

The Role of Decision Making in attaining Sustainability in Industrial and Manufacturing Fields: PCIA Based Approach

Somnath Singroul*¹, Chhatrapal Dewangan², Atul Kumar Sahu³, Nitin Kumar Sahu⁴

Department of Industrial and Production Engineering, Guru Ghasidas Vishwavidyalaya, Bilaspur, Chhattisgarh, India¹⁻⁴

*Corresponding Author

Abstract: In this study, decision making tools in the form of Plan, Control, Improve, Act (PCIA) based approach is discussed for attaining sustainability in diverse application fields related to Industrial and manufacturing filed. The developed techniques can help decision makers in attaining appropriate insights and decision tactics. This study examines how decision-making frameworks based on PCIA can support sustainability objectives across diverse industrial sectors. Modern industries face complex sustainability challenges high emissions, resource depletion, waste generation and social impacts. Iterative management cycles and data-driven decision tools help organizations navigate these challenges. We outline a PCIA methodology where Plan entails setting sustainability goals and strategies, Control involves continuous monitoring of key indicators, Improve focuses on process optimization and Act implements corrective measures and institutional learning.

This PCIA approach is applied to case studies in beverage, oil, cement, steel, furniture manufacturing and academic institutions. Beverage sector, planning may target renewable energy and packaging reduction, control uses sensor data for waste and water use and improvement implements circular-economy practices. In the cement and steel industries, PCIA guides low-carbon material choices and process innovation as stakeholders evaluate trade-offs via Life cycle assessment (LCA) and multi-criteria decision analysis. The study demonstrates that combining lean principles and digital tools within PCIA yields better decisions for environmental performance. Our findings suggest that a structured PCIA cycle integrating planning, monitoring, continuous improvement and decisive action can help managers systematically align industrial operations with sustainability targets. Ultimately, embedding PCIA fosters transparency, accountability and continuous learning in organizational sustainability strategy, advancing long-term resilience and competitiveness.

Keywords: Decision making, Industrial and manufacturing, sustainability, Life cycle assessment, critical thinking.

1. INTRODUCTION

Sustainable industrial practice requires holistic decision-making that balances economic, environmental and social objectives (Ghadimi et al., 2017). Modern manufacturing and service organizations are increasingly adopting digital tools and lean management to guide their choices. Digital transformation enables predictive analytics and real-time monitoring, reducing waste and improving efficiency (Rodriguez-Sanchez & Sellers-Rubio, 2021). Such data-driven approaches support stakeholders in making more informed, timely decisions that align with environmental goals. Likewise, quality management frameworks like the Plan–Do–Check–Act (PDCA) cycle are widely used for continuous improvement (Dubey et al., 2019). In this context, we introduce a Plan-Control-Improve-Act (PCIA) cycle analogous to PDCA, tailored for sustainability. In PCIA, “Plan” involves defining sustainability targets and strategies (e.g. clean energy plans, water reduction “Control” emphasizes performance monitoring and compliance; “Improve” targets ongoing process optimization lean practices, technological upgrades and “Act” drives implementation of new solutions and policy adjustments (Ahi & Searcy, 2013).

Research shows that cross-sector industries must integrate sustainability factors into every stage of operations. For instance, oil and gas firms recognize that decisions across exploration, extraction and distribution have broad environmental and social impacts (Govindan et al., 2013; Ghadimi et al., 2017). One study notes that “addressing economic, technical, social and environmental risks and opportunities during decision-making is critical to fulfilling stakeholders’ objectives” in the energy sector. Similarly, in cement manufacturing responsible for global CO₂ emissions companies are pressed to select alternative fuels and low-carbon materials to meet carbon-neutral targets (Akintayo et al. 2024). The steel industry likewise confronts choices between scrap recycling, green electricity and new processes such as hydrogen reduction (Zhu et al., 2012). Academics note that steel makers need systematic methods for selecting

sustainable materials and optimizing processes with sustainability indicators, yet few currently apply such decision models (Ince et al., 2023).

Against this backdrop, this paper synthesizes existing literature on industrial decision-making and sustainability and proposes the PCIA framework to guide continuous improvement. Present study relevant decision-support approaches life-cycle assessment with multi-criteria decision-making in targeted sectors: beverage, oil, cement, steel, higher education campus operations and furniture. Through these examples, we illustrate how PCIA can be customized to different contexts to help managers identify, monitor and refine sustainability initiatives. Our discussion is supported by recent scholarly research and reports, ensuring an up-to-date perspective on these rapidly evolving topics.

2. LITERATURE REVIEW

The literature highlights several themes: continuous improvement cycles, digitalization and multi-criteria decision frameworks as key enablers of sustainable manufacturing (Shah & Ward, 2007). Continuous improvement cycles and iterative management cycles such as PDCA (Plan-Do-Check-Act) form the backbone of quality and environmental management systems (Peng et al., 2023; Seuring & Müller, 2008). The PDCA cycle is “a four-step model for carrying out change repeated again and again for continuous improvement” (Vinodh et al., 2011). PCIA adapts this idea: the planning stage identifies sustainability objectives, the control stage involves ongoing monitoring of environmental metrics, the improve stage corresponds to implementing process enhancements and the act stage institutionalizes lessons learned. Lean manufacturing principles originally from the Toyota Production System also emphasize waste minimization and continuous refinement (Kumar et al., 2016; Peng et al., 2023). Lean methods focus on “productivity growth, inefficiency elimination and continuous improvement” to enhance value (Seuring & Müller, 2008). Embedding lean in sustainability initiatives means constantly searching for ways to reduce resource use and waste, an approach aligned with the PCIA cycle’s iterative improvements (Vinodh et al., 2011).

Recent studies underscore digital transformation’s impact on sustainability decision-making find that digital technologies significantly improve process optimization and decision-making in manufacturing, thereby advancing sustainability (Peng et al. 2023). Manufacturers show that digitalization leads to “predictive modeling and real-time data insights enable stakeholders to make decisions with significant sustainability outcomes” (Kleindorfer et al., 2005). Key benefits include reduced material and energy waste, higher product quality and adaptive production planning. However, adoption is still uneven; the authors note that without data-driven planning and supportive regulations, firms struggle to integrate these technologies into sustainability frameworks. Nonetheless, many argue digital tools are essential: real-time sensor data can trigger process controls to curb energy spikes and advanced analytics can reveal hidden inefficiencies.

Given the complexity of sustainability goals, MCDM frameworks and life-cycle assessments (LCA) have been widely applied. In the cement industry use an integrated LCA-MCDM approach to rank production methods by environmental impact (Akintayo et al. 2024). Their framework evaluates multiple cement types slag cement vs. traditional clinker) across impact categories, finding slag cements greatly reduce CO₂ emissions. Similarly, furniture manufacturing research incorporates MCDM to balance lean efficiency and sustainability. For instance, develop a supplier-selection model for the furniture industry that includes 18 lean and sustainability distance, labor practices, waste and emissions (Jabbour et al., 2013).

The analysis yields a structured framework, showing how decision-makers can systematically consider diverse criteria (Singh et al., 2012). These studies demonstrate that formal decision models help managers make tradeoffs transparent. In the steel sector, a recent systematic review highlights the need for decision models that integrate sustainability indicators into production planning (Veljić et al., 2025). Although companies often set environmental targets scrap usage rates, emissions limits, they rarely use comprehensive decision frameworks to guide choices (Tseng et al., 2018). It emphasizes that identifying relevant metrics like material lifecycles, energy use, social factors and embedding them in decision tools is critical for truly sustainable manufacturing.

Sustainability in industry demands robust decision-support (Bevilacqua et al., 2007). It suggests combining traditional improvement cycles with modern analytical tools (Elkington, 1998). The PCIA approach proposed here builds on these foundations: it is an iterative planning–monitoring–improvement–action loop leveraging lean thinking, digital data and multi-factor analysis to guide sustainable industrial decisions (Dabhadkar, 2015; Depczyński et al., 2023).

3. PCIA-BASED METHODOLOGY

The PCIA methodology shown in Figure 1 adapts continuous improvement cycles to sustainability decision-making. In PCIA, Plan sets clear sustainability targets (energy reduction, emissions cap, waste minimization) and develop strategies

or projects to achieve them. This may involve engineering designs, material choices, supply chain adjustments and stakeholder engagement. Control implements monitoring and control systems to track key performance indicators. These could be energy meters, emissions sensors, waste audits, or social metrics. Control ensures that performance is measured against targets and that any deviations are detected early.

Improve means analyze collected data and identify opportunities for process optimization. Use lean methods and advanced analytics predictive models to refine operations. Improvements might include equipment upgrades, workflow redesign, or staff training. Act works based on insights, make informed decisions and adjustments. This involves implementing corrective actions, updating procedures and revising policies. The Act phase closes the loop, informing the next planning cycle.

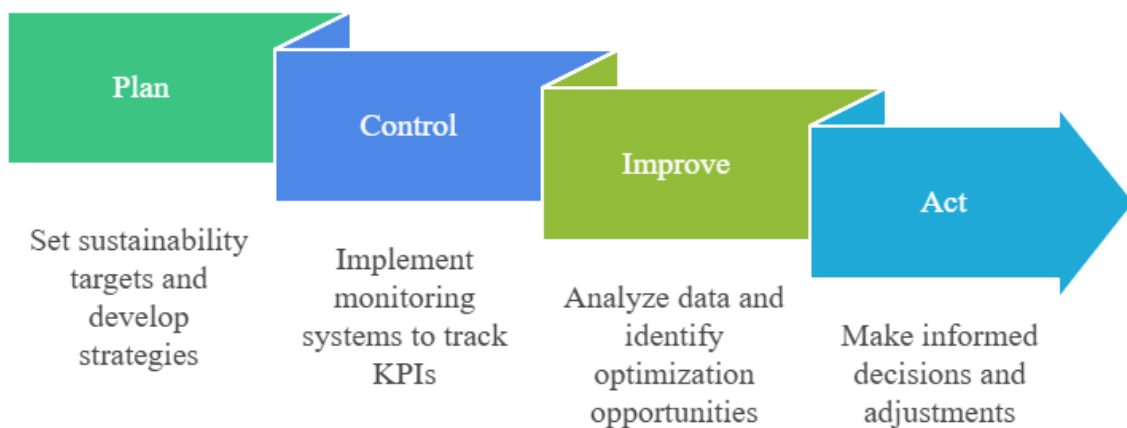


Figure 1: PCIA Methodology for sustainability

In effect, PCIA guides sustainable decision-making as an ongoing, adaptive process. It extends the classic PDCA cycle by explicitly emphasizing Control (monitoring/regulation) and Improve (active optimization) in support of sustainability goals. The approach is meant to be dynamic: each cycle’s learning feeds into the next planning stage. Figure 2 illustrates a theoretical framework adapted from recent studies. Digital transformation and environmental regulation drive process optimization and decision-making, which together influence sustainability outcomes. This underscores how PCIA can be enabled by technology for data collection/control and governance policies shaping planning and action.

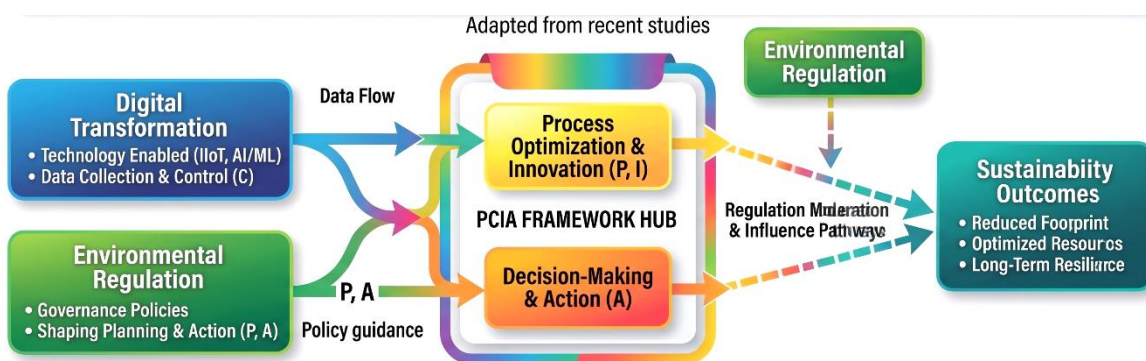


Figure 2: Theoretical framework linking digital transformation, process optimization, decision-making and sustainability.

3.1 PCIA in the Beverage Industry

The beverage sector faces sustainability pressures from water use, energy consumption and packaging waste. A PCIA approach helps breweries and bottlers systematically tackle these. In Plan, a brewery may set goals to cut energy use and packaging waste by X%. It might invest in renewable boilers or redesign bottles for recyclability. In Control, the plant would install sensors to track real-time energy like electricity, steam and water consumption at each stage and monitor packaging scrap rates. For instance, sensors in fermentation and HVAC systems can send alerts when consumption spikes. In the Improve phase, managers analyze this data to find efficiency gains perhaps adjusting process timings,

implementing heat-recovery, or swapping to lighter glass. Packaging waste can be reduced by switching to reusable containers or optimizing carton layouts. Finally, in Act, the plant formally implements the successful changes and updates its standard operating procedures.

Emphasizing this cycle aligns with known beverage industry practices. Studies note that beverage companies are adopting circular-economy measures such as energy efficiency, resource optimization, sustainable product design and waste valorization. Effective waste management recycling bottling scrap or repurposing spent grain and eco-design of containers are key managerial practices in beverages. These correspond to PCIA stages planning eco-design, controlling waste output, improving processes for waste reuse and acting on those insights. Digitalization further supports beverage PCIA modern breweries use IoT sensors to enable predictive control of brewing operations, reducing water and energy use.

A soft-drink plant might launch a PCIA cycle where Plan includes switching to 100% recycled PET and optimizing bottle design. Control is achieved through automated counters and cameras that measure defective bottles or spilled liquid. Improve could involve fine-tuning fill levels and using an AI algorithm to detect leaks, reducing waste output. Act means adopting these best practices plant-wide and adjusting procurement like sourcing recycled resin. By iterating PCIA cycles, beverage companies continuously raise efficiency and reduce environmental footprint.

High water usage is another concern in beverages. The next cycle might focus on water: Plan to reduce water per unit produced, Control by metering each stage, Improve through reuse of rinse water and act by training staff on leak prevention. By systematically applying PCIA, beverage firms meet both consumer demand for “green” products and regulatory standards on waste. Metrics from their cycles can be shared (e.g. liters of water per liter produced, kg CO₂ per gallon) to guide continuous improvement and report progress.

3.2 PCIA in the Oil Industry

The oil and gas sector is under intense pressure to mitigate climate and social impacts. Every decision from drilling new fields to refining crude has sustainability implications. A PCIA approach provides structure. In Plan, oil companies define targets such as reducing flaring by 50% or cutting spill rates to zero. This may involve planning new carbon-capture facilities or selecting extraction technologies with lower methane leakage. In Control, extensive monitoring systems are installed: SCADA sensors continuously measure emissions, flaring volumes and water contamination levels. Real-time data ensure operations stay within safe bounds and highlight violations. Improve involves analyzing operational data and stakeholder feedback. For instance, if a pipeline sensor network detects inefficiencies, the company might invest in predictive maintenance to prevent leaks. Environmental and social performance factors enter here: inclusive planning with communities or adjusting extraction schedules to minimize ecosystem disruption. In Act, management enacts remediation and policy changes retrofitting plants or altering supply chains based on the insights gained.

Academic case studies affirm this integration emphasizes that oil companies must incorporate environmental and social risks into decisions at every stage, from exploration to decommissioning. It suggests a framework where sustainability considerations water use, emissions, community impact are treated alongside economics in all plans. This aligns with PCIA: each plan is inherently a sustainability plan, each control loop includes environmental metrics and improvements explicitly seek greener outcomes. An oil company might plan to use a cleaner solvent in extraction (Plan), continuously monitor solvent losses and emissions (Control), optimize solvent recovery units (Improve) and then update industry guidelines (Act). By making PCIA part of standard operating procedure, oil firms can track progress on ESG goals and iteratively improve performance.

3.3 PCIA in the Cement Industry

Cement manufacturing is extremely carbon-intensive, accounting for 7–8% of global emissions. PCIA can guide decarbonization in this sector. In Plan, a cement plant may set goals like increasing alternative clinker usage or switching to renewable fuels. Strategic planning might include investing in industrial heat pumps or carbon capture and storage. Control requires comprehensive measurement: plants use continuous emissions monitoring systems to track CO₂, NO_x and particulate emissions from kilns. They also meter raw material and energy flows to ensure plans are adhered to. In Improve, data from CEMS and production are analyzed perhaps using LCA tools to identify high-impact stages. For instance, if clinker production is the top CO₂ source found, 55% of impact), the plant may shift to slag or fly-ash cements. They also optimize kiln operation, implement waste heat recovery and refine mix designs for efficiency. Finally, Act means formalizing these optimizations: updating process standards, retraining staff and possibly reshaping supply agreements sourcing instead of clinker.

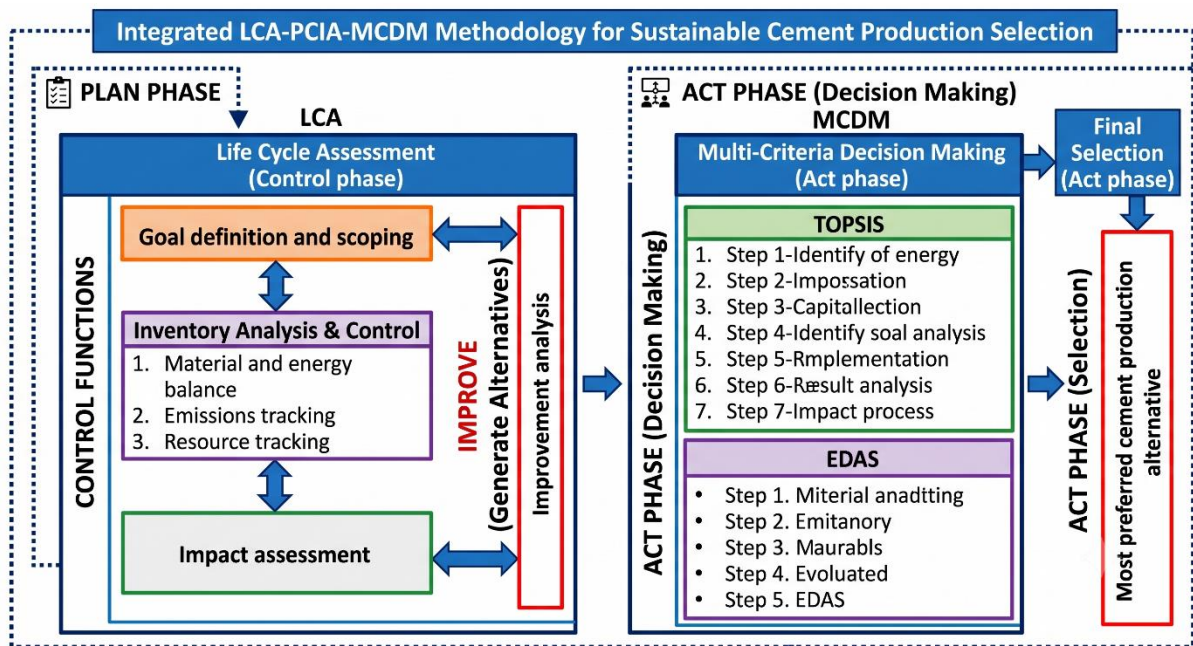


Figure 3: Proposed methodology for selecting the most preferred cement production method.

Figure 3 shows a framework that can be viewed as a planning tool that identifies the optimal cement type under multiple criteria. Integrating such models into PCIA provides a structured plan step, where; the company can evaluate alternatives using LCA and TOPSIS, and then plans production changes accordingly. The Control step involves implementing sensors and audits to verify emissions reductions after changes. Improve could draw on simulated analysis, if local cement plants find cements perform well, they scale up production of those mixes. Act includes sharing these results with regulators and investing in downstream technologies concrete recycling.

Sustainability reports echo this need for multi-faceted control and improvement. The complex path to net-zero cement, which requires new fuels, materials and policy levers. The PCIA cycle concretizes this path at each iteration; it incorporates the latest innovations (green hydrogen, alternate binders) into operations. By continuously planning (e.g. trialing biofuels), controlling (metering emissions), improving (incrementally lowering clinker ratio) and acting (institutionalizing cleaner processes), cement companies can progressively approach their climate targets.

3.4 PCIA in the Steel Industry

The steel industry faces similar decarbonization challenges. Traditional blast furnaces emit massive CO₂ and electrical arc furnaces raise electricity demand. Under PCIA, a steel plant might Plan a shift to low-carbon steelmaking: for example, increasing scrap usage or planning a pilot hydrogen furnace. Strategic plans may involve scheduling steel grades requiring less refining or collaborating with renewable energy providers. In Control, plants deploy continuous emission monitoring and resource tracking. They may also introduce digital twin simulations to monitor production efficiency. Data on furnaces' energy use and emissions are continuously logged and environmental CO₂ per ton of steel are tracked.

In the Improve phase, analysis of operational data would highlight opportunities. For instance, if data show a high variance in furnace efficiency, process engineers could optimize heat cycles or oxygen injection rates. Studies suggest that material selection is a key decision: one analysis found for a steel component, low-carbon steel (with recycled content) and optimized processes achieved better environmental-economic trade-offs. Thus, PCIA's Improve step might involve experimenting with alternative inputs (e.g. scrap vs. iron ore). Finally, Act means implementing these optimizations plant-wide and influencing the supply chain. For instance, management might adjust procurement specifications to favor certified green steel suppliers, or update contract terms to encourage renewable energy adoption.

Sustainable steelmaking hinges on integrating material choices and sustainability indicators into decisions. Their review concludes that industries must embed these factors into decision models to demonstrate a view that aligns exactly with PCIA's ethos. By iterating PCIA cycles, a steel company can advance systematically: each cycle reduces dependence on virgin inputs, improves recycling rates and lowers emissions intensity. This creates a feedback loop of continuous learning and stakeholder engagement working with regulators on carbon pricing) that steers the industry toward greener production.

3.5 PCIA in Academic Institutions

Sustainability is now a priority in higher education, affecting campus operations, curricula and culture. Universities form sustainability offices and master plans to integrate environmental goals across all activities. PCIA can guide campus decision-making similarly. In Plan, a university might set targets carbon neutrality by 2035, zero waste events. Strategies might include building renewable energy installations or embedding sustainability into hiring and curriculum development. Control involves monitoring campus energy use, waste streams and educational outcomes. For instance, smart meters track building consumption, waste audits quantify recycling rates and course evaluations measure sustainability learning.

In Improve, the data guide campus programs. If buildings show high heating use, the university may retrofit insulation or adjust heating schedules. If student surveys reveal low engagement, curricula might be revised to include more sustainability content. A recent study applying a decision framework for learning management systems shows how analytic models can support sustainable institutional choices: by weighting factors like cost, security and usability, the authors found Moodle was the most sustainable LMS option, underscoring the value of systematic choices. This principle extends to campus operations: for example, a multi-criteria analysis could be used to select campus suppliers or transportation plans. The Act stage then institutionalizes these improvements: formal policy changes are made divesting endowment funds from fossil fuels, purchasing agreements for green energy and new practices are scaled across departments.

Importantly, educational institutions also apply PCIA conceptually to teach sustainability. Decision-making exercises and case studies prepare students for “considerate decision-making” about socio-scientific issues. The key is that universities practice what they preach: they measure results and continuously revise their strategies. Transparent and systematic decision processes support long-term institutional resilience and align with education-for-sustainability goals. In other words, a PCIA cycle embedded in campus governance and curriculum design both models and reinforces sustainable thinking.

3.6 PCIA in the Furniture Industry

The furniture sector particularly wood and panel production present sustainability opportunities through material choice and supply chain design. A PCIA cycle here might focus on responsible sourcing and lean operations. In Plan, a furniture manufacturer could target use of certified wood and minimize chemical coatings. It might adopt a just-in-time production strategy to reduce overproduction. Control would involve tracking supply chain wood certification rates, emissions from transportation and on-site waste. Modern ERP systems and supplier scorecards provide the data. The industry also uses multi-criteria tools: for instance, researchers have integrated lean and sustainability distance to customer, labor practices, carbon footprint, etc. into a structured supplier-selection framework.

Through Improve, managers act on these insights. If data reveal high transport emissions from distant suppliers, the company may switch to local wood sources or optimize logistics. Lean methods identify non-value processes excess inventory, rework to cut. The furniture MCDM study found that proximity to customer and fair labor practices were especially critical criteria; learning this, a firm might improve local engagement and workforce conditions. After implementing such improvements, Act consolidates them into standards for example, revising purchasing policies to include sustainability and training procurement staff accordingly.

This PCIA cycle aligns with broader industry trends. The furniture study by demonstrates the value of a holistic lean-sustainability framework. The structured approach they propose is essentially the “Plan” phase of PCIA, where decision-makers set weighted goals. Our methodology then carries it forward: once weights and priorities are set, Control and Improve steps operationalize them through continuous measurement and iteration. In practice, companies combining lean manufacturing and sustainability report gains: fewer defects, less material waste and stronger brand reputation. By systematically cycling through PCIA, furniture manufacturers can progressively make products greener while maintaining efficiency.

4. CONCLUSION

Decision-making is the keystone of sustainable transformation in industry. This paper has outlined a PCIA approach that adapts iterative improvement cycles to the sustainability context. By explicitly integrating continuous monitoring and systematic optimization into decision processes, PCIA helps managers navigate complex trade-offs among economic, environmental and social objectives. Through case examples in beverages, oil, cement, steel, academia and furniture, we have shown that the same core logic applies: set clear targets, measure performance with technology-enabled controls, refine processes via lean and analytics and act on those insights to institutionalize changes.

In each sector, tailoring the PCIA cycle addressed specific challenges. Beverage producers use it to cut water and packaging waste through sensor-driven controls. Oil firms apply it to manage environmental risk across operations. Cement and steel companies employ it to decarbonize processes by planning alternative materials and using LCA/MCDM analyses. Universities leverage it to embed sustainability in campus and curricula. Furniture firms incorporate lean and sustainability to select suppliers and optimize production. Crucially, recent research supports this unified view: lean principles and digitalization consistently improve process efficiency and enable better sustainability decisions. For example, data-driven monitoring directly informs the PCIA “Control” phase, while multi-criteria models can formalize the “Plan” phase in each case.

Ultimately, embedding PCIA cycles fosters a culture of continuous improvement and accountability. Decisions become evidence-based and transparent and organizations learn iteratively from outcomes. As firms report, such systemic approaches can yield cost savings, innovation and brand value by meeting stakeholder expectations. The PCIA framework thus helps translate the abstract goal of “sustainability” into concrete management practice across industries. Future work can develop customized PCIA toolkits for different sectors or integrate emerging themes like circular economy specifics. However, the core message is clear: sustainability is an ongoing journey and robust decision-making cycles like PCIA are essential maps for that journey.

REFERENCES

- [1]. Ahi, P., & Searcy, C. (2013). A comparative literature analysis of definitions for green and sustainable supply chain management. *Journal of Cleaner Production*, 52, 329–341. <https://doi.org/10.1016/j.jclepro.2013.02.018>
- [2]. Bevilacqua, M., Ciarapica, F. E., & Giacchetta, G. (2007). Development of a sustainable product lifecycle in manufacturing firms: A case study. *International Journal of Production Research*, 45(18–19), 4073–4098. <https://doi.org/10.1080/00207540701450142>
- [3]. Dabhadkar, G. (2015). Incorporating environmental and social factors into decision-making of an oil and gas industry to improve sustainability (Unpublished master’s thesis). University of Arkansas. <https://scholarworks.uark.edu/etd/1075>
- [4]. Depczyński, R., Secka, J., Cheba, K., D’Alessandro, C., & Szopik-Depczyńska, K. (2023). Decision-making approach in sustainability assessment in steel manufacturing companies—Systematic literature review. *Sustainability*, 15(15), 11614. <https://doi.org/10.3390/su151511614>
- [5]. Dubey, R., Gunasekaran, A., Childe, S. J., Papadopoulos, T., & Helo, P. (2019). Supplier relationship management for circular economy: Influence of external pressures and top management commitment. *Management Decision*, 57(4), 767–790. <https://doi.org/10.1108/MD-04-2018-0396>
- [6]. Elkington, J. (1998). Partnerships from cannibals with forks: The triple bottom line of 21st-century business. *Environmental Quality Management*, 8(1), 37–51. <https://doi.org/10.1002/tqem.3310080106>
- [7]. Ghadimi, P., Dargi, A., & Heavey, C. (2017). Sustainable supplier selection in medical device industry: Toward sustainable manufacturing. *Procedia CIRP*, 15, 165–170. <https://doi.org/10.1016/j.procir.2014.06.035>
- [8]. Govindan, K., Khodaverdi, R., & Jafari, A. (2013). A fuzzy multi criteria approach for measuring sustainability performance of a supplier based on triple bottom line approach. *Journal of Cleaner Production*, 47, 345–354. <https://doi.org/10.1016/j.jclepro.2012.04.014>
- [9]. Gupta, S., Meissonier, R., Drave, V. A., & Roubaud, D. (2020). Examining the impact of cloud ERP on sustainable performance: A dynamic capability view. *International Journal of Information Management*, 51, 102028. <https://doi.org/10.1016/j.ijinfomgt.2019.10.013>
- [10]. Ince, M. N., Tasdemir, C., & Gazo, R. (2023). Lean and sustainable supplier selection in the furniture industry. *Sustainability*, 15(22), 15891. <https://doi.org/10.3390/su152215891>
- [11]. Jabbour, C. J. C., de Sousa Jabbour, A. B. L., Govindan, K., Teixeira, A. A., & de Souza Freitas, W. R. (2013). Environmental management and operational performance in automotive companies in Brazil: The role of human resource management and lean manufacturing. *Journal of Cleaner Production*, 47, 129–140. <https://doi.org/10.1016/j.jclepro.2012.07.010>
- [12]. Kleindorfer, P. R., Singhal, K., & Van Wassenhove, L. N. (2005). Sustainable operations management. *Production and Operations Management*, 14(4), 482–492. <https://doi.org/10.1111/j.1937-5956.2005.tb00235.x>
- [13]. Kumar, V., Dixit, M., Javalgi, R. G., & Dass, M. (2016). Research framework, strategies, and applications of intelligent agent technologies (IATs) in marketing. *Journal of the Academy of Marketing Science*, 44(1), 24–45. <https://doi.org/10.1007/s11747-015-0426-9>
- [14]. Peng, Y., Ahmad, S. F., Irshad, M., Al-Razgan, M., Ali, Y. A., & Awwad, E. M. (2023). Impact of digitalization on process optimization and decision-making towards sustainability: The moderating role of environmental regulation. *Sustainability*, 15(20), 15156. <https://doi.org/10.3390/su152015156>

- [15]. Rodriguez-Sanchez, C., & Sellers-Rubio, R. (2021). Sustainability in the beverage industry: A research agenda from the demand side. *Sustainability*, 13(1), 186. <https://doi.org/10.3390/su13010186>
- [16]. Seuring, S., & Müller, M. (2008). From a literature review to a conceptual framework for sustainable supply chain management. *Journal of Cleaner Production*, 16(15), 1699–1710. <https://doi.org/10.1016/j.jclepro.2008.04.020>
- [17]. Shah, R., & Ward, P. T. (2007). Defining and developing measures of lean production. *Journal of Operations Management*, 25(4), 785–805. <https://doi.org/10.1016/j.jom.2007.01.019>
- [18]. Singh, R. K., Murty, H. R., Gupta, S. K., & Dikshit, A. K. (2012). An overview of sustainability assessment methodologies. *Ecological Indicators*, 15(1), 281–299. <https://doi.org/10.1016/j.ecolind.2011.01.007>
- [19]. Tseng, M. L., Tan, R. R., Chiu, A. S. F., Chien, C. F., & Kuo, T. C. (2018). Circular economy meets industry 4.0: Can big data drive industrial symbiosis? *Resources, Conservation and Recycling*, 131, 146–147. <https://doi.org/10.1016/j.resconrec.2017.12.028>
- [20]. Veljić, A., Viduka, D., Ilić, L., Karabasević, D., Šijan, A., & Papić, M. (2025). Sustainable decision-making in higher education: An AHP-NWA framework for evaluating learning management systems. *Sustainability*, 17(22), 10130. <https://doi.org/10.3390/su172210130>
- [21]. Vinodh, S., Arvind, K. R., & Somanaathan, M. (2011). Tools and techniques for enabling sustainability through lean initiatives. *Clean Technologies and Environmental Policy*, 13(3), 469–479. <https://doi.org/10.1007/s10098-010-0329-9>
- [22]. Zhu, Q., Sarkis, J., & Lai, K. H. (2012). Green supply chain management innovation diffusion and its relationship to organizational improvement. *International Journal of Production Economics*, 135(1), 63–73. <https://doi.org/10.1016/j.ijpe.2011.06.012>