivers underscore the importance of organizational culture, employee well-being, and human capital as the cornerstones of long-term success. Strong ergonomic work practices and a safety culture increase dependability, lower accident rates, and promote long-term results (Małysa and Gajdzik, 2020). Furthermore, ongoing human resource development and employee involvement improve environmental commitment and accountability (Lee et al., 2019; Madero-Gómez et al., 2023). Recent research emphasizes that sustainability implementation is strongly influenced by workforce knowledge structures, pro-environmental attitudes, and training systems that foster sustainability-oriented behavior. Learning organizations are more capable of integrating environmental practices into operational routines, as employees develop cognitive frameworks that support long-term ecological decision-making. Consequently, human capital development and sustainability education emerge as critical enablers of manufacturing transformation (Garavan et al., 2012; Wiek et al., 2011). Stakeholder engagement and corporate social responsibility (CSR) programs are two strong external drivers that promote environmentally friendly behavior (Afsar and Umrani, 2020). Organizations notice a greater alignment between social responsibility and organizational outcomes when employees actively participate in sustainability projects, particularly in emerging markets (Baykal and Divrik, 2023). Cost-cutting, energy efficiency, productivity gains, and innovation are all examples of economic drivers that enhance competitive advantage. According to empirical research, data-driven decision-making and predictive maintenance dramatically reduce waste, operational expenses, and downtime, enhancing sustainability and profitability (Polese et al., 2021; Mahfoud et al., 2024). Since businesses that utilize structured energy management techniques achieve quantifiable savings and a reduction in their environmental impact, energy efficiency remains a significant economic driver (Solnørdal and Foss, 2018). These factors also apply to supply chains: effective inventory control and logistics reduce waste and improve responsiveness (Panigrahi et al., 2024; Gibson, 2023). Due to their concrete and quantifiable nature, economic and environmental drivers typically have stronger and more consistent effects on performance outcomes, according to the literature (Madero-Gómez et al., 2023; Hariyani et al., 2023). Environmental drivers encourage businesses to adopt green innovation, eco-efficiency, and cleaner production practices to minimize their environmental impact. They frequently result from proactive environmental management, consumer expectations, or regulatory frameworks (Rosen and Kishawy, 2012; Andronie et al., 2021). With their clear routes to resource-efficient and low-carbon production, eco-innovation and circular economy concepts have taken center stage in contemporary manufacturing strategies (Chaurasiya and Singh, 2024). Sustainability initiatives are further aligned with market demand by the incorporation of green product design and rising consumer awareness (Bravo et al., 2022). Environmental performance is now recognized as being greatly enhanced by technological innovation, energy-efficient production systems, and the effective management of renewable resources (Fatma and Haleem, 2023; Panagiotopoulou et al., 2022). Developing internal green competencies also promotes continuous improvement and long-term capability building (Fatma and Haleem, 2023). Sustainability is closely linked to innovation and ongoing improvement driven by quality. Achieving environmental and social objectives without sacrificing process or product standards is made possible by combining quality management concepts with sustainable manufacturing (Abubakr et al., 2020). By coordinating sustainability objectives with competitiveness and customer value creation, innovation-oriented quality systems promote change (Cordova and Celone, 2019). Moreover, sustainable relationship management and customer-centric strategies that strengthen stakeholder trust and company reputation are examples of quality drivers that go beyond production (Ferrer-Estévez and Chalmeta, 2023). Together, these factors show that manufacturing sustainability is not only ecologically conscious but also operationally dependable, creative, and value-driven.

Materials and Methods

To investigate the impact of various factors on sustainable manufacturing performance in production-oriented organizations in Serbia, this study employed a quantitative, cross-sectional research design. This method was considered suitable for evaluating multiple relationships simultaneously and identifying trends across a wide range of industrial settings.

Data collection

To ensure widespread participation, a structured questionnaire was disseminated both electronically and in print to gather data. Employees from manufacturing companies across various industrial sectors, including food production, machinery, metal processing, and automotive components, provided a total of 153 valid responses. Because the respondents held a variety of professional roles, from managerial and administrative to technical and operational, the sample was representative of those directly involved in or supporting production processes. The survey was anonymous and voluntary to complete. Prior to their involvement, all participants were informed about the purpose of the study and the confidentiality of their responses, and they provided their informed consent. The study was conducted in accordance with ethical standards governing research involving human participants. In line with institutional and national guidelines, formal ethical approval was not required because the research did not involve interventions, experimental procedures, or the collection of sensitive personal data.

Sample characteristics

The final sample consisted of 153 respondents employed in manufacturing and production-related organizations in the Republic of Serbia. With respect to gender, 139 respondents were male (90.8%) and 14 were female (9.2%), reflecting the gender structure commonly observed in manufacturing and industrial sectors. The demographic characteristics of the respondents are summarised in Table 1. The sample is predominantly male (90.8%), with most respondents holding a university degree (75.8%). The average age of respondents was 41.19 years (SD = 8.74), ranging from 20 to 66 years. Regarding educational attainment, the majority of respondents held higher education degrees. More than three quarters of the participants had completed university-level education, while a smaller proportion possessed doctoral qualifications. The remaining respondents had completed secondary or college-level education. Participants were employed across a wide range of manufacturing sectors, including food and beverage production, metal processing, automotive industry, energy and gas, chemical and pharmaceutical industries, as well as other manufacturing activities. In terms of organizational roles, the respondents represented various hierarchical levels, including top and middle management (e.g., directors, owners, and department managers), engineers and technical specialists (e.g., production, quality, and process engineers), and operational and technical staff. This diversity enhances the relevance and credibility of the collected data for analyzing sustainable manufacturing practices.

Table 1. *Demographic characteristics of respondents (N=153).*

Variable	Category	n	%
Gender	Male	139	90.8
	Female	14	9.2
Education level	Secondary school	10	6.5
	College	19	12.4
	University degree	116	75.8
	Doctoral degree	8	5.2
Age (years)	Mean (SD)	41.19 (8.74)	
	Range	20–66	

Note. Percentages may not sum to exactly 100 due to rounding

Instrument development and data analysis

Prior empirical studies on organizational performance and sustainable manufacturing provided the foundation for developing the questionnaire. It contained measurement items intended to evaluate four types of drivers: quality drivers (QM), environmental protection drivers (EPM), economic drivers (EM), and social drivers (SM). In this study, the term “drivers” is used consistently to refer to the social, economic, environmental, and quality-related factors that support sustainable manufacturing implementation. Environmental performance (ENP), social performance (SP), economic performance (EP), process performance (PP), innovation and development performance (IDP), and stakeholder performance (STP) were the six performance outcomes that were measured accordingly. A five-point Likert scale (1 = strongly disagree; 5 = strongly agree) was used to rate each item. Items were modified to represent the unique traits of Serbian manufacturing companies, ensuring clarity and contextual relevance. The appropriateness of the wording, structure, and response options for the target population was confirmed by a pilot test conducted with a small subset of respondents (n = 15). Before the full-scale survey, minor formatting and language changes were made. IBM SPSS Statistics (version 26) was used to analyze the data. To give a general picture of respondent characteristics and variable distributions, descriptive statistics were calculated. Bivariate relationships between drivers and performance metrics were investigated using Pearson’s correlation coefficients. Several multiple linear regression analyses were conducted to test the proposed relationships. Six categories of performance outcomes - environmental, social, economic, process, innovation and development, and stakeholder - were designated as dependent variables, and four categories of drivers - social, economic, environmental, and quality - were designated as predictor variables. To evaluate each driver’s distinct contribution while accounting for shared variance among predictors, separate regression models were estimated for each outcome dimension, with all drivers entered simultaneously.

Unstandardized coefficients (B), standard errors (SE), standardized coefficients (β), p-values, and R2 and adjusted R2 values were used to report the results as measures of explanatory power. Model diagnostics validated the assumptions of linearity and homoscedasticity. Multicollinearity diagnostics were examined prior to regression analyses, and variance inflation factor (VIF) values were below commonly accepted thresholds, indicating that multicollinearity did not pose a concern for the estimated models.

Results

Descriptive statistics and correlations between study variables

Descriptive statistics, reliability coefficients, and correlations between study variables are presented in Table 2. All scales demonstrated acceptable internal consistency, with Cronbach's alpha values ranging from .69 to .87. The distributions of the variables were considered acceptable for the planned parametric analyses. Skewness values were within ±2, while kurtosis values were mostly close to conventional thresholds, with several values slightly exceeding ±2. Given the sample size and the absence of extreme deviations, the variables were treated as sufficiently approximately normally distributed for correlation and regression analyses. The four types of drivers were positively and strongly correlated with each other (rs = .57–.74, ps < .001). They also showed positive associations with all performance outcomes, with correlations ranging from moderate to strong (rs = .41–.75, ps < .001). The pattern of correlations suggests that stronger sustainability drivers are consistently associated with higher performance across environmental, social, economic, process, innovation and development, and stakeholder domains. Among the performance indicators, intercorrelations were consistently strong (rs = .51–.76, ps < .001), indicating that higher levels of one type of performance were generally accompanied by higher levels of other performance dimensions.

Table 2. *Descriptive statistics, reliability coefficients, and correlations between study variables*

	1	2	3	4	5	6	7	8	9	10
1. Social drivers	1									
2. Economic drivers	0.622 **	1								
3. Environmental drivers	0.624 **	0.734 **	1							
4. Quality drivers	0.628 **	0.643 **	0.571 **	1						
5. Environmental performance	0.524 **	0.611 **	0.704 **	0.445 **	1					
6. Social performance	0.559 **	0.645 **	0.604 **	0.579 **	0.619 **	1				
7. Economic performance	0.592 **	0.633 **	0.629 **	0.586 **	0.704 **	0.701 **	1			
8. Process performance	0.557 **	0.624 **	0.660 **	0.558 **	0.655 **	0.668 **	0.746 **	1		
9. Innovation and development performance	0.474 **	0.638 **	0.665 **	0.417 **	0.751 **	0.647 **	0.764 **	0.732 **	1	
10. Stakeholder performance	0.494 **	0.552 **	0.500 **	0.528 **	0.508 **	0.630 **	0.687 **	0.701 **	0.608 **	1
Min–max	6–25	4–19	4–20	4–20	5–24	4–20	4–20	4–20	4–20	4–20
M	18.58	14.77	14.75	15.05	17.98	15.21	14.13	14.95	14.98	14.86
SD	3.36	2.79	3.29	3.01	3.99	2.94	3.19	2.79	3.34	3.08
Skewness	−0.85	−1.34	−1.27	−1.06	−1.10	−1.23	−0.82	−1.39	−1.21	−1.18
Kurtosis	0.86	2.55	1.87	1.12	0.69	1.91	0.88	3.13	1.30	2.06
α	0.69	0.71	0.74	0.75	0.79	0.76	0.76	0.74	0.87	0.81

Note: M = mean; SD = standard deviation. ** p < 0.01

Multiple regression analyses of drivers predicting performance outcomes

Results of six multiple regression analyses are presented in Table 3. Together, the four types of drivers explained between 36% and 51% of the variance in performance outcomes, with adjusted R^2 values ranging from .36 (stakeholder performance) to .51 (environmental performance). For environmental performance, environmental drivers were the strongest positive predictor (β = .53, p < .01), and economic drivers also showed a significant positive effect (β = .19, p < .05), whereas social and quality drivers were nonsignificant. In the case of social performance, three drivers, economic (β = .30, p < .01), environmental (β = .19, p < .05), and quality (β = .20, p < .05), emerged as significant positive predictors, while social drivers did not contribute significantly. For economic performance, all four drivers showed significant positive associations: social (β = .18, p < .05), economic (β = .21, p < .05), environmental (β = .25, p < .01), and quality (β = .19, p < .05). In contrast, for process performance, only environmental drivers significantly predicted outcomes (β = .36, p < .01), while the remaining predictors were nonsignificant. Regarding innovation and development performance, economic (β = .35, p < .01) and environmental drivers (β = .43, p < .01) both emerged as strong predictors, whereas social and quality drivers did not reach significance. Finally, for stakeholder performance, economic (β = .25, p < .05) and quality drivers (β = .23, p < .05) were significant positive predictors, while social and environmental drivers were nonsignificant. Taken together, the results indicate that environmental and economic drivers most consistently predicted performance across domains, with environmental drivers in particular showing the strongest effects for environmental and innovation and development outcomes.

Table 3. *Multiple regression analyses predicting performance outcomes from sustainability drivers*

Performance

	Environmental		Social		Economic		Process		IDP		Stakeholder	
Drivers	B (SE)	β	B (SE)	β	B (SE)	β	B (SE)	β	B (SE)	β	B (SE)	β
Social	0.13 (0.09)	0.11	0.12 (0.07)	0.13	0.18 (0.08)	0.18 *	0.10 (0.07)	0.16	0.04 (0.08)	0.04	0.12 (0.08)	0.13
Economic	0.27 (0.13)	0.19 *	0.31 (0.10)	0.30 **	0.24 (0.11)	0.21 *	0.18 (0.09)	0.18	0.42 (0.11)	0.35 **	0.27 (0.12)	0.25 *
Environmental	0.64 (0.11)	0.53 **	0.17 (0.08)	0.19 *	0.24 (0.09)	0.25 **	0.31 (0.08)	0.36 **	0.44 (0.09)	0.43 **	0.10 (0.09)	0.11
Quality	−0.06 (0.11)	−0.04	0.19 (0.08)	0.20*	0.21 (0.09)	0.19 *	0.15 (0.08)	0.16	0.08 (0.09)	0.08	0.23 (0.09)	0.23 *
R^2	0.521		0.494		0.512		0.507		0.494		0.374	
adj. R^2	0.508		0.480		0.499		0.494		0.480		0.357	

Note. B = unstandardized regression coefficient (standard errors in parentheses); β = standardized regression coefficient; R2 = coefficient of determination; adj. R2 = adjusted R2. * p < 0.05; ** p < 0.01

Discussion

The study's findings offer new empirical insights into how social, economic, environmental, and quality drivers impact long-term organizational performance in Serbia's manufacturing industry. The results indicate that social drivers have a moderate but positive influence, while quality drivers exhibit mixed effects. In contrast, economic and environmental drivers have the most substantial impact on performance outcomes, aligning with global research trends. The significant influence of economic drivers underscores the ongoing importance of cost optimization, efficiency, and innovation in fostering sustainable manufacturing. Technologies such as automation, artificial intelligence, and predictive maintenance can increase productivity while reducing waste production and operating expenses (Polese et al., 2021; Mahfoud et al., 2024; Agrawal et al., 2023). In addition to increasing production efficiency, these technological advancements make organizational systems more robust and flexible. Additionally, one of the main factors facilitating sustainable industrial transformation is technological and economic preparedness (Narkhede et al., 2025; Renna and Materi, 2021). Environmental factors are also important, as evidenced by the increased consciousness of ecological responsibility in contemporary manufacturing. The importance of environmental considerations in this study aligns with earlier research that emphasizes energy efficiency, the circular economy, and green innovation as crucial components of sustainable operations (Rosen and Kishawy, 2012; Panagiotopoulou et al., 2022; Shaikh et al., 2024). This research indicates that manufacturing companies in transition economies, such as Serbia, are starting to recognize environmental performance as both a source of competitive advantage and a compliance requirement. Furthermore, it has been demonstrated that combining environmental management systems with green product design improves an organization's long-term resilience and reputation (Bravo et al., 2022; Ghazali et al., 2023). Employee engagement, safety, and corporate social responsibility are valued, but they are still evolving as strategic pillars in the region's manufacturing culture, influenced by moderate social drivers. From a cognitive-organizational perspective, the findings suggest that sustainability performance is not driven exclusively by technological readiness or financial investment, but also by the extent to which employees internalize sustainability principles. Workforce training, participatory decision-making, and organizational learning mechanisms contribute to the translation of sustainability strategies into operational practices. This reinforces the view that sustainable manufacturing transformation requires alignment between technological systems and human cognitive capacities (Norton et al., 2015). This partially supports earlier research, which shows that when social initiatives - such as training, well-being, and stakeholder involvement - are fully incorporated into management practices, they improve performance focused on sustainability (Madero-Gómez et al., 2023; Baykal and Divrik, 2023; Lee, 2018). The statistically minor impact, compared to economic and environmental drivers, however, may be the result of organizational priorities that prioritize operational and financial stability over more extensive social change, in the context of developing or transition economies such as Serbia. Challenges such as limited financial resources, regulatory gaps, and lower awareness present significant barriers to adoption. For example, studies on the long-term growth of the Serbian manufacturing sector highlight the need for innovative industrial policy, structural limitations, and a lack of specialization in high-value goods (Mićić and Savić, 2018). Additionally, sustainability advancement has been linked to Serbia's readiness for digital transformation, indicating that technological capabilities may serve as a facilitator of sustainable practices in manufacturing organizations (Rakic et al., 2021). Understanding what drives businesses to adopt sustainable manufacturing practices is crucial in light of these opportunities and challenges. The findings collectively demonstrate that a balanced set of drivers is necessary for sustainable performance in manufacturing organizations. While social and quality dimensions enhance organizational adaptability and long-term resilience, economic and environmental factors offer the structural underpinnings for sustainable transformation. Understanding these driver mechanisms is particularly crucial for guiding managerial strategy and industrial policy in transition economies like Serbia, where businesses frequently face financial constraints, technological gaps, and evolving regulatory environments. Adopting green technologies or efficiency improvements alone will not be enough to achieve sustainability in manufacturing; human-centric innovation, environmental responsibility, and economic rationality must all be integrated systemically. Sustainable manufacturing can be accelerated by implementing circular economy practices, and enhancing digital transformation readiness, according to emerging research (Lim et al., 2023; Dacre, 2024). This is especially true in developing nations where workforce engagement and resource optimization continue to be significant obstacles. To achieve synergistic effects on sustainability outcomes, recent studies emphasize the importance of multi-level driver frameworks that integrate social participation, technological capability, and quality management (Scharmer et al., 2024; Hariyani et al., 2023; Abubakr et al., 2020; Gholami et al., 2021). Future studies should, therefore, examine how organizational culture, digital technologies, and policy tools interact to strengthen these forces and bridge current implementation gaps. This kind of data can help the transition economies develop targeted programmes that enhance competitiveness, foster innovation, and ensure alignment with international sustainability goals. Although the sample included respondents from diverse manufacturing sectors, future studies could further examine sector-specific differences in sustainability drivers and performance relationships.

Conclusions

This research examined how quality, social, economic, and environmental drivers influence long-term organizational performance in Serbian manufacturing firms. The findings underscore the importance of creativity, effectiveness, and ecological responsibility in promoting sustainability, demonstrating that both economic and environmental factors have a significant positive impact. By emphasizing the growing importance of employee engagement, safety, and well-being in creating resilient organizations, social drivers also play a significant role. Quality drivers, on the other hand, exhibit conflicting results, indicating that their role in sustainability is still developing in this regard. Overall, the results highlight the need for a well-rounded strategy that balances economic and environmental priorities with more robust social and quality-oriented practices. In addition to investing in people, organizational culture, and systems for continuous improvement, managers should concentrate on increasing technological innovation and resource efficiency. Despite offering insightful empirical data from a transition economy, this study remains limited to a single country and sector. Future studies should investigate the interactions between these drivers over time and across different geographical and industrial contexts. A deeper understanding of the dynamic mechanisms underlying sustainability in global manufacturing systems may be possible through comparative, longitudinal, and multi-level analyses.

Acknowledgements

We would like to express our gratitude to everyone who has contributed to this research, including those who have made contributions in aspects such as data collection and manuscript review.

Funding

This research has been supported by the Ministry of Science, Technological Development and Innovation (Contract No. 451-03-137/2025-03/200156) and the Faculty of Technical Sciences, University of Novi Sad through project “Scientific and Artistic Research Work of Researchers in Teaching and Associate Positions at the Faculty of Technical Sciences, University of Novi Sad 2025” (No. 01-50/295).

Conflict of interests

The authors declare no conflict of interest.

Data availability statement

The original contributions presented in the study are included in the article. Further inquiries can be directed to the corresponding author.

Institutional Review Board Statement

All ethical considerations were observed, including the confidentiality of personal information, voluntary participation, and data protection in accordance with applicable legal and institutional guidelines.

Author Contributions

Conceptualization, S.Vasić; methodology, S.Vasić; software, S.Vasić. and K.R.; validation, S.Vasić and N.B.; formal analysis, S.Vasić; investigation, S.Vasić and N.B.; resources, S.Vulanović and N.B.; data curation, S.Vasić., K.R., D.V. and N.B.; writing-original draft preparation, S.Vasić; writing-review and editing, S.Vasić.; visualization, S.Vulanović; supervision, N.B.; project administration, S.Vasić and K.R.; funding acquisition, S.Vasić, K.R., N.B., and D.V.;

All authors have read and agreed to the published version of the manuscript.

References

Abubakr, M., Abbas, A. T., Tomaz, I., Soliman, M. S., Luqman, M., & Hegab, H. (2020). Sustainable and smart manufacturing: An integrated approach. *Sustainability, 12(6),* 2280. https://doi.org/10.3390/su12062280

Afsar, B., & Umrani, W. A. (2020). Corporate social responsibility and pro-environmental behaviour at workplace: The role of moral reflectiveness, coworker advocacy, and environmental commitment. *Corporate Social Responsibility and Environmental Management, 27(1)*, 109–125. https://doi.org/10.1002/csr.1777

Agrawal, R., Majumdar, A., Kumar, A., & Luthra, S. (2023). Integration of artificial intelligence in sustainable manufacturing: Current status and future opportunities. *Operations Management Research, 16(4),* 1720–1741. https://doi.org/10.1007/s12063-023-00383-y

Andronie, M., Lăzăroiu, G., Ștefănescu, R., Uță, C., & Dijmărescu, I. (2021). Sustainable, smart, and sensing technologies for cyber-physical manufacturing systems: A systematic literature review. *Sustainability, 13(10),* 5495. https://doi.org/10.3390/su13105495

Baykal, E., & Divrik, B. (2023). Employee involvement in sustainability projects in emergent markets: Evidence from Turkey. *Sustainability, 15(18),* 13929. https://doi.org/10.3390/su151813929

Bravo, A., Vieira, D., & Rebello, T. A. (2022). The origins, evolution, current state, and future of green products and consumer research: A bibliometric analysis. *Sustainability, 14(17),* 11022. https://doi.org/10.3390/su141711022

Chaurasiya, S., & Singh, G. (2024). Exploring sustainable manufacturing: A comprehensive review of literature and practices. In Proceedings of the Sustainable Manufacturing Conference (pp. 11–19). *Springer.* https://doi.org/10.1007/978-981-99-6094-1_2

Cordova, M. F., & Celone, A. (2019). SDGs and innovation in the business context: Literature review. *Sustainability, 11(24),* 7043. https://doi.org/10.3390/su11247043

Dacre, N. (2024). A systematic exploration of Industry 5.0 supply chains for sustainable manufacturing. *International Journal of Production Research, 62(12),* 4225–4248. https://doi.org/10.1080/09537287.2024.2380361

Fatma, N., & Haleem, A. (2023). Exploring the nexus of eco-innovation and sustainable development: A bibliometric review and analysis. *Sustainability, 15(16),* 12281. https://doi.org/10.3390/su151612281

Ferrer-Estévez, M., & Chalmeta, R. (2023). Sustainable customer relationship management. *Marketing Intelligence & Planning, 41(2)*, 244–262. https://doi.org/10.1108/MIP-06-2022-0266

Garavan, T. N., Carbery, R., & Rock, A. (2012). Mapping talent development: Definition, scope and architecture. European *Journal of Training and Development, 36(1),* 5–24. https://doi.org/10.1108/03090591211192601

Ghazali, I., Abdul-Rashid, S. H., Md Dawal, S. Z., Irianto, I., Herawan, S. G., Ho, F. H., Abdullah, R., Abdul Rasib, A. H., & Padzil, N. W. S. (2023). Embedding green product attributes preferences and cultural consideration for product design development: A conceptual framework. *Sustainability, 15(5),* 4542. https://doi.org/10.3390/su15054542

Gholami, H., Abu, F., Lee, J. K. Y., Karganroudi, S. S., & Sharif, S. (2021). Sustainable manufacturing 4.0—Pathways and practices. *Sustainability, 13(24),* 13956. https://doi.org/10.3390/su132413956

Gibson, P. A. (2023). Shortening the supply chain through smart manufacturing and green technology*. Sustainability, 15(22),* 15735. https://doi.org/10.3390/su152215735

Hariyani, D., Mishra, S., Hariyani, P., & Sharma, M. K. (2023). Drivers and motives for sustainable manufacturing system. *Innovation and Green Development, 2(1),* 100031. https://doi.org/10.1016/j.igd.2022.100031

Karuppiah, K., Sankaranarayanan, B., & Lo, H. W. (2024). A systematic literature review on the evolution of sustainable manufacturing practices: Key findings and implications. *Clean Engineering and Technology, 22*, 100798. https://doi.org/10.1016/j.clet.2024.100798

Lee, C. W., Wu, W., & Yang, C. F. (2019). Employees' perceptions of training and sustainability of human resource. *Sustainability, 11(17),* 4622. https://doi.org/10.3390/su11174622

Lee, D. H. (2018). The effect of safety management and sustainable activities on sustainable performance: Focusing on suppliers. *Sustainability, 10(12),* 4796. https://doi.org/10.3390/su10124796

Lim, S. T., Zailani, S., Mohd Sidek, N. Z., & Shaharudin, M. R. (2023). Drivers and barriers of circular economy business model adoption and its impact on sustainable production in Malaysia*. Environment, Development and Sustainability, 26,* 17551–17578. https://doi.org/10.1007/s10668-023-03350-6

Madero-Gómez, S. M., Rubio Leal, Y. L., Olivas-Luján, M., & Yusliza, M. Y. (2023). Companies could benefit when they focus on employee wellbeing and the environment: A systematic review of sustainable human resource management. *Sustainability, 15*(6), 5435. https://doi.org/10.3390/su15065435

Mahfoud, H., Moutaoukil, O., Benchekroun, M. T., & Latif, A. (2024). Real-time predictive maintenance-based process parameters: Towards an industrial sustainability improvement. In Proceedings of the International Conference on Advanced Intelligent Systems for Sustainable Development (pp. 18–34). *Springer.* https://doi.org/10.1007/978-3-031-54288-6_3

Małysa, T., & Gajdzik, B. (2020). Predictive models of accidents at work in the steel sector as a framework for sustainable safety. *Energies, 14(1),* 129. https://doi.org/10.3390/en14010129

Mićić, V., & Savić, L. (2018). Sustainable development of the Serbian manufacturing industry. *Ekonomika, 64(4*), 47–55. https://doi.org/10.5937/ekonomika1804045m

Narkhede, G. B., Pasi, B. N., Rajhans, N., & Kulkarni, A. (2025). Industry 5.0 and sustainable manufacturing: A systematic literature review. *Benchmarking: An International Journal, 32(2),* 608–635. https://doi.org/10.1108/BIJ-03-2023-0196

Norton, T. A., Parker, S. L., Zacher, H., & Ashkanasy, N. M. (2015). Employee green behavior: A theoretical framework. *Organization & Environment, 28(1),* 103–125. https://doi.org/10.1177/1086026615575333

Panagiotopoulou, V. C., Stavropoulos, P., & Chryssolouris, G. (2022). A critical review on the environmental impact of manufacturing: A holistic perspective*. The International Journal of Advanced Manufacturing Technology, 118(1–2),* 603–625. https://doi.org/10.1007/s00170-021-07980-w

Panigrahi, R. R., Shrivastava, A. K., & Kapur, P. K. (2024). Impact of inventory management practices on the operational performances of SMEs: Review and future research directions. *International Journal of System Assurance Engineering and Management, 15(5)*, 1934–1955. https://doi.org/10.1007/s13198-023-02216-4

Polese, F., Gallucci, C., Carrubbo, L., & Santulli, R. (2021). Predictive maintenance as a driver for corporate sustainability: Evidence from a public-private co-financed R&D project. *Sustainability, 13(11),* 5884. https://doi.org/10.3390/su13115884

Rakic, S., Pavlovic, M., & Marjanovic, U. (2021). A precondition of sustainability: Industry 4.0 readiness. *Sustainability, 13(12),*

6641. https://doi.org/10.3390/su13126641

Renna, P., & Materi, S. (2021). A literature review of energy efficiency and sustainability in manufacturing systems. *Applied Sciences, 11(16),* 7366. https://doi.org/10.3390/app11167366

Rosen, M. A., & Kishawy, H. A. (2012). Sustainable manufacturing and design: Concepts, practices and needs. *Sustainability, 4(2)*, 154–174. https://doi.org/10.3390/su4020154

Scharmer, V. M., Vernim, S., Horsthofer-Rauch, J., Jordan, P., Maier, M., Paul, M., Schneider, D., Woerle, M., Schulz, J., & Zaeh, M. F. (2024). Sustainable manufacturing: A review and framework derivation. *Sustainability, 16*(1), 119. https://doi.org/10.3390/su16010119

Shaikh, M. B. N., Ali, M., Chaudry, U. M., & Khan, M. K. (2024). Metrics for sustainability and circular economy practices in context to modern manufacturing environment. *Circular Economy and Sustainability, 4(3*), 2073–2091. https://doi.org/10.1007/s43615-024-00395-1

Solnørdal, M., & Foss, L. (2018). Closing the energy efficiency gap—A systematic review of empirical articles on drivers to energy efficiency in manufacturing firms. *Energies, 11(3)*, 518. https://doi.org/10.3390/en11030518

Wiek, A., Withycombe, L., & Redman, C. L. (2011). Key competencies in sustainability. *Sustainability Science, 6(2),* 203–218. https://doi.org/10.1007/s11625-011-0132-6