Asia Pacific
Academy of Science Pte. Ltd.

Sustainable Social Development 2025, 3(5), 8393.
https://doi.org/10.54517/ssd8393

Article

In harmony with the nature: How does the circular economy achieve sustainable development in Mexican automotive industry?

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CITATION

Rodríguez-Gonzále RM, Maldonado-Guzmán G. In harmony with the nature: How does the circular economy achieve sustainable development in Mexican automotive industry? Sustainable Social Development. 2025; 3(5): 8393. https://doi.org/10.54517/ssd8393

ARTICLE INFO

Received: 7 January 2026
Revised: 28 January 2026
Accepted: 30 January 2026
Available online: 3 March 2026

Abstract: The circular economy has attracted increasing attention from researchers, academics, policymakers, business professionals, and public institutions, largely driven by environmental concerns and current policies focused on sustainability and resource preservation. Despite the extensive discussion in the literature regarding the advantages of circular economy adoption in manufacturing firms and its contribution to sustainable development, existing empirical evidence remains limited and inconclusive. In response to this gap, the present study seeks to deepen understanding of the outcomes associated with circular economic implementation by examining its effects on sustainable performance and sustainable development. To this end, a survey was administered to 300 manufacturing companies within the Mexican automotive sector, and the proposed research framework was empirically tested using partial least squares structural equation modeling (PLS-SEM). The findings indicate that circular economy practices exert a significant positive influence on both sustainable development and sustainable performance. Additionally, sustainable development not only enhances sustainable performance directly but also mediates the relationship between circular economy practices and sustainable performance.

Keywords: circular economy; sustainable development; sustainable performance; manufacturing companies; automotive industry

1. Introduction

Sustainable development (SD) is increasingly recognized as a strategic pathway through which manufacturing firms can achieve long-term transformation by integrating environmental sustainability into routine operations while enhancing economic performance [1]. This perspective requires a reassessment of ecosystem constraints within the broader context of ecological transition and economic inequality, promoting production models that are environmentally sustainable, economically efficient, and socially equitable [2–4]. Despite this recognition, the literature highlights persistent shortcomings in the effective monitoring, assessment, and implementation of SD initiatives within manufacturing organizations [5,6].

This situation reveals a clear gap between the normative importance of SD and the ambiguity of firm-level empirical outcomes [7]. Within this debate, the circular economy (CE) has emerged as a key framework for translating SD principles into strategic and operational practices by challenging the traditional linear model of take–make–use–dispose and promoting regenerative production systems [1,8]. Nevertheless, important questions remain regarding the ability of CE initiatives to simultaneously support economic competitiveness and deliver measurable environmental benefits [1,9].

Recent studies emphasize the need to examine CE and SD in an integrated manner to capture their combined social, economic, and environmental effects [10–13]. However, empirical research directly analyzing the CE–SD relationship remains limited, particularly at the firm level and in developing economies [11,14,15]. Consequently, there is a need for more robust empirical evidence that clarifies how CE practices contribute to SD within sustainability-oriented organizational frameworks [1,15].

Against this backdrop, this study examines the relationship between CE practices, SD, and sustainable performance (SP) in automotive manufacturing firms in Mexico, addressing the following research question: How do circular economy practices influence sustainable performance directly and indirectly through sustainable development? The analysis is based on survey data from 300 firms and employs partial least squares structural equation modeling (PLS-SEM) using SmartPLS 4.0 [16]. The automotive sector provides a relevant empirical context, as it accounts for approximately 15% of Mexico's environmental depletion and degradation costs while representing a key driver of economic growth [17].

The findings provide robust empirical evidence of positive relationships between CE practices, SD, and SP, and confirm the role of SD as a driver of sustainable performance. By doing so, this study contributes to closing existing gaps in the literature on the CE–SD nexus and extends empirical evidence from a developing economy context [1,18].

2. Materials and methods

This study is grounded in the resource-based view (RBV), which conceptualizes firms as bundles of heterogeneous and imperfectly mobile resources and capabilities that are embedded within organizational strategies and generate differential social, economic, and environmental outcomes [19,20]. From this perspective, sustained performance advantages arise when firms possess valuable, rare, inimitable, and non-substitutable resources and capabilities that competitors cannot easily replicate [18,21,22]. Accordingly, the assessment of business performance provides insight into how effectively manufacturing firms deploy and integrate these resources and capabilities to create value [23].

Within this framework, CE practices can be conceptualized as a bundle of firm-specific resources and capabilities that support the redesign of production systems, the management of material and energy flows, and the reduction of environmental impacts. These capabilities include, among others, knowledge related to eco-efficient process design, organizational routines for recycling and remanufacturing, coordination mechanisms for closed-loop supply chains, and managerial competencies for integrating circular principles into operational decision-making. As predominantly intangible and path-dependent resources, these CE-related capabilities are difficult to imitate and can therefore serve as sources of sustained competitive advantage [15].

Moreover, manufacturing firms can enhance the effectiveness of CE capabilities by embedding them within broader sustainability-oriented strategies that strengthen SP [18]. In this context, SD can be understood as an enabling capability that allows firms to integrate, align, and reconfigure CE-related resources over time. By guiding organizational priorities toward long-term environmental, social, and economic objectives, SD strengthens the firm's ability to convert CE initiatives into consistent performance outcomes. Consequently, CE practices supported by a strong SD orientation are more likely to generate enduring improvements in SP and to contribute meaningfully to sustainability objectives within manufacturing firms [15].

2.1. Circular economy and sustainable performance

The concept of the CE is widely recognized in the literature as one of the most feasible sustainability-oriented approaches for transforming the prevailing linear production model adopted by manufacturing firms worldwide [24]. This transition is driven by strategies focused on reducing industrial waste, extending the useful life of materials and products through reuse, and promoting environmental regeneration [25]. Consequently, CE practices contribute to mitigating environmental degradation associated with end-of-life vehicles and battery waste, while simultaneously fostering higher levels of SP [26,27]. Nonetheless, prior research identifies three overarching types of relationships between CE and SP: conditional relationships, in which CE adoption is a prerequisite for improvements in SP; beneficial relationships, where CE and SP reinforce each other; and trade-off relationships, whereby CE implementation leads to both positive and negative effects on SP [28].

Within this context, the relationship between CE practices and SP can be positioned along a continuum that ranges from a fully integrated and strongly positive association to a fragmented and potentially adverse interaction [8,29,30]. As a result, the existing literature does not yet provide conclusive evidence that CE adoption necessarily leads to substantial improvements in the SP of manufacturing firms [31]. Recent empirical studies reflect this ambiguity by reporting mixed findings regarding the CE–SP relationship. On the one hand, several investigations have identified a positive association between the implementation of various CE practices and higher levels of SP in manufacturing organizations [32–37].

On the other hand, several studies have reported a negative association between CE practices and SP [38–41]. In contrast, other empirical investigations have identified no statistically significant relationship between CE and SP [8,42,43]. Collectively, these findings indicate that the body of literature examining the CE–SP linkage remains fragmented and insufficiently developed [7,28,44]. One plausible explanation for the divergence in results lies in the heterogeneous use of CE practices across studies, as certain practices may generate adverse outcomes, whereas others may contribute positively to SP [28].

Mora-Contreras [17], based on a review of 44 empirical studies examining the relationship between CE practices and SP, identified a substantial gap related to the inconsistent application of CE theories and practices. To address this limitation, the author proposed the adoption of the most frequently used CE theoretical frameworks and practices in literature, thereby enabling greater comparability of research findings. More recent studies have provided additional empirical insights. For instance, one investigation reported that the implementation of CE practices led to improvements in the financial performance of automotive manufacturing firms in Mexico [45]. Similarly, other research offered empirical evidence supporting a positive relationship between CE adoption and SP in Mexican manufacturing firms [46]. Consequently, the literature suggests that sustainability-oriented strategies within manufacturing organizations can enhance the effective deployment of CE initiatives [47]. Based on the evidence and arguments presented above, the following research hypothesis is proposed.

H1: The implementation of circular economy practices has a positive and significant effect on sustainable performance in automotive manufacturing firms.

2.2. Circular economy and sustainable development

Global consumption of goods, natural resources, and raw materials has expanded at an accelerated pace over the past two decades, prompting growing concern among scientific, academic, and business communities regarding the environment's capacity to withstand the progressive depletion of natural resources [48,49]. In this context, it is unsurprising that CE practices have received increasing attention in both academic and industrial spheres as a strategic approach for improving the management and efficiency of resource use [48]. This growing interest is largely attributed to the potential of CE initiatives to support climate change mitigation, reduce the environmental burden associated with industrial waste generation, and ultimately contribute to the advancement of SD [50–52].

Accordingly, several studies in existing literature have sought to quantify the relationship between the CE and SD across different analytical levels, including products, firms, and regions [48]. Notable contributions include product-level analyses, as reported in prior studies [53,54], as well as industry-focused research examining CE implementation within specific sectors [55]. In addition, other investigations have approached this relationship from a regional perspective [56,57]. More recent empirical work has identified strong linkages between CE practices and specific Sustainable Development Goals (SDGs), including SDGs 7, 8, 9, 10, 11, 12, and 13 [58]. Similarly, cross-country analyses conducted in several European nations have confirmed the existence of associations between CE and the SDGs, particularly SDGs 6, 8, 9, 11, 12, 13, 14, and 15; however, these studies did not offer detailed explanations regarding the underlying mechanisms of such relationships [59].

From this perspective, CE and SD can be understood as closely connected and mutually reinforcing concepts, as both pursue aligned objectives related to the promotion of social, economic, and environmental sustainability [1,15]. CE practices provide organizations with viable alternatives to the conventional linear economic model by emphasizing recycling, remanufacturing, and the reuse of materials and resources [60]. In parallel, SD offers a comprehensive framework for sustainability that integrates three fundamental dimensions: social, economic, and environmental [61–63]. Despite this conceptual alignment, relatively few studies in the existing literature have explicitly examined and discussed the relationship between these two constructs in depth [1].

In a recent study, Dantas [58] argued that the CE is strongly associated with the achievement of SD objectives, primarily because it integrates innovative technologies with advanced circular production practices, thereby facilitating the attainment of SD outcomes within manufacturing firms. However, the empirical evidence reported in the literature remains inconclusive, underscoring the need for additional studies that provide stronger and more consistent validation of this relationship [48,58]. This need is particularly relevant given the inherent complexity of measuring sustainability-related outcomes in manufacturing contexts [48]. In this regard, Martinho [64] suggests that more robust results can be obtained by employing the indicators most used in the literature for both CE and SD. Based on the arguments and evidence discussed above, the following research hypothesis is proposed.

H2: The implementation of circular economy practices has a positive and significant effect on sustainable development in automotive manufacturing firms.

2.3. Sustainable development as mediating variable

The World Economic Forum has identified biodiversity loss, climate change, and the deterioration of social cohesion as some of the most significant risks that manufacturing firms are expected to confront over the next decade, a situation that has been further exacerbated by the COVID-19 pandemic [65–67]. In response to this environmental and social context, manufacturing organizations are increasingly required to confront emerging business challenges by incorporating SD practices into their routine operations [68,69]. Consequently, the adoption of SD across the business sector reinforces the critical role of manufacturing firms in addressing environmental and social issues, as the objectives of the contemporary sustainability agenda cannot be achieved without the active involvement of companies [70,71].

Nevertheless, the implementation of SD practices by manufacturing firms has progressed at a relatively slow pace [72]. This delay is largely attributable to the negative economic and social impacts caused by the COVID-19 pandemic, which has constrained firms’ capacity to adopt SD initiatives, resulting in lower levels of SD implementation and, consequently, reduced SP [70–73]. Moreover, the predominant focus on the economic dimension of SD, together with market pressures emphasizing short-term financial outcomes, has further limited the effective integration of SD within organizational strategies [74]. In response to these challenges, an increasing number of manufacturing firms are embracing a broader interpretation of SD that extends beyond profit maximization, aiming to generate value for society and the environment while simultaneously improving SP [73,75,76].

Over the past decade, academic interest in the adoption and implementation of sustainable SD within manufacturing firms has grown substantially [73]. However, much of the existing evidence suggests that SD initiatives are frequently adopted in a symbolic manner, primarily to enhance organizational legitimacy in the eyes of stakeholders, rather than to generate tangible improvements in SP [70–75]. For instance, a study published in 2019 reported that approximately 72% of the world’s 1141 largest corporations referenced SD-related issues in their corporate reports [76]. Despite this apparent commitment, only about 25% of large manufacturing firms implemented meaningful strategies or business models aimed at advancing SD, and merely 1% of manufacturing companies disclosed measurable outcomes related to their SP [76].

Furthermore, several studies have relied on corporate disclosures and survey-based evidence to assert firms’ commitment to enhancing SP [73]. Nonetheless, there remains limited clarity regarding the specific mechanisms through which manufacturing firms operationalize SD practices to achieve improved SP, as well as how these practices generate performance outcomes across different organizational and contextual settings [77,78]. Consequently, despite the growing volume of scholarly debate surrounding the motivations for SD adoption and its impact on SP, the empirical understanding of the relationship between these two constructs and their associated outcomes continues to be fragmented and incomplete [79,80]. Based on the arguments outlined above, the following research hypothesis is proposed.

H3: Sustainable development has a positive and significant effect on sustainable performance in automotive manufacturing firms.

The literature indicates that SD not only enables manufacturing firms to mitigate adverse effects on ecosystems and the natural environment but also contributes to the promotion of human well-being and the generation of economic value within a sustainability-oriented framework [81]. Accordingly, many empirical studies emphasize SD initiatives that prioritize the reduction of resource consumption and environmental pollution in manufacturing operations, while simultaneously enhancing SP [82]. This effect is particularly evident when SD functions as a mediating variable in the relationship between CE practices and SP [83]. Consequently, the formulation and implementation of SD policies and activities within manufacturing firms require a balanced consideration of both economic value creation and the responsibility to protect and preserve natural systems [84].

Over the past decade, literature has increasingly emphasized the importance of reducing industrial waste and improving resource efficiency within manufacturing firms [24]. In this context, CE practices are widely regarded as one of the most viable approaches for achieving these objectives, while also serving as a strategic pathway to enhance industrial sustainability, particularly within the automotive sector [85,86]. Nevertheless, not all industrial solid waste can be effectively remanufactured or recycled due to material degradation and product safety constraints, a challenge that is especially pronounced in the automotive industry [87–89]. As a result, the implementation of CE practices alone is insufficient to ensure sustainability improvements; rather, it must be complemented by a firm-level commitment to SD objectives [90].

Accordingly, the literature increasingly acknowledges the adoption of CE practices by manufacturing firms as a critical driver for achieving higher levels of SP [24]. This relevance is particularly evident when CE initiatives are aligned with organizational commitments to the Sustainable Development Goals (SDGs), especially SDGs 12 and 13 established by the United Nations [91]. Moreover, specific CE practices, such as battery recycling through life-cycle extension and the reuse of materials, play a significant role in reducing the demand for virgin raw materials and limiting environmental degradation [92]. These outcomes contribute directly to improvements in SP among manufacturing firms. Nevertheless, evidence suggests that SP gains may be further amplified when SD acts as a mediating mechanism in the relationship between CE practices and SP, reinforcing the integrative role of sustainability-oriented strategies [24].

Furthermore, the recycling of industrial waste contributes to the mitigation of greenhouse gas and CO_2 emissions by significantly reducing reliance on the extraction and processing of virgin raw materials, which in turn enhances the SP of manufacturing firms [93]. In general, the implementation of CE practices requires lower energy consumption compared to production processes based on primary resources, thereby supporting improvements in SP. However, evidence suggests that these performance gains may be further strengthened when SD is incorporated as a mediating mechanism between CE and SP [83]. At the same time, the relationship between CE and SP is inherently complex; therefore, beyond the environmental and sustainability-related benefits of CE practices, the pursuit of SD objectives should be explicitly considered during their implementation [24,94]. Based on the arguments discussed above, the following research hypothesis is proposed.

H4: Sustainable development mediates the relationship between circular economy practices and sustainable performance in automotive manufacturing firms.

Figure 1, presented below, shows the formulation of the four hypotheses in the research model.

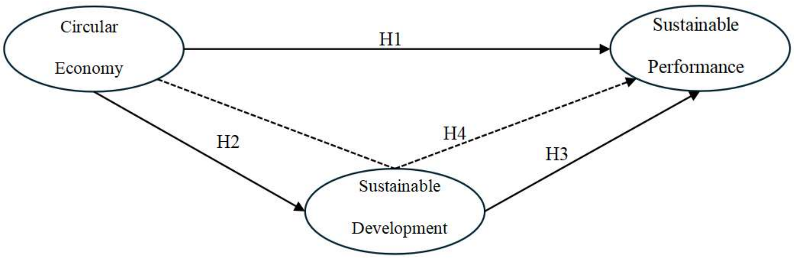

Figure 1. Research model.

3. Results and discussion

3.1. Methodology

The hypotheses proposed in the research model were empirically tested through a study conducted among manufacturing firms in the Mexican automotive industry. In the initial phase, a business panel was convened, involving three academics specializing in sustainability, two public administration officials responsible for corporate financing programs, and five senior managers from automotive manufacturing firms. The insights obtained from this panel informed the development of a structured survey designed to collect data on CE, SP, and SD. Prior to its full deployment, the survey instrument was subjected to a pilot test involving 10 automotive manufacturing firms, which enabled minor refinements related to wording, layout, and clarity. This procedure is considered essential for ensuring instrument validity, particularly in studies employing self-administered questionnaires or researcher-developed measurement scales [95].

3.2. Sample and data collection

Data related to CE practices, SP, and SD were collected through a structured survey administered to manufacturing firms operating in the automotive sector in Mexico. The sampling frame was constructed using the official directory of manufacturing firms registered with the Mexican Association of the Automotive Industry, which listed 916 active companies as of January 2021. This directory was selected as represents the most comprehensive and authoritative registry of automotive manufacturing firms in the country, thereby ensuring adequate sectoral coverage and external validity of the study.

A simple random sampling technique was employed to guarantee that each firm in the population had an equal probability of selection, thus minimizing selection bias and enhancing the representativeness of the sample. Based on the size of the population, a margin of error of ±5% and a confidence level of 95% were established, which are consistent with commonly accepted standards in empirical research within management and sustainability studies. Under these parameters, 600 firms were randomly selected and invited to participate in the survey.

The data collection process was conducted between January and June 2021 and resulted in a final sample of 300 valid and complete responses, corresponding to an overall response rate of 50%. This response rate is considered satisfactory for firm-level survey research and compares favorably with similar empirical studies conducted in the manufacturing and sustainability literature. The sample size achieved also exceeds the minimum requirements for partial least squares structural equation modeling (PLS-SEM), thereby ensuring sufficient statistical power for hypothesis testing and model estimation.

The questionnaires were initially addressed to senior managers, who were asked to forward the survey to the most appropriate functional areas within their organizations. Managers were responsible for identifying respondents with the requisite knowledge and expertise to accurately answer the different sections of the instrument, particularly those related to CE practices, sustainability strategies, and performance outcomes. This procedure was adopted to enhance the accuracy and reliability of the information provided, as it ensured that responses were supplied by individuals directly involved in relevant operational and strategic decision-making processes [96].

To mitigate potential response bias, a standardized protocol was implemented during data collection. All participants were explicitly informed that their responses would be treated as strictly anonymous and confidential, and that there were no correct or incorrect answers. This assurance was intended to reduce the likelihood of socially desirable or strategically biased responses and to encourage candid reporting of organizational practices and outcomes [97,98]. Such procedures are widely recommended in survey-based research to enhance response quality and internal validity.

In addition, the potential presence of common method bias was assessed using Harman’s single-factor test. According to this diagnostic approach, common method variance is unlikely to be a concern if no single factor accounts for more than 50% of the total variance in an exploratory factor analysis [97,98]. The results indicated that the first factor explained less than the recommended threshold (40%), suggesting that common method bias did not pose a significant threat to the validity of the observed relationships among the constructs included in the research model.

3.3. Variables and data analysis

To determine the most suitable measurement instruments for CE, SD, and SP, an extensive review of the relevant literature was conducted. CE was measured using the scale proposed by prior research, which conceptualizes CE through eight items and has demonstrated applicability within the automotive industry context, particularly in Spain [99]. Sustainable development was assessed using a nine-item scale developed by D'Amato, which captures the multidimensional nature of SD [100]. Similarly, sustainable performance was measured using a seven-item scale derived from D'Amato's work [101]. All items across the three constructs were evaluated using a five-point Likert-type scale, ranging from 1 (strongly disagree) to 5 (strongly agree).

To adapt the scale, it was translated into Spanish and presented to 8 academic experts in the subject and the industry. They made suggestions to improve the clarity of the items. Once this process was completed, a pilot test was carried out with 10 companies, which gave positive feedback on the clarity of each item, after which the survey was conducted with the other companies.

Data analysis was conducted using partial least squares structural equation modeling (PLS-SEM) with SmartPLS software version 4.0 [16]. This methodological approach was selected because the study is grounded in a composite-based modeling framework [102,103]. In this research model, composite indicators play a central role in the operationalization of the emergent construct that mediates the proposed relationships [104]. This is particularly relevant given that composite indicators do not incorporate an explicit error term, in contrast to models employing causal formative indicators [105]. Moreover, composite indicators can yield consistent results even when they are not unidimensional or when their components do not share a single conceptual domain, allowing them to capture diverse facets of a given construct [105,106]. Appendix shows the items used in measuring CE, SD, and SP, the results obtained from the application of the PLS-SEM, and it is observed that the factor loadings of all the items of the three measurement scales are higher than the value of 0.6 recommended by Hair [105], which indicates, that the items used to measure CE, SD, and SP are appropriate and the existence of reliability and validity of the scales used.

3.4. Results

The selection of partial least squares structural equation modeling (PLS-SEM) to test the hypotheses proposed in the research model is primarily justified by two fundamental considerations. First, PLS-SEM is particularly suitable for analyzing theoretical frameworks that are still in an early stage of development or have not yet been extensively validated in literature across different fields of knowledge [103, 107–109]. Second, this technique is especially appropriate when the primary objective of the study is the prediction and explanation of the constructs included in the research model [110]. In this regard, PLS-SEM facilitates both the treatment of measurement error associated with latent constructs and the estimation of multiple regression relationships among the composite scores representing CE, SD, and SP practices in manufacturing firms [105].

3.5. Reliability and validity of measurement scales measurement model

The assessment of the reliability and validity of the CE, SD, and SP measurement scales was conducted using Cronbach's alpha, Dijkstra–Henseler's rho, the composite reliability index (CRI), and the average variance extracted (AVE), as reported in **Table 1** (Panel A) [107]. Discriminant validity was examined using both the Fornell–Larcker criterion and the heterotrait–monotrait (HTMT) ratio, as shown in **Table 1** (Panel B) [104]. The results of the PLS-SEM analysis indicate that Cronbach's alpha, Dijkstra–Henseler's rho, and CRI values for all constructs exceed the recommended threshold of 0.70, demonstrating a strong fit between the research model and the observed data [107,111]. In addition, the AVE values are above the minimum recommended level of 0.50, further confirming the convergent validity of the measurement model [111,112].

Table 1. Measurement model. reliability, validity and discriminant validity.

PANEL A. Reliability and validity						
Variables	**Cronbach's Alpha**	**Dijkstra-Henseler rho**		**CRI**		**AVE**
Circular economy	0.947	0.954		0.956		0.729
Sustainable development	0.927	0.938		0.945		0.670
Sustainable performance	0.951	0.954		0.960		0.774
PANEL B. Fornell-Larcker criterion				**Heterotrait–Monotrait ratio (HTMT)**		
Variables	**1**	**2**	**3**	**1**	**2**	**3**
1. Circular economy	**0.854**					
2. Sustainable development	0.470	**0.818**		0.500		
3. Sustainable performance	0.244	0.289	**0.880**	0.253	0.308	

Note: PANEL B: Fornell-Larcker Criterion: Diagonal elements (bold) are the square root of the variance shared between the constructs and their measures (AVE). For discriminant validity, diagonal elements should be larger than off-diagonal elements.

In addition, **Table 1** reports the results of the discriminant validity assessment, which provide empirical support for the adequacy of the measurement instruments and their ability to distinguish among the different constructs included in the model. Specifically, the Fornell–Larcker criterion (Panel B) is satisfied, as the average variance extracted (AVE) values for each construct exceed the squared correlations between all pairs of constructs. Furthermore, the heterotrait–monotrait (HTMT) ratio also confirms discriminant validity, given that the obtained values range between 0.282 and 0.442, which are well below the threshold of 0.85 recommended in the literature [104]. Collectively, these results indicate that both criteria provide consistent evidence of discriminant validity.

Although Cronbach's alpha values for some constructs were relatively high, this result should be interpreted with caution. High alpha coefficients may reflect strong conceptual coherence among indicators rather than item redundancy, particularly when constructs are measured using theoretically grounded and well-established scales. To mitigate the limitations of Cronbach's alpha, composite reliability and convergent and discriminant validity were also assessed. The results confirm the robustness of the measurement model and suggest that the high alpha values do not undermine the validity of the constructs.

3.6. Structural model

Structural equation modeling (SEM) was employed to test the proposed research model due to its ability to simultaneously estimate multiple relationships among latent constructs. Although both covariance-based SEM (CB-SEM) and variance-based SEM are appropriate analytical techniques, this study adopts the variance-based approach using partial least squares structural equation modeling (PLS-SEM). This choice is justified by the primary objective of the research, which focuses on explaining and predicting the relationships between CE, SD, and SP, rather than on the strict confirmation of an established theoretical model.

In addition, the proposed model includes multiple constructs and a mediating relationship, resulting in a level of structural complexity for which PLS-SEM is particularly well suited. Moreover, the use of PLS-SEM is appropriate given the survey-based nature of the data and its robustness to deviations from multivariate normality, which are common in organizational and sustainability research. Finally, PLS-SEM allows for the maximization of explained variance in the endogenous constructs, making it especially suitable for empirical studies that aim to assess predictive relationships in applied manufacturing contexts.

The PLS-SEM results indicate that the estimated model exhibits satisfactory statistical properties. Specifically, the adjusted R^2 values exceed the minimum recommended threshold of 0.10, suggesting adequate explanatory power [107,113]. In addition, the standardized root mean square residual (SRMR), geodesic discrepancy (dG), and unweighted least squares discrepancy (dULS) values are all below the corresponding HI99 benchmarks, indicating an excellent overall model fit [114]. The structural path estimates further reveal that CE practices exert a significant and positive effect on SP ($\beta = 0.143$; $p = 0.028$) and on SD ($\beta = 0.476$; $p < 0.001$). These findings provide empirical support for hypotheses H1 and H2, demonstrating that the adoption of CE practices contributes to improvements in both SP and SD within manufacturing firms. **Table 2** presents these results in a more detailed and systematic manner.

Table 2. Structural equation model.

Paths	**Path (*t*-value; *p*-value)**	**95% Confidence interval**	**f^2**	**Support**
CE → SP (H1)	0.143 (2.196; 0.028)	[0.014–0.260]	0.143	Yes
CE → SD (H2)	0.476 (8.102; 0.000)	[0.342–0.573]	0.476	Yes
SD → SP (H3)	0.225 (3.379; 0.001)	[0.094–0.354]	0.225	Yes
Indirect effects				
CE → SD → SP	0.107 (3.239; 0.001)	[0.047–0.174]	0.156	Yes
Endogenous variable	Adjusted R^2	Model fit	Value	HI99
		SRMR	0.036	0.046
SD	0.228	dULS	0.396	0.622
SP	0.122	dG	0.288	0.433

Note**:** CE: Circular Economy; SD: Sustainable Development; SP: Sustainable Performance. One-tailed t-values and p-values in parentheses; bootstrapping 95% confidence intervals (based on $n = 5000$ subsamples) SRMR: standardized root mean squared residual; dULS: unweighted least squares discrepancy; dG: geodesic discrepancy; HI99: bootstrap-based 99% percentiles.

The results further indicate that SD exerts a positive and statistically significant effect on the SP of manufacturing firms ($\beta = 0.225$; $p = 0.001$), providing empirical support for hypothesis H3. In addition, SD functions as a mediating variable in the relationship between CE practices and SP ($\beta = 0.107$; $p = 0.001$), thereby supporting hypothesis H4. These findings suggest that the adoption of SD initiatives contributes to improvements in SP within manufacturing firms. However, the magnitude of SP improvement is not substantially amplified when SD operates as a mediating mechanism between CE and SP. This result indicates that gains derived from enhanced efficiency and flexibility in production processes, as well as reductions in industrial waste through the adoption of innovative systems, have not yet translated into the expected performance outcomes.

4. Discussion

The results of this study support the proposed argument regarding the existence of a positive relationship between CE practices and the level of SP in manufacturing firms within the automotive industry, and they are consistent with prior empirical findings reported in the literature [45–47]. Several factors may explain this significant association. Although most model fit indices fall within recommended thresholds, some indicators approach borderline values. These results were carefully evaluated and interpreted considering the complexity of the research model and the characteristics of the survey-based data. In line with established guidelines for variance-based SEM, borderline fit values were not considered in isolation but assessed alongside explanatory power, path significance, and predictive relevance. Taken together, these complementary criteria support the robustness of the model and suggest that the observed relationships are substantively meaningful despite minor deviations in certain fit indices.

The findings provide empirical support for the argument that the adoption of CE practices positively drives SD in automotive manufacturing firms. Consistent with prior studies highlighting the need for stronger empirical evidence on the CE–SD relationship [48,58,64], the results suggest that this effect operates through specific operational mechanisms rather than through abstract strategic alignment alone. CE practices promote SD by embedding resource efficiency routines into manufacturing operations, including waste valorization processes, remanufacturing activities, and the recovery of components and raw materials from end-of-life vehicles. These practices not only reduce material intensity and industrial waste but also generate economic value by lowering production costs and extending the productive life of resources. In parallel, increased reliance on renewable energy sources and cleaner production technologies contributes to lower levels of environmental pollution, thereby reinforcing firm-level sustainable development outcomes.

The results also confirm a positive relationship between SD activities and SP, in line with previous empirical findings [78–80]. This relationship can be explained by the role of SD as an enabling capability that translates sustainability-oriented initiatives into measurable performance outcomes. Through the systematic implementation of SD practices, firms develop organizational routines that support emissions reduction, improved resource utilization, and compliance with environmental standards, which in turn enhance operational efficiency, cost control, and long-term competitiveness. In this context, SD functions as a mechanism through which sustainability objectives are operationalized and converted into tangible performance gains.

Finally, the findings indicate that CE practices contribute to improvements in SP primarily when they are implemented in conjunction with SD activities. By integrating recycling, reuse, and product-life extension strategies into broader sustainability frameworks, firms are better able to mitigate greenhouse gas emissions and reduce dependence on virgin raw materials in vehicle manufacturing processes. These results are consistent with prior empirical evidence [83,93] and suggest that CE acts as a central driver of sustainable performance when supported by a coordinated SD orientation. Accordingly, SP and SD outcomes are more effectively achieved when CE initiatives are implemented systematically and aligned with firm-level sustainability strategies, rather than treated as isolated operational interventions [115–118].

Although the findings provide strong empirical support for positive relationships between CE, SD, and SP, prior literature reports mixed and, in some cases, contradictory results. Several studies have documented weak, insignificant, or even negative effects of CE initiatives on firm performance, often attributing these outcomes to high implementation costs, technological limitations, organizational resistance, or misalignment between environmental objectives and short-term economic priorities [119–123].

In this regard, the present results suggest that such inconsistencies may be highly context dependent. In the automotive manufacturing sector—particularly in developing economies—strong regulatory pressures, economies of scale, and accumulated technological capabilities may facilitate the translation of CE practices into tangible sustainability and performance gains [124–126]. Moreover, the findings indicate that positive outcomes are more likely when CE initiatives are embedded within a broader sustainable development orientation, helping to reconcile prior contradictory evidence from studies that examined CE practices in isolation or without considering their integration with firm-level sustainability strategies [127, 128].

From a resource-based view perspective, the findings can be interpreted by conceptualizing CE practices as a bundle of firm-specific resources and capabilities that enable manufacturing firms to reconfigure production processes, manage material flows, and reduce environmental impacts in ways that are difficult for competitors to replicate. Within this framework, SD functions as an enabling dynamic capability that allows firms to integrate, build, and reconfigure these circular capabilities over time in response to environmental pressures and evolving stakeholder demands. By embedding CE practices within a broader sustainable development orientation, firms enhance their ability to translate resource deployment into SP advantages. This interpretation strengthens the coherence of the results with RBV logic by clarifying how CE contribute to SP not merely as isolated operational activities, but as strategically embedded capabilities supported by dynamic sustainability-oriented routines.

4.1. Practical implications

The findings of this study offer relevant practical implications for executives, policymakers, business practitioners, and public administrators in the automotive manufacturing sector. First, the positive effects of CE practices on SP and SD underscore the need for a strategic transition from linear to circular business models aimed at reducing greenhouse gas emissions and industrial waste. For automotive managers, this transition can be operationalized through concrete practices such as product life-cycle extension via remanufacturing and refurbishment, modular vehicle design to facilitate component reuse, and systematic recycling of metals, plastics, and critical raw materials.

Second, firms are encouraged to adopt closed-loop supply chain systems, including take-back programs for end-of-life vehicles, collaboration with certified recyclers, and procurement policies that prioritize recycled content and sustainability criteria. Although the implementation of CE practices may involve initial costs, prior evidence suggests that these investments are generally outweighed by the associated economic, environmental, and performance benefits, particularly in developing economies.

Third, given the strong influence of CE practices on both SP and SD, policymakers and public administration authorities should promote their adoption through targeted incentives, regulatory frameworks, and support programs across the automotive industry. Such policies can contribute to sustainable employment creation, the development of green economic activities, and the long-term sustainability of local communities. Finally, consistent with prior research [115–118], the coordinated implementation of CE and SD practices should be treated as a strategic priority, as their integration can generate positive spillover effects across automotive supply chains, particularly among manufacturing suppliers with significant environmental impacts.

5. Conclusions and future research directions

The findings of this study lead to several key conclusions. First, although the literature has consistently highlighted the importance of adopting CE practices as a means of enhancing SP and SD, the empirical evidence reported to date remains fragmented and inconclusive. Considering this situation, the present study underscores the need to further encourage the scientific and academic community, business leaders, policymakers, and organizational decision-makers to deepen the analysis of the relationships among CE, SP, and SD.

Second, this study contributes to the advancement of knowledge by providing robust empirical evidence demonstrating that the adoption of CE practices has a positive effect on both SP and SD. These findings allow us to conclude that the simultaneous implementation of CE and SD initiatives leads to improved SP within manufacturing firms in the automotive industry. From a policy perspective, the findings are directly aligned with Mexico’s environmental and industrial policy framework. The positive impact of CE practices on SP and SD supports the objectives of the General Law for Waste Prevention and Integrated Management (LGPGIR), which promotes waste reduction, recycling, and extended producer responsibility, particularly in industries with high environmental impact such as automotive manufacturing. Policymakers may therefore leverage these findings to strengthen incentive schemes, regulatory instruments, and public–private collaboration mechanisms aimed at accelerating the adoption of SD within the Mexican automotive industry.

Future studies should consider the integration of the Sustainable Development Goals (SDGs) and the application of green strategies that may further enhance SP in automotive manufacturing firms, as well as the exploration of alternative business models to validate and extend the findings obtained in this study.

Third, while sustainable development is treated in this study primarily as an outcome of circular economy practices, theory also suggests that it may operate as a mediating mechanism linking circular initiatives to broader organizational performance outcomes. Future research could explicitly model sustainable development as a mediator, employing alternative research designs and more granular indicators to explore its dynamic and process-oriented role within sustainability-oriented business strategies.

Finally, this study provides robust evidence of the direct effects of CE practices on SP, and it does not explicitly examine the underlying mechanisms through which these effects occur beyond the aggregate mediating role of SD. Future research could extend this work by exploring additional mediating variables—such as organizational learning, green innovation, digitalization, or stakeholder engagement—to better understand the processes through which CE initiatives generate sustainability-related performance outcomes.

This study is subject to several limitations that should be acknowledged. First, the data are based on self-reported measures collected through a survey, which may be affected by perceptual bias or socially desirable responses, despite the use of anonymity assurances and procedural remedies to reduce response bias. Second, the cross-sectional design of the study limits the ability to draw strong causal inferences and does not capture the dynamic or longitudinal effects of CE practices on SD and SP. Third, this study analyzes the automotive manufacturing sector at an aggregate level and does not differentiate between sub-sectors such as vehicle assembly, auto parts production, or component suppliers. As a result, potential heterogeneity in the adoption and impact of circular economy practices across sub-sectors may not be fully captured.

Author contributions: Conceptualization, RMRG and GMG; methodology, GMG; software, GMG; validation, RMRG; formal analysis, RMRG; investigation, RMRG; resources, GMG; data curation, GMG; writing—original draft preparation, RMRG; writing—review and editing, GMG; visualization, GMG; supervision, GMG; project administration, RMRG; funding acquisition, GMG. All authors have read and agreed to the published version of the manuscript.

Funding: None.

Conflict of interest: The authors declare no conflict of interest.

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Appendix

Table A1. Measurement model assessment.

Indicators	Constructs	Factor Loads (*p*-value)
Circular Economy (CE) Cronbach's Alpha: 0.947; Dijkstra–Henseler's rho (ρA): 0.954; CRI (ρc): 0.956; AVE: 0.729		
CE1	The firm regularly applies environmental criteria in the purchasing events and selection of suppliers.	0.775 (0.000)
CE2	The firm has established environmental criteria to reduce the consumption of raw materials, water or energy in the design and production of its products.	0.825 (0.000)
CE3	The firm regularly uses components or raw materials in the production of its products that are biodegradable.	0.860 (0.000)
CE4	Some of the components or raw materials used in the production of the products are reused, recycled or remanufactured.	0.863 (0.000)
CE5	The firm regularly uses renewable energy for the recovery and use of waste	0.883 (0.000)
CE6	The firm regularly uses some treatments (filtration, etc.), to expand the use of industrial resources such as oils, acids, lubricants, etc.	0.886 (0.000)
CE7	The company regularly recovers the products that its customers no longer use	0.884 (0.000)
CE8	The company regularly sells waste and industrial materials that it no longer uses (chemicals, oils, packaging, plastics, etc.).	0.849 (0.000)
Sustainable Development (SD) Cronbach's Alpha: 0.927; Dijkstra–Henseler's rho (ρA): 0.938; CRI (ρc): 0.945; AVE: 0.670		
SD1	Expand the economy's productive potential	0.837 (0.000)
SD2	Foster economic growth to facilitate satisfaction of basic needs	0.829 (0.000)
SD3	Decouple economic growth and material consumption	0.833 (0.000)
SD4	Stabilize the economy's productive potential	0.878 (0.000)
SD5	Stabilize economic growth to safeguard ecological thresholds while redistributing Access.	0.871 (0.000)
SD6	Decouple economic growth and material consumption while taking rebound effects into account.	0.892 (0.000)
SD7	Limit and transform the economy's productive potential	0.893 (0.000)
SD8	Downscale economic growth while reducing inequalities and exploitation	0.875 (0.000)
SD9	Dematerialize society and economy through emphasizing the role of sufficiency, happiness, and equity.	0.639 (0.000)
Sustainable Performance (SP) Cronbach's Alpha: 0.951; Dijkstra–Henseler's rho (ρA): 0.954; CRI (ρc): 0.960; AVE: 0.774		
SP1	The company's activities enable the transition to a low-carbon economy	0.851 (0.000)
SP2	The company's activities protect and/or restore the environment by focusing on environmental quality aspects and improving resource efficiency.	0.867 (0.000)
SP3	The company's activities help maintain, protect, transform, and/or strengthen the economy.	0.869 (0.000)
SP4	The company's activities help to protect, transform, strengthen, and/or develop society, human well-being, and/or employment.	0.883 (0.000)
SP5	During the last 3 years, the company has invested in the integration of environmentally friendly technology to improve business activities.	0.885 (0.000)
SP6	The integration of sustainable policies in the company's activities has achieved a reduction in operating and/or production costs.	0.913 (0.000)
SP7	The integration of sustainable policies in the company's activities has had a positive effect on recorded profits.	0.889 (0.000)