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Business Process Reengineering with a Circular Economy PDCA Model from the Perspective of Manufacturing Industry

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Abstract: In times of increasing awareness of sustainability and the need for efficient business processes, this study explores the integration of business process reengineering with circular economy principles within Serbian manufacturing organizations. Addressing the need for sustainable development, the research aims to propose and validate a model that harmonizes business process reengineering with the circular economy to improve environmental and organizational performance. The study conducted an extensive survey and analysis across 135 manufacturing organizations in Serbia, assessing their readiness and current practices in adopting circular economy strategies through business process reengineering, utilizing the Plan-Do-Check-Act (PDCA) model. The findings reveal a moderate level of integration, with an average implementation score of 44.70% across surveyed organizations. Notably, organizations with ISO 9001 and ISO 14001 certifications demonstrated higher levels of model implementation. The study highlights the potential of integrating business process reengineering with circular economy principles as a path to sustainable manufacturing. It also highlights the need for targeted strategies to improve management commitment, resource allocation, and participation in sustainable practices. The research contributes valuable insights for policymakers, industry stakeholders, and academic discourse, advocating for a more systematic approach to embedding circular economy principles within organizational processes for a sustainable future.

Keywords: circular economy; business process reengineering; plan-do-check-act model; sustainability in manufacturing processes; resource management; waste management practices

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1. Introduction

Business process reengineering and the circular economy represent two transformative concepts that have influenced organizational strategies and sustainability practices recently. Their integration offers a pathway toward achieving efficiency and sustainability in business operations, especially in manufacturing processes. Business process reengineering was defined in the early 1990s, focusing on radical redesigning of business processes to achieve significant improvements in critical performance measures such as cost, quality, service, and speed [1]. The core idea behind business process reengineering was to examine business processes from a "clean slate" perspective, focusing on the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in productivity, cycle times, and quality. The main objectives of this concept include: improving process efficiency and effectiveness; improving flexibility to adapt to new market conditions; reducing operational costs; and improving customer service. Despite its potential, the concept of business process reengineering has faced criticism for its focus on efficiency and productivity, often at the expense of environmental sustainability and social impact. This has led to the exploration of integrating business process reengineering with sustainability-focused approaches [2], e.g., via the circular economy approach.

The circular economy represents a model of production and consumption that involves sharing, leasing, reusing, repairing, refurbishing, and product eco-design to boost the recyclability of existing materials and products as long as possible [3,4]. This approach is in contrast with the traditional linear economy, which has a 'take, make, dispose' model of production. By extending product lifecycles, the circular economy aims to achieve a more sustainable economy that reduces waste, optimizes resource use, and minimizes environmental impact. The main principles of the circular economy include design aimed at minimal waste and pollution, increased use of products and materials, and regeneration by means of natural systems. The concept of a circular economy not only addresses environmental sustainability but also offers economic and social benefits by promoting innovation, job creation, and economic resilience [5]. Recognized as a forward-thinking strategy, the circular economy addresses both present and future sustainability challenges. However, merely connecting the circular economy with waste management, including waste-to-energy processes, is insufficient [6,7]. The optimization of industrial energy use is very significant, which benefits both organizational energy requirements and economic sustainability. With the circular economy being a key focus in the EU, there is a need to refine waste management practices into a durable, sustainable model. This involves developing advanced waste management technologies and identifying major waste and energy uses in various industrial sectors [8].

Integrating business process reengineering with circular economy principles presents an opportunity for organizations to redesign their business processes not just for efficiency and productivity, but also for sustainability. This integration allows for a rethinking of how resources are used, how products are designed, produced, and consumed, and how end-of-life processes are managed to minimize waste and maximize resource efficiency. The synergy between business process reengineering and the circular economy lies in their shared focus on innovation and redesign [9,10]. While business process reengineering concentrates on process innovation to improve performance, circular economy focuses on product and process redesign to close the loop of product lifecycles. By incorporating the principles of the circular economy into business process reengineering initiatives, organizations can achieve a more holistic transformation that balances economic efficiency with environmental sustainability.

Given the pressing issues of global climate change and the significance of the reduction of industrial waste, organizations are motivated to shift from traditional linear models to a circular economy framework. Establishing a standard management system for the circular economy is essential. Numerous analyses have aimed to lay the groundwork for a standardization system based on circular economy principles [11–14]. This analysis contributes by proposing a PDCA requirements model based on circular economy principles, offering a foundation to develop, improve, and update the basis for a current and future standard for the circular economy. This study addresses the problems of sustainable development in the face of global challenges such as population growth, climate change, and escalating energy consumption. It emphasizes the importance of rethinking and redesigning business processes and models to incorporate the principles of the circular economy, aiming to create more sustainable and efficient systems within the industrial sector.

The primary goal of this work is to propose a performance-oriented model that meets the requirements for applying circular economy principles in industrial organizations, particularly focusing on production organizations identified as significant generators of waste and energy consumption. By doing so, the study seeks to establish a foundation for sustainable development through environmental and economic indicators customized for the industry. The primary aim of this research is to integrate and validate a PDCA model, which is based on the standards of ISO 9001 [15], to serve as a practical framework that both underpins and accelerates the application of circular economy practices within the manufacturing sector, thereby laying the foundation for sustainable development through environmental and economic indicators. This model was empirically tested in 135 industrial organizations across Serbia, revealing the current state of circular economy awareness and readiness to adopt sustainable practices. The principal conclusions highlight the varying degrees of the application of circular economy principles within the surveyed organizations, demonstrating a promising yet uneven landscape of circular economy integration. The study underscores the potential of the PDCA model to systematically improve circular economy practices in production processes, suggesting that this model can serve as a basis for future system management certification and standardization efforts. In essence, this study is significant because it not only provides a snapshot of current circular economy practices among Serbian production organizations but also offers a scalable and systematic approach to improving sustainability across the industry. It lays the groundwork for future research and policy-making, aiming to foster wider adoption of circular economy principles and contribute to the global sustainability agenda.

The research questions that arise and that are addressed in the paper are: (1) How can the level of management commitment to circular economy principles be improved in manufacturing organizations to increase the overall adoption of sustainable practices? (2) What role does organizational size play in the successful integration of circular economy practices? (3) How do ISO certifications influence the adoption and effectiveness of circular economy practices?

2. Literature Review

2.1. Business Process Reengineering through Transformation and Evolution

Business process reengineering was defined and recognized in the 1990s as a radical approach to organizational change, focusing on the fundamental rethinking and radical redesign of business processes [1]. The work of Michael Hammer laid the basis for business process reengineering by challenging organizations to rethink how work is performed to drastically improve customer service, cut operational costs, and become world-class competitors [16]. Over the years, business process reengineering's focus has shifted in response to criticism, technological development, and changing business environments. Initially criticized for its emphasis on efficiency at the expense of employee well-being and job security, the literature on business process reengineering began to incorporate more holistic approaches to redesigning business processes. Early applications of business process reengineering often face issues like low employee engagement, resistance to change, and the complexities of implementation [17]. Criticism arose over business process reengineering's broad approach, which seemed to overlook the human elements and the depth of organizational cultures, sometimes resulting in short-lived improvements [18,19]. This included a greater emphasis on change management, employee involvement, and the alignment of IT with business goals [20–23].

The development of digital technologies caused business process reengineering to further evolve from a purely process-centric approach to one that also considers the potential of technology to transform business models. The authors [24] began to integrate information technology as a core element of business process reengineering, highlighting its role in enabling more streamlined and customer-focused processes. As business process reengineering matured, it included a more balanced strategy that included gradual change, active involvement of stakeholders, and a sustained focus on improvement [25]. The synthesis of business process reengineering with methodologies such as lean manufacturing and total quality management fostered more comprehensive improvement. The study [26] identifies common factors across these systems, including management style, employee engagement, and customer focus, despite their distinct origins and development paths. This paper [26] highlights the importance of continuous improvement and the role of management and employee participation in achieving sustainable business improvement, providing a unique perspective by comparing systems concurrently, offering insights into their effectiveness and implementation challenges. This comparative study contributes to a deeper understanding of quality and operations improvement systems, suggesting areas for future research and practical application in integrating these methodologies.

Despite its trials, the approach of business process reengineering—with specific process examination, through redesign, and outcome-centric practices—has stood the test of time. Evidence from research has shown that when business process reengineering is conducted effectively, it can lead to substantial performance improvements across industry sectors [27]. It finds that while firm performance does not change significantly during the business process reengineering project implementation, it improves notably afterward. Additionally, projects with a specific functional focus tend to contribute more to firm performance than broader, cross-functional projects, suggesting a higher potential failure risk with increasing project scope. The analysis, based on panel-data regression models, indicates that the success of business process reengineering efforts can vary significantly, with functionally focused projects offering more reliable benefits. On the other hand, the study [28] explores the impact of process orientation on firm performance, focusing on Austrian manufacturing firms. It treats process orientation as a multidimensional construct and assesses its effects on profitability, customer satisfaction, product quality, and time-based performance. The findings indicate that process performance measurement, a process-oriented organizational structure, the application of continuous process improvement methods, and a culture aligned with the process approach significantly improve organizational performance.

More recent literature has expanded the concept of business process reengineering in the context of digital transformation, agile methodologies, and the circular economy. Studies and publications now often discuss business process reengineering in tandem with digital technologies such as blockchain, artificial intelligence, and the Internet of Things (IoT). This reflects a shift towards using technology not only to improve existing processes but to enable new, innovative ways of doing business. Specifically, the study [29] investigates how traditional business process reengineering modeling, infrastructural alignment, and procedural actors struggle to fit in the dynamic context of digital transformation. Based on an ethnographic study of a company undergoing digital transformation, they identify tensions arising from applying the traditional business process reengineering approach and propose updated logics: light touch processes, infrastructural flexibility, and mindful actors. This study contributes to rethinking business approaches by highlighting the need for flexibility, adaptability, and mindfulness in managing business processes during digital transformation. On the other hand, the study [30] explores the potential of using machine learning in business process reengineering to improve efficiency, reduce costs, and manage complexity. The study reveals a significant opportunity for innovative machine learning applications in business process reengineering. It proposes a machine learning model inspired by lean six sigma principles to automate business process reengineering, aiming to eliminate waste and variance, which could revolutionize the approach to re-engineering business processes.

Additionally, the integration of business process reengineering with sustainability and circular economy principles has recently emerged as a new focus area. The impact of reengineering business processes on sustainability and environmental impact has been the focus of recent research. The importance of redesigning business processes with an emphasis on their impact on sustainability was analyzed in [31]. One of the most recent papers [2] explores the impact of business process reengineering on the sustainability of distressed firms, focusing on Lebanese micro, small, and medium enterprises. Through interviews with 42 managers, the study identifies cultural change and technology implementation as key business process reengineering activities that significantly improve organizational performance, particularly in financial success and employee retention. The findings show the importance of managing business process reengineering effectively to overcome challenges and risks, highlighting the essential role of psychological and emotional aspects in the process. The research emphasizes the contextual significance of Lebanese firms in understanding the dynamics of business process reengineering implementation and outcomes. The evolution of business process reengineering over time reflects its adaptability and relevance in the face of changing business technological development. From its origins as a radical approach to improving efficiency and effectiveness to its current application in digital transformation and sustainability efforts, business process reengineering continues to be a vital concept for organizations seeking to innovate and improve their operations. Table 1 presents a comparison analysis of the presented findings in the literature.

Table 1. Literature review summarized on business process reengineering.

Reference	Focus	Methodologies	Key Findings	Main Contribution
[16]	Impact of BPR on organizational performance	Case study analysis	Emphasized drastic improvements in service and cost reduction	Foundational work on rethinking how work is performed in organizations.
[17,18]	BPR's focus and impact	Critical review	Highlighted the negative impact on employee well-being and organizational culture	Addressed criticism of BPR for overlooking human and cultural aspects.
[20,21]	Integration of IT in BPR	Case studies	Stressed the importance of employee involvement and IT alignment	Highlighted change management and IT alignment in BPR.
[24]	Role of technology in BPR	Case study analysis	Technology as a core element for streamlined processes	Integrated IT as a central component in BPR.
[25]	Evolution of BPR methodologies	Longitudinal analysis	BPR evolved to include more balanced strategies	Described the mature elements of BPR
[26]	Comparative analysis of BPR with other systems	Comparative study	Identified common factors influencing system effectiveness	Compared BPR with lean manufacturing and TQM
[27,28]	Impact of BPR on performance metrics	Quantitative analysis	Found improvements across sectors	Presented significant performance improvements due to BPR.
[29,30]	BPR in digital transformation and machine learning	Ethnographic and case study	Highlighted the need for adaptability in BPR during digital transformation	Examined BPR's role in digital transformation and potential automation through machine learning.

2.2. Principles and Challenges of the Circular Economy

The circular economy concept has evolved as a response to the global realization that the traditional linear economy—characterized by the 'take-make-dispose' model—is unsustainable in the long run. This evolution is supported by a shift towards sustainability that integrates economic activity with environmental well-being and resource efficiency [32]. The circular economy concept is rooted in theoretical foundations and practical applications, which have been extensively discussed in literature and practice. The foundation's reports, such as [33], provide an overview of the circular economy's economic, environmental, and social benefits. These publications discuss that the circular economy approach not only mitigates environmental risks and ecological scarcity but also offers substantial economic opportunities through new business models and innovations. Academic contributions have significantly enriched the theoretical support of the circular economy [3]. The authors examined the circular economy's conceptual framework, contrasting it with linear and recycling economies and highlighting its potential to create a sustainable economic system that decouples growth from resource consumption. The authors discussed that while the circular economy has gained prominence among policymakers and businesses as a strategic approach to sustainability, there is a lack of clarity on how it aligns with or diverges from broader sustainability objectives. This contrast, they suggest, could hinder the development of sustainability science and the effective implementation of practices grounded in these concepts. To address this gap, the study conducted a comprehensive literature review to explore the similarities, differences, and relationships between sustainability and the circular economy. The findings indicate that while both concepts share common goals of environmental protection and resource efficiency, the circular economy focuses more narrowly on economic and operational strategies to minimize waste and maximize resource circulation, potentially overlooking broader sustainability concerns that include social equity and long-term ecological resilience. The development of the circular economy is also influenced by practical applications and case studies demonstrating its implementation across various sectors. For instance, the case study analysis [34] showcases how businesses and governments are applying circular economy principles to reduce waste, improve resource efficiency, and create sustainable value chains. The study [35] presents a literature review to explore the implementation of the circular economy concept in the manufacturing industry and its relationship with sustainable development. The review reveals a shift from theoretical discussions to empirical studies and the development of implementation tools, indicating progress in the field. However, it also finds that most empirical studies focus primarily on the environmental dimension of sustainability, often neglecting social and economic aspects. On the other hand, the analysis [36] demonstrates another case study that, in the context of building construction, reuse practices offer greater environmental benefits than recycling. By designing a modular building for disassembly and reuse and comparing it with traditional construction methods focused on recyclability, the study finds that reuse can reduce greenhouse gas emissions by 88% and positively impact other environmental indicators. It highlights the need for a strategic shift towards designing buildings with reuse in mind to achieve substantial environmental savings compared to traditional recycling methods. This study contributes to guiding the adoption of more sustainable practices in construction. Moreover, the paper [9] addresses the significant challenges companies encounter when redesigning their supply chains for the circular economy, an area previously lacking systematic analysis. Through a literature review and a multiple-case study in the household appliance sector, the research identifies and categorizes 24 challenges that can hinder the transition towards a circular economy. Notably, it differentiates between challenges that are well-known in related research areas and those that are relatively new or have distinct relevance within the circular economy context [37].

Integrating the concepts of circular economy and energy management represents a new shift towards sustainable development, offering a holistic approach to environmental management and resource efficiency. When integrated with energy management, the focus extends to ensuring that the energy used throughout the lifecycle of products and services is optimized, reused (i.e., circular), and comes from renewable sources wherever possible, thus reducing energy-related emissions. This dual focus not only reduces waste but also cuts down on greenhouse gas emissions, contributing to climate change mitigation. The authors [38] have emphasized the importance of designing out waste and pollution from the beginning, suggesting that energy efficiency should be a key consideration during the design phase of products and services. This proactive approach ensures that products not only use materials that are recyclable and sustainable but also consume less energy over their lifetime, from production to disposal. Renewable energy is another crucial aspect highlighted in the literature [39]. The transition to renewable energy sources is important for reducing the carbon footprint of production processes and for powering the recycling and remanufacturing processes that are central to the circular economy, while at the same time reducing operational costs. This transition not only mitigates environmental impacts but also improves energy security by reducing dependence on non-renewable energy sources [40,41]. The literature also discusses the concept of product life extension, as extending the useful life of products through repair, maintenance, and refurbishment can significantly reduce the need for new resources and energy for manufacturing new products [42–45]. This not only conserves resources but also saves the energy that would have been used in the production of new items. Resource recovery and recycling are further explored as means to conserve energy. By recovering and recycling materials at the end of their lifecycle, the energy required for extracting and processing virgin materials is significantly reduced. This process, detailed by the authors of [46], is key to minimizing the overall energy consumption associated with product lifecycles. Their work addresses the gap in evaluating current end-of-life product circularity decision-making methods, which predominantly focus on technical and economic factors, often overlooking crucial areas such as legislative pressures and customer demands. The proposed product recovery multi-criteria decision tool integrates these diverse factors, providing a comprehensive framework for assessing product recovery options at a strategic level. Additionally, the study highlights key decision-making factors essential for evaluating end-of-life strategies, offering a significant contribution to the field of circular economy by enabling more informed and sustainable decision-making processes for product recovery.

The integration of the circular economy and energy management also presents challenges, such as technological barriers, the need for investment in new infrastructure, and the necessity for collaboration across sectors and industries [47]. With this in mind, the study [48] explores the integration of energy management capabilities and circular economy business models in agricultural small and medium-sized enterprises (SMEs), focusing on a high-tech hydroponic tomato cultivation firm. It identifies energy management and auditing capabilities as important for developing organizational competencies that support circular economy business models, contributing to sustainable development. These capabilities improve knowledge on sustainable production methods and accountability, forming the micro foundations of the dynamic capabilities required for a circular economy. The study highlights the importance of fostering an organizational culture centered on energy conservation and how it promotes the knowledge and implementation of circular economy business models.

Another aspect of the circular economy development concept is its multidisciplinary nature, incorporating insights from environmental science, economics, and social sciences. This multidisciplinary approach is evident in the work [49], which analyzes the barriers to implementing the circular economy and suggests multidisciplinary strategies to overcome these challenges, emphasizing the role of technological innovation, policy regulation, and consumer behavior change. For instance, the study [50] examines the circular economy concept from six perspectives, suggesting that the realization of a fully circular economy faces significant challenges and complexities. It discusses the lessons from ecosystem recycling, thermodynamic limits, material rebound and shifting to energy, market processes, consumer and firm behavior, and geographical and transport issues, indicating that these factors complicate the achievement of a completely circular economy. The paper discusses a pragmatic approach to policy, emphasizing the need for a mix of short-term, implementable policies and long-term strategic initiatives to gradually transition towards more circular material flows. It also highlights the importance of addressing behavior, market dynamics, and geographical factors in policy design. Here, Table 2 presents the comparison of findings.

To address the gap in the literature regarding the application of the PDCA model within the context of circular economy integration in manufacturing processes, this study investigates how the PDCA framework can be effectively utilized in manufacturing firms for the adoption of circular economy principles.

The necessity for this study arises from the need to improve the environmental sustainability and efficiency of industrial organizations, particularly within the context of the manufacturing sector. While circular economy principles offer an approach to sustainable production, their implementation often lacks a structured and performance-oriented approach that aligns with industry requirements. The PDCA model, renowned for its efficacy in driving continuous improvement, has not been comprehensively evaluated or tailored as a core framework for the application of CE principles in industrial settings. Consequently, this study is encouraged by the problem of developing and validating a performance-oriented model, centered around PDCA, that can effectively guide organizations in integrating circular economy strategies into their operations. This model aims to bridge the gap between theoretical circular economy principles and their practical application. The literature review shows there is a gap in detailed models that integrate business process reengineering and the circular economy concept together effectively, focusing on being efficient, productive, and sustainable at the same time. Hence, this paper proposes a practical model that would help business organizations, especially in manufacturing, benefit from a circular economy approach in their business process reengineering efforts. The proposed model has been verified in industry. This research aims to provide new data on how this combination affects environmental sustainability, business performance, and social benefits.

Table 2. Literature review summarized on circular economy.

Reference	Focus	Methodologies	Key Findings	Main Contribution
[3,4]	Conceptual framework of the CE	Theoretical analysis	Discussed sustainability and resource efficiency	Explored the CE's framework contrasting with linear economies.
[32,33]	Economic, environmental, and social benefits of a CE	Literature review	Integrated economic activity with environmental well-being	Highlighted the wide-reaching benefits of a CE.
[34,35]	Practical applications of a CE	Case study analysis	Demonstrated the CE's application in various sectors	Showcased CE implementation and its relationship with sustainable development
[36,37]	Challenges in CE implementation	Case study and review	Identified distinct challenges unique to a CE	Industry covered: manufacturing, building construction. Discussed the challenges in redesigning supply chains for a CE.
[38,39]	Role of energy management in a CE	Review and theoretical discussion	Emphasized renewable energy and efficiency	Presented the importance of energy efficiency and renewable sources in a CE.
[42,43]	Product life extension in a CE	Theoretical	Discussed extending the useful life of products	Discussed product life extension strategies and their resource-saving benefits.
[46]	End-of-life product recovery in a CE	Development of decision tools	Proposed a multi-criteria decision tool for product recovery	Proposed a framework for assessing product recovery strategies in a CE.
[47,48,50]	Barriers and strategies for CE implementation	Multidisciplinary analysis	Suggested strategies to overcome barriers	Analyzed multidisciplinary barriers and strategies in CE implementation.

3. Methods

3.1. Research Design and Data Collection

In the study, a structured online survey as well as in-person interviews served as the primary data collection instruments. This survey was designed to align with ISO 9001 and ISO 14001 [51] standards, reflecting the requirements of the proposed model. The survey questions were divided into 14 distinct categories, each corresponding to a different aspect of the PDCA cycle. To select participants, a comprehensive database of organizations within specific industrial sectors in Serbia was compiled using data from the Business Registers Agency of Serbia. The collected data were then statistically analyzed to compute averages, standard deviations, and the minimum and maximum values of the measured parameters. Furthermore, the study utilized statistical tests such as the Mann–Whitney U test and Kruskal–Wallis test to explore the relationships between the implementation of the model and various organizational characteristics, thus providing a framework for assessing the impact of the integrated model on environmental sustainability, organizational performance, and resource efficiency within the surveyed organizations.

The initial step was to identify the circular economy model that can be verified in complex industry environments, especially in manufacturing companies. The model proposed [52] includes three perspectives on the implementation of circular economy strategies: environmental impact, economic profits, and resource scarcity. Together, they form a unified vision for the circular economy approach, which presents a framework based on these perspectives:

1. The environmental impact perspective, where this viewpoint advocates for a world where environmental impacts are significantly reduced. It involves stakeholders such as societies, nations, government entities, and individuals, all aiming to lessen environmental degradation. The focus here is on reducing and avoiding environmental damage by minimizing solid waste, landfill usage, and emissions of pollutants. Circular economy strategies under this perspective are designed to manage waste from various devices and equipment, particularly in the electrical and electronic sectors, to aid in the responsible disposal and recycling of these items.
2. The economic profits perspective, which highlights the pursuit of economic gains by individual firms to ensure survival and competitive advantage. It calls for an integrated approach to business models, supply chain management, product design, and material selection. The primary stakeholders are industrial and business enterprises, with the objective being the sustenance and enhancement of profits through the application of circular economy principles.
3. The resource deficiency perspective, which emphasizes the critical need for resources for societal well-being and the potential social issues arising from resource shortages. Circular economy strategies promote the reuse of resources, addressing the challenges posed by limited materials and increasing industrial activities worldwide. The focus is on achieving a circular flow of resources and materials, with nations and communities as key stakeholders. The goal is to encourage the regenerative use of resources, ensuring long-term sustainability and prosperity.

The next step included finding and analyzing a suitable business reengineering model that could be incorporated into the chosen circular economy approach. The model used for further analysis is presented in [53] and includes a six-phase plan for business process reengineering from beginning to end, based on a thorough review of existing studies. These phases are understanding, initiating, planning, executing, transforming, and evaluating. Initially, top management must acknowledge the need for change, what business process reengineering entails, and outline a strategy for its implementation. The next step involves setting a vision and selecting specific business processes for redesign. The objectives should be clear and measurable, and a team for the reengineering project must be formed, including leaders and essential staff from relevant departments. The third phase focuses on analyzing current processes, identifying inefficiencies, and setting benchmarks for improvement. The goal is to find significant opportunities for new processes that offer major advantages. In the “transforming” phase, the redesigned process is tested on a small scale to refine the new design, improve understanding among managers and employees, and estimate the full impact of the changes. After successful pilot testing, the new process is fully implemented. This involves educating employees, ensuring leadership support, aligning structures, reallocating resources, and adjusting reward systems. Communication is key to managing any resistance. The final phase evaluates the reengineering’s success against the initial objectives. If goals are not met, adjustments should be made. This phase emphasizes an ongoing commitment to business process reengineering.

The model that is proposed and used in this study incorporates the previous two models [52,53] and is adjusted to meet the specific verification needs for manufacturing organizations. It draws from the PDCA approach outlined in the ISO 9001 standard [15], incorporating an analysis of the needs and requirements of the circular economy concept previously defined in the literature. This analysis was performed with the cooperation of management teams from selected organizations, incorporating their insights and experiences to refine the model for practical application. Based on the feedback received, several adjustments were made to the initial model to better align with the operational realities of the manufacturing sector. These adjustments included:

- Modifications made to ensure the model could be scaled across different organizational sizes and adapted to different manufacturing processes.
- An improved focus on strategies for more effective resource use, which is important for organizations with limited access to new technologies.
- Emphasis on helping organizations align with ISO 9001 and ISO 14001 standards.

The model was designed to incorporate feedback loops, enabling continuous improvement and adaptation based on ongoing input from the management teams to ensure that the model remained relevant and effective in the face of changing industrial practices. Management teams highlighted the need for clear and concise documentation and reporting mechanisms within the model. This feedback led to the development of a more streamlined approach to documentation that supports quality control. Before full-scale implementation, the model was pilot tested in a subset of organizations. Management teams were actively involved in this phase, providing real-time data and feedback that were important for final adjustments and validation of the model’s effectiveness.

The goal was to adapt the straightforward and widely recognized PDCA framework to the unique context of (SMEs), which is not typically examined for its energy consumption processes, sustainability, or reengineering practices. This approach provides a detailed view into the various aspects of the circular economy requirements beyond merely measuring energy costs or waste disposal in the industry. The model aims to not only quantify findings but also establish benchmarks that can aid other organizations, particularly SMEs across various regions and categories, in finding effective solutions for achieving circular economy goals through reengineering production processes.

The proposed model is presented in Figure 1.

Integrating the principles of circular economy and business process reengineering into a cohesive model offers a strategic approach to sustainable and efficient business practices (Figure 1). On the other hand, the PDCA cycle provides a dynamic framework for implementing this integrated model. The Plan phase consists of: (1) Objective setting and alignment to establish clear, measurable objectives that align with both circular economy principles and business process reengineering goals. This includes reducing waste, optimizing resource use, and improving process efficiency. (2) Stakeholder engagement to identify and involve all relevant stakeholders from the outset, including suppliers, customers, employees, and regulatory bodies, to ensure broad support and input. (3) Process identification and analysis to select key business processes for redesign, focusing on those with the highest environmental impact and inefficiency. This also includes conducting a thorough analysis to understand current challenges and opportunities. (4) Vision and strategy development to develop a strategic vision that integrates circular economy principles with business process reengineering objectives, outlining a roadmap for transformation and sustainability.

(5) Objective and target value definition to identify major waste streams in current business processes, with a defined target value to achieve a specific percentage reduction in waste generation within a set timeframe and then, to propose resource efficiency improvements through action to analyze current resource use (materials, energy, and water),identify inefficiencies and furthermore, to analyze the possible carbon footprint reduction by calculating the current carbon footprint of the organization's operations and identifying key contributors. The Do phase identifies the following steps: (1) Design and innovation to redesign business processes to eliminate waste, promote recycling, and reuse resources, while also streamlining operations for efficiency and competitiveness. (2) Pilot and implementation planning to plan and execute small-scale pilot projects to test redesigned processes, ensuring they meet the objectives of circular economy and business process reengineering. (3) Resource allocation and training to allocate necessary resources, including technology and human capital, and provide training to ensure everyone is equipped to contribute to the new processes. The Check phase consists of: (1) Performance measurement and analysis to establish KPIs related to both environmental sustainability and process efficiency, and then, to collect and analyze data to assess performance against these KPIs. (2) Feedback and stakeholder communication to gather feedback from stakeholders and communicate progress and findings regularly to ensure transparency and foster continuous improvement. (3) Environmental and economic impact assessment to evaluate the environmental benefits achieved through circular economy practices and the economic impacts of business process reengineering, identifying areas of success and those needing improvement. And finally, the Act phase has following steps: (1) Standardization and integration to formalize successful practices into standard operating procedures across the organization, ensuring the integration of circular economy and business process reengineering becomes part of the organizational culture. (2) Continuous improvement to use insights gained from the Check phase to refine processes further, improve sustainability, and improve efficiency, fostering a culture of continuous improvement. (3) Scalability and expansion to explore opportunities to scale successful practices to other areas of the organization and beyond, potentially sharing successes and learnings with industry peers to promote broader adoption of integrated circular economy and business process reengineering practices. By following these sub-categories within the PDCA cycle, organizations can systematically implement a model that leverages the strengths of both approaches.

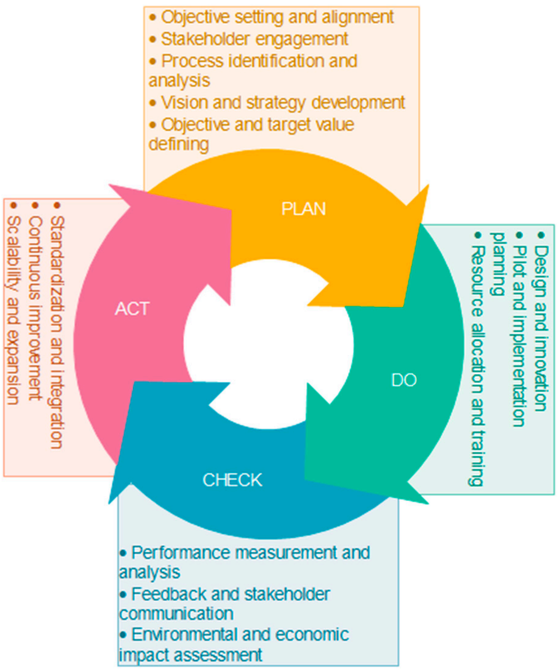

Figure 1. PDCA cycle model integrating circular economy and business process reengineering approaches.

The analysis involves a verification study based on the proposed model that was performed through an online survey aimed at organizations in the manufacturing sector in Serbia. This survey, designed according to ISO 9001 and ISO 14001 standards and based on the proposed model, featured sections for both basic company information and detailed inquiries regarding practices connected with the circular economy approach. These inquiries were organized into 14 different categories aligned with the PDCA cycle, allowing for responses that could be "Yes" (awarded 2 points), "No" (0 points), or "Partially" (1 point). The total points from these responses helped assess each organization's level of circular economy implementation and readiness for business process reengineering.

3.2. Participant Selection and Data Compilation

To gather participants, a database of organizations within the specified industrial sectors in Serbia was formed using a search tool from the Business Registers Agency of Serbia. Criteria to be included in the database were: being a production organization, registration with the Business Registers Agency, operational status (not undergoing bankruptcy or restructuring), and having an online presence. Contact was made with 221 organizations through email, phone, or direct visits, resulting in participation from 135 organizations. The survey, which had a response rate of 61.08%, ran from April to December 2023, with managers responding to the questionnaire. The responses are provided in the Supplementary Materials.

The key indicators used to assess the readiness of organizations for adopting circular economy strategies, as seen in the provided survey (in the Supplementary Materials), cover a range of operational and management aspects, focusing on: waste management practices, energy efficiency and renewable energy, supplier and material selection, resource optimization, environmental impact, product lifecycle evaluation, systematic approach and documentation, leadership and planning, standard and regulatory requirements, employee involvement and communication, energy goals and objectives, process approach, fact-based decision making, review, and continuous improvements.

The methodology guarantees the standards for the quality of conclusions with its alignment with ISO standards. This ensures that the investigation is grounded in internationally recognized frameworks for quality and environmental management, which supports the validity and reliability of the findings, as the surveyed practices and principles are based on well-established, documented, and audited processes within organizations. Then, structured data collection was achieved by using a structured online survey and in-person interviews that provided an approach to data collection, reducing the risk of oversight and ensuring that various aspects of business process reengineering, and circular economy integration were addressed. Then, a suitable sampling method was formed through the selection of data from a database that ensured that the conclusions were generalizable to the wider population of manufacturing organizations. Also, by including organizations of various sizes and years in the market, the study accounted for variability and diversity in organizational characteristics.

3.3. Statistical Analysis and Tests

Data from the survey were analyzed statistically, calculating averages, standard deviations, and minimal and maximal values for all measured parameters. The study also explored the relationship between the implementation of the model and certain organizational characteristics using basic data from the survey responses. Statistical tests such as the Mann–Whitney U test and Kruskal–Wallis test were applied to analyze the data.

Based on the presented model outlined in the description of integrating circular economy models and business process reengineering into manufacturing industries, particularly within the context of the Serbian manufacturing sector, several hypotheses can be formulated for further analysis. The aim is to examine the impact of the integrated model on environmental sustainability, organizational performance, and resource efficiency. The approach will mirror the method used in the example provided, focusing on the relationship between the implementation of the proposed model and the level of development within organizations.

3.4. Hypotheses Development

Considering the challenges faced in implementing this model within the organizations in Serbia, notably the financial limitations, the study proposes the following hypotheses:

General Hypothesis (GH): A significant and positive relationship exists between the integrated implementation of the circular economy and business process reengineering model in manufacturing companies and their environmental and organizational performance.

Hypothesis 1 (H1). *Organizations that have implemented ISO 9001 quality management systems exhibit a higher level of implementation of the business process reengineering framework within the proposed model.*

Hypothesis 2 (H2). *Organizations certified with ISO 14001 environmental management systems demonstrate a higher level of implementation of the circular economy framework within the proposed model.*

Hypothesis 3 (H3). *The size of an organization influences the application level of the integrated model.*

4. Results

The analysis was conducted by gathering data through interviews and questionnaires from 135 organizations across Serbia, aiming to include areas with less industrial development. The focus was on manufacturing organizations with production facilities in Serbia. These organizations had to meet specific criteria to be part of the study: they needed to be registered with the Business Registers Agency in Serbia, be operational (not undergoing bankruptcy or restructuring), and be located within Serbia. The first part of the questionnaire included the organizations' basic properties. The research sample's characteristics were analyzed based on the location, size, and market experience of the organizations. The organizations were spread across various regions, with 14.81% located in the City of Belgrade, 22.22% in the Vojvodina region, 22.96% in Sumadija and West Serbia, and the majority, 40.00%, in South and East Serbia. When it came to the size of the organizations based on the number of employees, 33.33% had 0–10 employees; the next category, with 11–50 employees, represented 30.37% of the sample; organizations with 51–250 employees accounted for 19.26%; and those with more than 250 employees made up 17.04%, indicating a mix of small to large entities. Regarding their years on the market, a small portion, 5.19%, had been operating for less than 3 years. Only 8.15% fell into the 3–5 year category. Those operating for 5–10 years made up 22.22%, showing a moderate level of experience. However, a significant majority, 64.44%, had been on the market for more than 10 years, highlighting the presence of well-established organizations within the sample.

The organizations were categorized by their economic activities as follows: 25.19% in the food industry, 23.70% in metal processing and mining, 19.26% in the wood industry, 9.63% in the chemistry, rubber, and non-metals industry, 8.89% in agriculture, 4.44% in the automotive sector, 4.44% in construction, 2.96% in the energy sector, 0.74% in the pharmaceutical industry, and 0.74% in the textile and leather industry. The territorial distribution of these organizations followed a specific pattern. For the analysis, it was important to review the management system certifications within these organizations. More than half, 59.26%, have ISO 9001 (Quality Management System) certification, 44.44% have ISO 14001 (Environmental Management System) certification, and 34.81% have ISO 45001 [54] (Occupational Health and Safety) certification. Notably, 40.0% of the organizations did not have any standard certifications.

The profile of the analyzed organizations included their energy use, focusing on the types of energy sources they utilize: electricity, natural gas, oil, compressed air, and renewable sources like solar, wind, or geothermal energy. About 68.89% of the organizations use one or two types of energy sources; 23.7% use three types; and only 7.41% use four or more types. The age of the machines and equipment affects energy efficiency. Specifically, 42.96% of organizations have equipment older than 10 years; 40.0% have equipment aged between 5 and 10 years; and 17.04% have machinery less than 5 years old. When it comes to significant energy users, 69.63% of the organizations identified fewer than 5, 14.81% identified between 6 and 10, and 15.56% identified more than 11 significant energy consumers.

The second part of the questionnaire looked into how organizations incorporate circular economy principles, focusing on how they manage materials and energy, within the proposed model in Figure 1 and readiness for business process reengineering. Generally, findings show 76.67% of organizations sort their waste, which is promising. Less than half, 40.74%, reuse plastics or other non-biodegradable materials in their operations. Additionally, 38.52% try to minimize packaging material, and 36.30% encourage returning old or used packaging or products. The survey also explored how organizations are rethinking their use of materials and energy for more circular processes. Notably, 46.67% regularly review their energy-saving practices, yet only 16.30% use renewable energy in their production. In terms of efficiency, 50.0% have implemented closed internal transport systems, but just 21.11% use automatic leak detection. Regular maintenance of energy-related equipment is performed by 64.93% of organizations. Regarding specific circular processes, 24.44% use energy recovery and water recirculation, 21.85% use secondary raw materials, 15.56% have closed water reuse cycles, and 7.78% utilize wastewater or rainwater. It’s also important to note that 48.15% regularly assess their environmental impact, despite 40.74% being legally required to do so. In terms of product lifecycle, 34.07% of organizations evaluate theirs, 22.59% promote rational energy use or renewables through their products or services, 10.74% are involved in developing renewable energy products or technologies, and 25.93% focus on optimizing energy costs in their offerings. Table 3 presents the statistical descriptions for the sample and variables.

Table 3. Statistical summary of the sample and key variables.

Variable	Mean	Standard Deviation	Minimum	Maximum
Number of employees	51.70	82.30	0	>250
Years on the market	10.67	7.45	<3	>10
ISO 9001 certification	59.26%	-	No	Yes
ISO 14001 certification	44.44%	-	No	Yes

The sample of 135 manufacturing organizations was selected from a comprehensive database, primarily sourced from the official records of the Business Registers Agency of Serbia. The selection criteria were set to include only production organizations that were actively operating, which meant they were not in the process of bankruptcy or restructuring procedures. Moreover, these organizations were required to have an established online presence, allowing for accessible communication channels. The survey outreach was extensive, utilizing various contact methods such as emails, phone calls, and, in some instances, direct visits to ensure a response rate.

These results highlight the current awareness and willingness among organizations to adopt more sustainable practices and technologies. The key contribution of this research was to verify the presented model based on the PDCA cycle. This is designed for easy application in future research across various industries and locations.

4.1. Business Process Reengineering in Circular Economy Planning—Establishing the Foundation for Circular Economy Implementation—The PLAN Phase of the Circular Economy System Approach

The initial stage of the suggested model is business process reengineering in circular economy planning, defined as the PLAN phase. This stage is fundamental in both approaches and also within the defined ISO 9001 framework, which influenced the majority of the survey questions. The data reveals that the PLAN phase is applied, on average, in 49.37% of cases. This is promising, indicating a readiness and eagerness to integrate the circular economy concept into business operations and a willingness to implement reengineering practices to achieve this. Organizations show a 48.99% average in identifying a system approach to the circular economy and 49.33% in management's commitment to a circular economy, displaying leadership's intent to fully engage with circular economy practices. To be more specifically, around half of the organizations have systems in place for tracking and documenting energy consumption (50.37%) and waste management (55.93%). A similar percentage have clear boundaries for these systems within their operations (51.85%). Less than half of the organizations have a document that defines effective energy management (45.19%), and a roughly similar proportion have one for waste management (49.26%). About 40.74% include continuous performance improvement and energy efficiency in their energy management systems. Almost half have a defined environmental protection policy or energy policy (49.63%). Leadership within these organizations plays an important role in defining responsibilities for effective energy (60.74%) and waste management (52.22%). However, less than half promote the importance of energy efficiency throughout the organization (48.52%) and ensure awareness among employees about energy efficiency (45.19%) and waste management (40.00%).

The research sample's planning for sustainability within a circular economy framework is noteworthy at 54.91%, and the enactment of legal requirements for a circular economy is at 56.79%, demonstrating organizations' commitment to more sustainable practices. This is to be expected since a majority have quality management systems certification at 59.26% and environmental management systems at 44.44%, incorporating elements of the circular economy. More specifically, long-term planning includes energy performance for most organizations (61.85%), and a majority have defined plans for energy use, savings, and system performance (58.15%). Over half of the organizations have a waste management plan (52.59%) and a plan for energy system performance (47.04%). When it comes to compliance with standards and regulations, a significant number of organizations identify, apply for, and have access to relevant legal requirements related to energy use, consumption, and efficiency (61.85%) and the management of biodegradable materials and waste (52.96%). They also ensure that these legal requirements are regularly followed and monitored (55.56%).

The definition of a circular economy profile has a 36.21% average implementation, and establishing circular economy goals and benchmarks is at 50.0%. These numbers suggest that the organizations are already operating in ways that align with circular economy principles, highlighting the potential to further improve production processes for better sustainability. The majority of organizations carry out waste selection (76.67%), but fewer use reusable non-biodegradable packaging (40.74%) or biodegradable materials (38.52%). Only a third have incentive policies for the return of old or used packaging or products (36.30%). Around half reassess their packaging processes to minimize material use (54.44%). Less than half review their energy-saving programs regularly (46.67%), and only a small percentage use renewable energy sources (16.30%). Other practices include the use of closed internal transport systems (50.00%), regular maintenance of energy transformation equipment (55.93%), and energy recovery and water recirculation (24.44%). Less than a quarter of the organizations select suppliers based on environmental criteria (28.15%). Concerning product development and innovation, only a fraction of organizations develop products or services promoting rational energy management, the use of renewable energy (22.59%), or products in the renewable energy sector (10.74%). A quarter of the organizations aim to optimize energy costs in their products or services (25.93%).

According to Figure 2, complete planning implementation does not exist within organizations in Serbia, while 5.18% do not engage in any aspect of the PLAN phase. The figure also indicates that 48.89% of the sample falls below the average in applying defined requirements in the planning phase, with 51.11% exceeding the average.

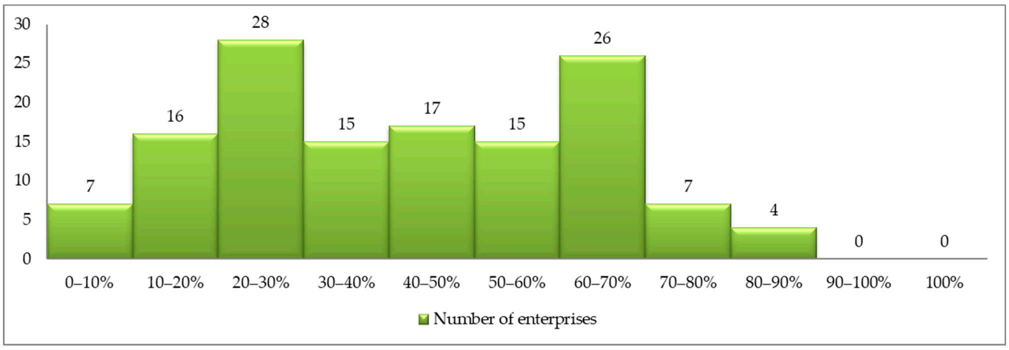

Figure 2. The PLAN phase with business process reengineering for circular economy implementation in Serbian organizations—distribution of Serbian manufacturing organizations across different levels of implementation for the PLAN phase of business process reengineering integrated with circular economy principles: 0–10%—7 organizations are in the earliest stages of implementation, indicating very minimal adoption of the PLAN phase practices; 10–20%—16 organizations have begun to adopt the PLAN phase practices but are still below a fifth of the way toward full implementation; 20–30%—28 organizations are making progress with adoption, having implemented between a fifth and nearly a third of the PLAN phase practices; 30–40%—15 organizations have crossed the initial stages and are approaching the halfway mark in implementation; 40–50%—17 organizations are nearing the midpoint of full implementation, indicating a balanced approach to planning for the circular economy; 50–60%—15 organizations have passed the midpoint of implementation, suggesting an above-average adoption of the planning practices; 60–70%—26 organizations are showing a significant level of integration, having implemented more than half but less than three-quarters of the PLAN phase practices; 70–80%—7 organizations are well advanced in their implementation, with only a few steps away from nearing complete integration; 80–90%—4 organizations are at the higher end of the implementation spectrum, indicating robust planning systems in place that align closely with the model; 90–100%—No organizations are within this range, which would indicate nearly full implementation of the PLAN phase; 100%—No organizations have fully achieved a complete implementation of the PLAN phase practices.

4.2. Business Process Reengineering in Action—Executing Circular Economy Practices—The DO Phase of the Circular Economy System Approach

The second stage of the model, the DO phase, involves practical steps such as engaging employees, internal communication, and establishing a documentation system aligned with the principles of the circular economy. It's important to note that the documentation system should include instructions for activities and proof that these activities have been completed. Organizations scored an average of 5.26 points in the DO phase, with a 56.04% average in applying DO phase requirements, which represents quite substantial when compared to similar studies using the energy management system application with the PDCA model approach [55–57]. About 58% of employees regularly report on energy consumption and waste management in their periodic reports. However, less than half actively monitor or report on these aspects during their workday. Training in effective energy and waste management, including environmental protection, has been completed by roughly one-third of the workforce, suggesting there is room for improvement in educational initiatives. Communication within organizations regarding the circular economy stands at an average application level of 60.28%. The involvement of employees in sharing information about energy and waste management in their regular reports shows a lower average application rate of 45.86%. Encouragement for open discussion on energy saving is even higher, at nearly 69% (68.52%). Discussion about the quantity of waste generated is slightly less common, featuring in just over 56.3% of internal communications. Meanwhile, suggestions for improving energy efficiency in processes are actively solicited in just over half of the cases (52.22%).

The documentation system's average application level, which includes managing procedures and rules related to energy consumption and waste management, is 57.41%. More specifically, 60% of organizations maintain records related to energy management, and slightly more, about 64.44%, do the same for waste management. However, clearly defined procedures for managing this documentation are present in less than half (47.78%) of the organizations, indicating a potential area for development. The process approach related to the circular economy, which considers procedures and optimizations, scores higher at 60.62%. This figure is quite meaningful, as thorough monitoring of production processes allows for a complete understanding of circular economy principles and the potential improvements that could be implemented. A significant majority of organizations are aware of the processes that heavily impact energy consumption (74.81%) and those with potential negative environmental effects (72.96%). Opportunities for boosting energy efficiency within processes are identified in 63.8% of organizations, and procedures for maintaining significant processing equipment are established in just over 57.04% of cases. Tracking production scrap is also carried out by a similar percentage of organizations, yet only a small fraction (38.15%) has systems in place to reintegrate scrap back into the production cycle.

In production, most processes transform inputs such as raw materials, energy, and information into outputs like products, and these material and energy flows are subject to further improvements. Figure 3 demonstrates the DO phase application in Serbian organizations, revealing that two organizations have fully implemented all requirements, while three of them have not implemented any. Nearly half of the organizations, 34.81%, fall below the average level of application in this phase, while a slightly larger portion, 65.19%, are above average.

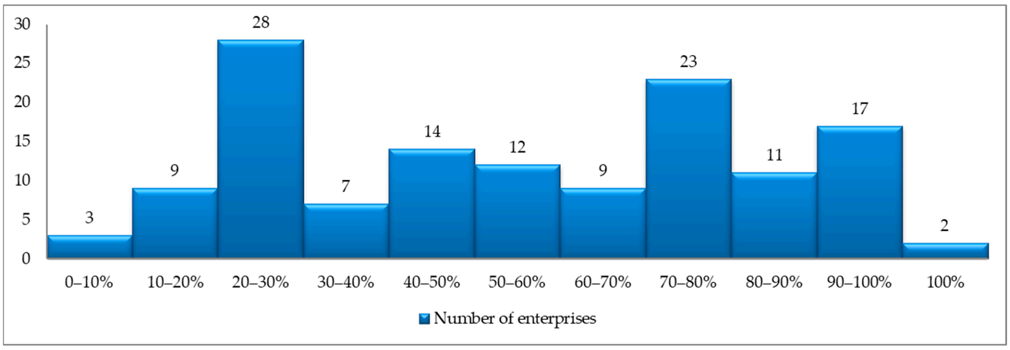

Figure 3. DO phase with business process reengineering for circular economy implementation in Serbian organizations—distribution of Serbian manufacturing organizations across different levels of implementation for the DO phase of business process reengineering integrated with circular economy principles: 0–10%—3 organizations have barely begun to take actions within the DO phase, suggesting either a very recent start or significant barriers to action; 10–20%—9 organizations are slightly more advanced than the previous group but still in the early stages of action implementation; 20–30%—28 organizations have made a fair amount of progress, having adopted around a quarter of the actions necessary in the DO phase; 30–40%—7 organizations are now moving towards the middle of the action spectrum but are still below the halfway mark; 40–50%—14 organizations are approaching the halfway point, suggesting they are implementing a balanced number of actions; 50–60%—12 organizations are just above the midway point of action implementation, indicating a moderate level of engagement with the DO phase; 60–70%—9 organizations have surpassed the moderate engagement mark, implementing a significant number of actions but still having room for improvement; 70–80%—23 organizations show a high level of active engagement, with substantial actions taken to integrate circular economy principles into their processes; 80–90%—11 organizations are nearing full implementation, suggesting robust actions and a strong commitment to the DO phase; 90–100%—17 organizations are on the cusp of full action implementation, missing very few elements to reach the highest level of the DO phase; 100%—2 organizations have fully implemented all actions within the DO phase, demonstrating complete engagement with the process reengineering principles.

4.3. Business Process Reengineering for Continuous Improvement—Evaluating and Refining Circular Economy Practices—The CHECK Phase of the Circular Economy System Approach

The CHECK phase of the model encompasses fact-based decision-making, which is one of the key principles of quality management systems. This stage involves setting up a system to gather and analyze data, which is important for managing an organization and making informed decisions. The collected data is used to compare current practices and predict future outcomes. In this phase of our research, a high percentage of organizations, 75.93%, recognize which of their processes are the most energy-intensive. Nearly three-quarters or 67.78%, can pinpoint exactly where the most waste is produced within their operations that cannot be recycled or repurposed. However, only 39.63% are able to determine the current energy performance of their facilities and identify major energy users. Less than half, 49.26%, can forecast future energy use and associated costs. Meanwhile, just 37.41% have identified and prioritized opportunities to improve the circularity of materials and energy within their operations.

The adoption of the CHECK phase stands at 47.7% across the organizations studied. Complete monitoring of the circular economy system approach is found in 5.18% of organizations, while minimal implementation of requirements is noted in 16.3%. According to Figure 4, less than half, 46.67%, falls below the average in applying the CHECK phase requirements, while 53.33% perform above average.

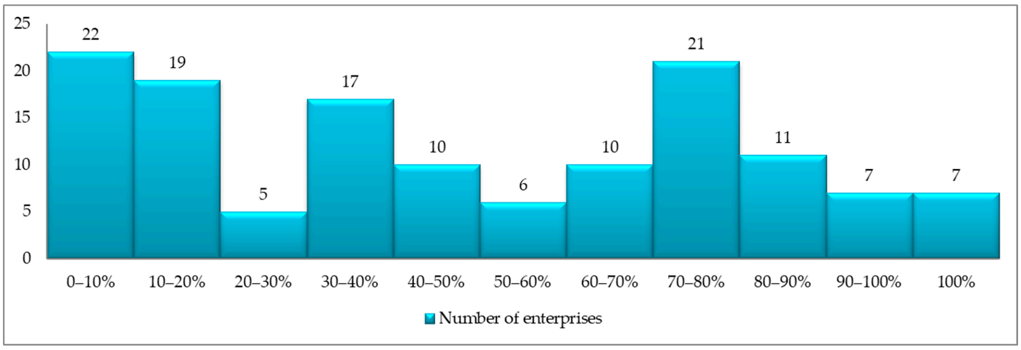

Figure 4. CHECK phase with business process reengineering for circular economy implementation in Serbian organizations—distribution of Serbian manufacturing organizations across different levels of implementation for the CHECK phase of business process reengineering integrated with circular economy principles: 0–10%—22 organizations are in the initial stages of evaluating and assessing their actions against their circular economy and business process reengineering objectives; 10–20%—19 organizations have made some progress but are still below one-fifth of the way toward full implementation of the CHECK phase; 20–30%—5 organizations have adopted about a quarter of the actions necessary for evaluation and monitoring, indicating early engagement in the CHECK phase; 30–40%—17 organizations have made moderate progress in this phase, implementing up to 40% of the necessary actions; 40–50%—10 organizations are approaching the halfway mark, indicating they are actively monitoring and evaluating their processes to some extent; 50–60%—6 organizations are slightly above the midway point of implementation, suggesting a higher level of engagement with monitoring and review processes; 60–70%—10 organizations have gone beyond moderate engagement, implementing a significant portion of the CHECK phase activities but not yet reaching advanced levels; 70–80%—21 organizations are highly engaged in this phase, with substantial monitoring and reviewing processes in place. They are implementing a vast majority of the required CHECK phase actions; 80–90%—11 organizations are nearing full implementation, which means they are conducting robust evaluations of their processes and making data-driven decisions; 90–100%—7 organizations have almost fully implemented the CHECK phase, indicating they are making full use of evaluation and monitoring to inform their practices; 100%: 7 organizations have completely adopted the CHECK phase, demonstrating they are fully utilizing data and feedback to refine and improve their processes.

4.4. Strategic Management and Leadership Review—Advancing Circular Economy Practices —The ACT Phase of the Circular Economy System Approach

The ACT phase represents an essential part of creating a sustainable circular economy practice model. Within the research sample, continuous improvement through management review occurs in 37.11% of organizations. Specifically, reviews focusing on proper management of circular economy practices, which also include monitoring consumption, encouraging savings, and increasing energy efficiency, are conducted in 55.56% of organizations. Similarly, management reviews addressing waste management, such as waste generation and the conservation of raw materials, are carried out in 52.59% of organizations. Furthermore, management in 35.56% of organizations plans actions that will improve waste management processes, and 39.26% look to improve energy management in future plans. The comprehensive application of the ACT phase within the circular economy approach is seen in 4.44% of organizations, with 34.07% meeting minimal requirements.

According to Figure 5, a significant majority of organizations, 55.56%, implement the ACT phase at a level below average. In contrast, 44.44% exceed the average level of application in this phase. To summarize the results of the study, a tabular representation was also provided in Table 4.

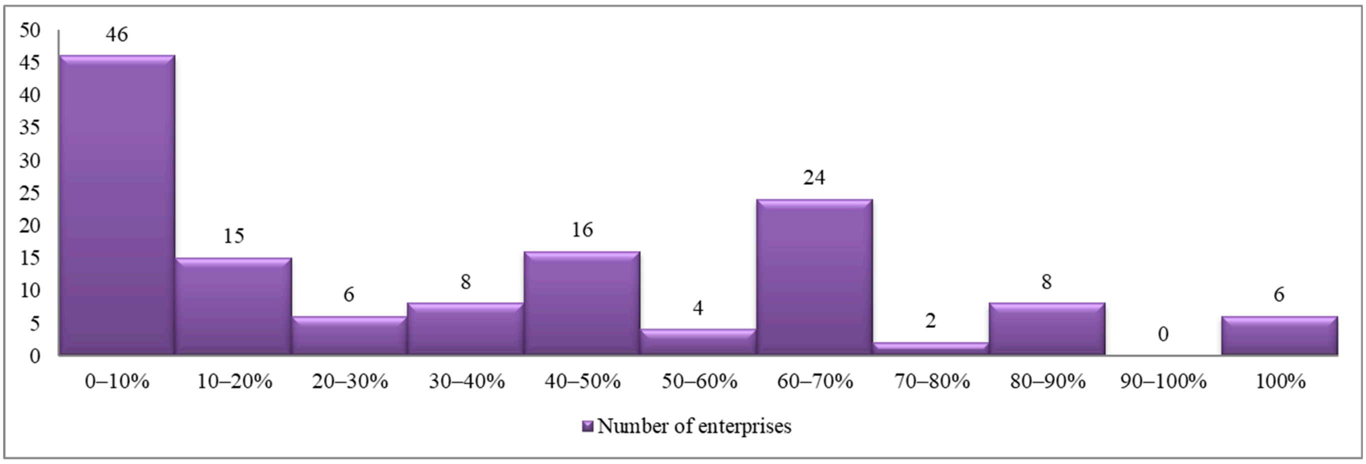

Figure 5. ACT phase with business process reengineering for circular economy implementation in Serbian organizations—distribution of Serbian manufacturing organizations across different levels of implementation for the ACT phase of business process reengineering integrated with circular economy principles: 0–10%—46 organizations have made very little to no progress in taking corrective and improving actions based on their CHECK phase findings; 10–20%—15 organizations have started to take action but have not progressed far, indicating early stages of implementing improvements; 20–30%—6 organizations are slightly more engaged in the ACT phase but still show a low level of action implementation; 30–40%—8 organizations have started to approach the mid-level of action implementation, but substantial work is still needed; 40–50%—16 organizations are close to the midpoint of full implementation, which suggests they are active in making improvements and standardizing successful changes; 50–60%—4 organizations have passed the midpoint but have not yet reached a high level of action implementation; 60–70%—24 organizations are implementing a significant number of actions based on the CHECK phase results and moving towards advanced levels of continuous improvement; 70–80%—2 organizations have a high level of action implementation, suggesting they are nearing the completion of their continuous improvement cycle; 80–90% —8 organizations are ready to fully integrate their improvement actions based on the PDCA model, demonstrating action towards improvement; 90–100%—There are no organizations in this range, indicating a gap just before full implementation; 100%—6 organizations have fully achieved the implementation of the ACT phase, signifying that they are fully engaged in the process of continuous improvement and are likely repeating the PDCA cycle effectively.

Table 4. The results of the survey.

Phase	Requirement Group	Average Points	Standard Deviation	Min. Points	Max. Points	Full Applicability	Full Non-Applicability	Average Level of Implementation
PLAN	System approach	6.86	4.91	0	14	15.56%	15.56%	48.99%
	Leadership	4.93	3.34	0	10	17.04%	14.81%	49.33%
	Energy planning	4.39	2.67	0	8	21.48%	12.59%	54.91%
	Standards and legal requirements	3.41	2.21	0	6	27.41%	17.78%	56.79%
	CE profile	26.07	13.69	0	72	0.00%	0.00%	36.21%
	CE objectives	4.00	2.63	0	8	18.52%	11.85%	50.00%
DO	Employees involvement	5.50	4.30	0	12	14.07%	22.22%	45.86%
	Communication	4.82	2.01	0	8	14.07%	5.93%	60.28%
	Documentation system	3.44	2.05	0	6	25.19%	15.56%	57.41%
	Process approach	7.27	3.88	0	12	20.00%	5.19%	60.62%
CHECK	Monitor, measure, and analyze business processes	8.59	5.78	0	18	5.19%	3.70%	47.70%
ACT	Management review and continual improvements	7.42	6.37	0	20	4.44%	23.70%	37.11%

4.5. Evaluating the Correlation between Circular Economy Principle Integration and Organizational Characteristics

The analysis examined the basic properties of organizations, derived from the initial part of the questionnaire, to explore the relationship between the level of business process reengineering for circular economy implementation in Serbian organizations and their specific characteristics. The Mann–Whitney U test revealed that organizations with a certified quality management system had significantly higher levels of circular economy implementation (median = 61.86%, n = 80) compared to those without an ISO 9001-certified system (median = 20.62%, n = 55), with a z-score of 9.78019 and a very significant p-value (p = 0.00001). This indicates a clear difference between the two groups and aligns with findings from other research that analyzed energy management systems [56,57]. And concerning only the business process reengineering framework of the model, the Mann–Whitney U test results show that organizations with a certified quality management system had significantly higher levels (median = 41.07%, n = 80) compared to those without (median = 14.28%, n = 55), with a z-score of 9.83169 and a p-value (p = 0.00001). The analysis revealed a significant difference between the two groups under study. Consequently, H1 has been validated by the evidence gathered.

Furthermore, the analyses covered how the implementation of business process reengineering for a circular economy correlates with specific characteristics, specifically certification of environmental management standards (ISO 14001). Using the Mann–Whitney U test, it was found that organizations with an ISO 14001-certified environmental management system showed significantly higher levels of the model's implementation, with a median of 68.56% for 60 organizations, in contrast to a median of 23.71% for 75 organizations without the ISO 14001 certification. This significant disparity, indicated by a z-score of 9.91003 and a highly significant p-value of 0.00001, mirrors trends seen in other studies focused on energy management systems [55–57]. Additionally, when examining the circular economy aspect alone, the results remained consistent. Organizations with ISO 14001 certification had markedly higher implementation levels, with a median of 51.96% among 60 organizations compared to a median of 21.43% among 75 organizations without ISO 14001 certification. This was also supported by a z-score of 9.75948 and a p-value of 0.00001. Thus, the significant differences observed confirm H2 through the gathered evidence.

The analysis also considered whether the number of employees affected the implementation level of business process reengineering for circular economy implementation. The Kruskal–Wallis test showed that larger organizations had a higher median implementation level (73.71%, $n = 23$) than medium-sized (68.56%, $n = 26$) and small organizations (42.27%, $n = 41$), with micro-organizations having the lowest level (19.59%, $n = 45$). The test returned a value of $X^2 = 109.3525$ and a p-value of less than 0.00001, signifying a significant result for $p < 0.05$, thus confirming H3 that the size of an organization influences the application level of management systems.

Therefore, GH was confirmed, demonstrating a significant and positive link between the adoption of the integrated circular economy and business process reengineering model in manufacturing companies and their environmental and organizational performance.

The relationship between organizational characteristics and the level of integration of circular economy principles was statistically analyzed, and the results are succinctly summarized in Table 5, which presents the tests used, their descriptions, and the corresponding significant values.

Table 5. Summary of statistical tests evaluating the relationship between circular economy integration and organizational characteristics.

Test	Description	Value
Mann–Whitney U (ISO 9001)	Comparison of circular economy implementation levels between organizations with and without ISO 9001 certification	$Z = 9.78019$, $p < 0.00001$
Mann–Whitney U (ISO 14001)	Comparison of model implementation levels between organizations with and without ISO 14001 certification	$Z = 9.91003$, $p < 0.00001$
Kruskal–Wallis (Org. Size)	Examination of the impact of organization size on the implementation level of the circular economy and business process reengineering model	$X^2 = 109.3525$, $p < 0.00001$

5. Discussion

The analysis highlights the application level of business process reengineering for the circular economy model across organizations in Serbia. According to the survey's third section, scores ranged from 0 to 194, with 194 being the maximum achievable score based on the outlined model in Figure 1. The average score across the examined organizations was 86.72, or 44.70%. This research aimed to explore how organizations adapt their business processes for a circular economy in response to challenging times in Serbia, in the middle of the war in Ukraine, and the impact of the post-COVID-19 pandemic on businesses. While there is a systematic approach to this model among Serbian organizations, the implementation level should be higher. There is an evident willingness among management to adopt this model, and while the circular economy approach is noted within these organizations, the implementation of business process reengineering remains limited. The data highlights that 58.52% of organizations scored below 50% in their requirement for business process reengineering for the circular economy model application, indicating a majority with minimal implementation. No organization showed full model application, with a very low overall implementation rate of 20.0% (Figure 6). This snapshot of current practices underlines the need for ongoing observation. The model, rooted in the PDCA cycle, was customized for the challenging organizational environment in Serbia, suggesting areas for improvement in management commitment, employee engagement, and communication regarding business process reengineering for the circular economy approach.

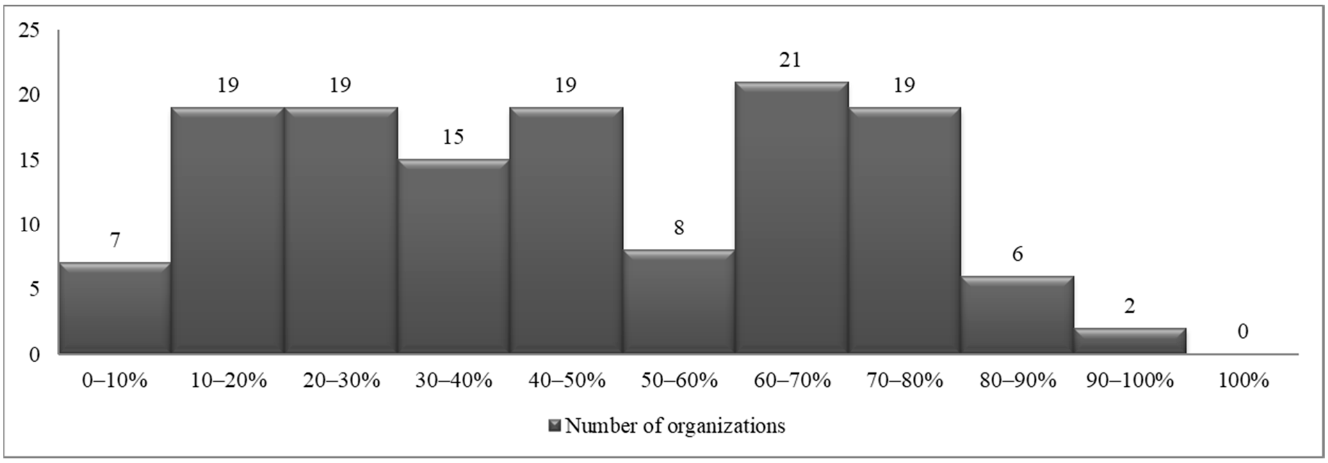

Figure 6. Business process reengineering for circular economy implementation in Serbian organizations.

In the comparative study [53], the impact of hotel ratings and organizational characteristics such as ISO 9001 certification on the implementation of EnMS was evaluated, and similarly, the presented study found that ISO certifications (ISO 9001 and ISO 14001) significantly influence the implementation of circular economy, with certified organizations exhibiting higher levels of implementation. Further comparison is seen in [56], where the relationship between the implementation of energy management systems and organizational characteristics like company size was analyzed. The significant differences found in EnMS implementation across different company sizes in [56] align with the presented findings, where larger organizations demonstrated higher levels of integration of circular economy principles. This comparison validates the findings. Moreover, [57] broadens this analysis to the influence of certified management systems on EnMS implementation across various enterprises, finding that certifications indeed elevate the level of system implementation. The studies in Denmark [58], Sweden [59], and Turkey [60] indicate various levels of implementation: Denmark (3–14%), Sweden (25–40%), and Turkey (22%). The study in Serbia, where the implementation was only 1.5% fully realized, aligns more closely with Denmark's lower rates. In the analyzed study, the average level of implementation of circular economy principles merged with business process reengineering across Serbian manufacturing organizations was higher, at 44.70%. This suggests that while both studies show partial implementations, the integration of circular economy principles might be progressing somewhat better than energy management practices in similar contexts.

The presented findings resonate with the wider objectives of the 2030 Agenda for Sustainable Development. Particularly, the adoption of circular economy strategies can directly contribute to the achievement of SDG 12 by optimizing resource use and waste management practices and indirectly support SDG 13 by reducing greenhouse gas emissions through improved energy efficiency and resource recovery processes. This nexus between circular economy, decarbonization, and energy efficiency represents a symbiotic approach towards cleaner production, which is important for transitioning to a green and sustainable economy. The recent paper on the European Emissions Trading System's impact on the SDGs [61] offers a parallel in understanding how systemic changes in environmental policy can drive sustainable outcomes. Similarly, the presented study suggests that the implementation of business process reengineering for circular economy within organizations not only fosters compliance with environmental policies but also promotes corporate alignment with global sustainability targets, thereby improving their contribution to the SDGs.

The findings highlight the need for targeted strategies to improve management commitment, resource allocation, and participation in sustainable practices. This implies that for successful integration, top management must not only introduce these initiatives but also allocate necessary resources, including training and technological investment, to support their implementation. The results show the need for the continuous development of skills and knowledge related to circular economy practices within organizations. Training programs, workshops, and education initiatives are important in raising awareness and developing competencies required for effective implementation. For policymakers, the study suggests the importance of creating supportive environments for organizations, particularly smaller ones, to adopt circular economy practices. Incentives or regulatory measures could be considered to lower the barriers to entry for implementing these principles. And the research highlights the potential for the PDCA model to serve as a basis for future system management certification and standardization efforts focused on circular economy integration.

The limitations of the study were due to its focus on a relatively narrow sample size, predominantly comprising small and micro-sized organizations in Serbia, which constituted 63.70% of the research sample. Such a demographic may not accurately reflect the broader spectrum of small enterprises, both within Serbia and globally. Additionally, the financial constraints of the majority of these organizations could have influenced the study's outcomes. A significant limitation also arose from the limited engagement and participation of the organizations approached for the study, coupled with a noticeable reluctance from their management teams to contribute to the research.

6. Conclusions

The proposed methodology for the study has several advantages and disadvantages. Among the pros, the use of the PDCA model provides a systematic approach to integrating business process reengineering with circular economy principles, which helps organizationscontinuously improve and adapt their operations towards sustainability. The methodology also includes a broad survey and statistical analysis, offering a comparable data set that reflects the current state and readiness of organizations in Serbia to adopt these practices. This approach allows for an assessment of the effectiveness of the integration and identifies specific areas for improvement. On the downside, the methodology relies heavily on self-reported data from organizations, which can introduce their own views and affect the reliability of the findings. The financial constraints of the smaller organizations in the study could also affect the results, as these entities may not have the resources to implement the necessary changes effectively. While the methodology provides valuable insights and a practical framework for integration, it also faces challenges related to data reliability, scope of applicability, and financial variability among surveyed entities.

The study explored the integration of business process reengineering with circular economy principles within Serbian manufacturing organizations, particularly in the challenging environment created by geopolitical conflicts and the post-COVID-19 pandemic. This analysis shows varying degrees of implementation success, as measured against a comprehensive framework designed to assess the effectiveness of integrating circular economy practices into a reengineered business process approach. With scores ranging from 0 to 194, where 194 represents the full potential based on the proposed model, the average attainment among organizations was 86.72, equating to a 44.70% realization of the model's capabilities. This result underscores a moderate engagement with the model's practices, highlighting a considerable gap toward full implementation. A key observation from the study is the predominant participation of small and micro-sized organizations, which accounted for 63.70% of the sample. This reflects the broader economic structure, where SMEs play a dominant role. Financial constraints were also noted as a potential factor that could distort the study's outcomes, reflecting the resource constraints faced by smaller entities.

The breakdown of implementation across different phases is as follows: the Plan phase at 49.37%, the Do phase at 56.04%, the Check phase at 47.70%, and the Act phase at 37.11%. Organizations with ISO 9001 and ISO 14001 certification showed better capabilities for the model implementation, thus proving Hypothesis H1. Additionally, larger and medium-sized organizations outperformed smaller companies in implementing these requirements, as denoted in Hypothesis H3. Furthermore, the research proposes a motivation model for hotel employees, suggesting that this should be incorporated into the broader state or regional training system.

The companies that had implemented ISO 9001 showed the applicability of the proposed model with a calculated success rate of 61.86%, whereas the organizations that implemented ISO 14001 demonstrated a higher potential for the applicability of the proposed model of 68.56%. This indicates that the implementation of ISO 9001 is already a strong foundation for process redesign based on circular economy principles, compared to the organization without any implemented management systems, in favor of Hypothesis H1. The potential for uptake of the proposed method is slightly increased with the implementation of ISO 14001, as per Hypothesis H2, but the difference is lower between companies with just ISO 9001 without ISO 14001 than between companies without any management system embedded.

This work outlines a method for assessing the implementation of the circular economy model using analytical tools, suggesting its applicability across different sectors and industrial conditions. Future research should extend to other industry sectors to gain comprehensive insights, offering valuable data for policymaking and industry improvements. Despite these challenges, there was a visible commitment among organizational management towards adopting circular economy practices, through the actual application of business process reengineering strategies. The data indicated that 58.52% of organizations fell below the 50% threshold for applying the model, with no organization achieving full application. This suggests widespread recognition of the model's value but also indicates significant barriers to its comprehensive implementation.

The study provides empirical evidence of the current state of integration between business process reengineering and the circular economy, contributing to the integration adaptation of the PDCA Model. Proposing a specifically customized PDCA-based model, the research contributes a novel framework that is aligned with international quality and environmental management standards (ISO 9001 and ISO 14001). This model is not only theoretically grounded but also empirically tested, adding to the scientific methodologies available for analyzing circular economy implementation. The second contribution is that the study develops and applies an analytical framework to assess readiness for a circular economy within the manufacturing sector. Thirdly, sector-specific insights are analyzed. By focusing on the manufacturing sector in Serbia, the study contributes sector-specific insights into the challenges and opportunities for integrating circular economy principles.

In conclusion, the study provides an understanding of the current state of circular economy practices and business process reengineering integration within the Serbian manufacturing sector. While there is a clear inclination towards sustainability and efficiency improvements, the path to fully realizing these models is fraught with challenges. The findings lay the groundwork for future research, suggesting a need for targeted strategies to improve participation, resource allocation, and management commitment towards sustainable practices. The study not only contributes to the academic discourse on sustainable manufacturing but also offers practical insights for industry stakeholders aiming to navigate the complexities of integrating circular economy principles into their operations.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/pr12050877/s1, Questionnaire and answers.

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