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-RESEARCH ARTICLE-

THE ROLE OF ENVIRONMENTAL COSTS ANALYSIS IN ACHIEVING SUSTAINABLE DEVELOPMENT: COMPETITIVE ADVANTAGE AS A MEDIATING VARIABLE

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─Abstract─

This paper has attempted to investigate how much of the EC can be used to fulfill the SD requirements in its social, environmental, and economic dimensions, considering

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CA as the intervening variable. The data have been collected through the application of questionnaire to six persons in ten industrial companies listed in Iraq Stock Exchange. The selected companies were chosen considering their need to reflect the sustainability reporting effects in their disclosures, as well as their environmental impacts related to the purpose of the study. The EC have been measured based on the indicators like prevention, appraisal, internal failure, external failure and EC intensity. SD has been analyzed on its social, environmental, and economic dimensions. In addition, the CA has been investigated as an intervening variable on its cost, profitability, differentiation, productivity, market share, and differentiation dimensions. The research results have revealed the fact that the EC can play an important role to support the fulfillment of the SD requirements, showing statistical significant effects on its social, environmental, and economic dimensions. While the amount of these effects on each dimension was different, the most significant effect was found to be in the social dimension. Furthermore, the results showed that the CA can mediate the relationship between the EC and the SD requirements; this gives interesting managerial implications for the industrial companies. Considering the environmental context in which many challenges appear, for example in Iraq, the inclusion of CA into the relationship makes the positioning of the companies as companies fulfilling the requirements of sustainability more likely.

Keywords: Sustainable Development, Environmental Costs, Competitive Advantage, Social Dimension, Environmental Dimension, Economic Dimension.

INTRODUCTION

In today's global environment, sustainability has turned out to be one of the key strategic factors that have to be taken into account by organisations. Assessments of the performance of the company are made not only on the basis of the profit obtained but increasingly include social responsibility of companies and consequences caused by activities of organisations for the environment (Fahmie et al., 2025). Due to the increasing problem of climate change, natural resources scarcity, and environmental degradation, the principle of sustainability development (SD) has been incorporated into the strategies of many companies. It is viewed as one of the main prerequisites for the survival and further growth of organisations in a complex and ever-changing environment.

There is also the growing pressure on industrial firms from government, investors and society to use environmentally friendly practices. The implementation of stricter rules of regulations and development of international standards causes the additional increase in environmental costs (EC) incurred by companies. They include activities associated with the prevention of pollution, waste management, and carbon emission treatment (Gupta, 2025). Therefore, EC constitutes a large component of the activity of any organisation since it affects the profitability and the competitiveness of companies.

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Thus, it became crucial to identify EC and understand its components since it became necessary not only for accountants but managers as well.

Nevertheless, conventional methods of accounting often show certain difficulties in identifying EC. These costs might be simply counted as additional operating costs or remain unaccounted, thus, causing incomplete and distorted information for managerial decisions making. In this regard, environmental cost accounting and systematic analysis of EC give the tools for identification, measurement, and allocation of the environmental costs associated with the production process. This helps to improve efficiency of resource utilization and waste reduction. The importance of cost accounting (CA) as the mediator tool consists in the explanation of how the outcomes obtained from EC analysis are transformed into sustainable organizational performance. Effective identification and analysis of EC might help to develop environmentally friendly products and encourage reduction of energy usage. Thus, it might improve CA while simultaneously promoting long-term financial and environmental sustainability. Moreover, incorporation of suppliers and customers in green supply chain can help to reduce unnecessary environmental costs and thus improve the organizational performance (Wong et al., 2020).

However, despite the growing importance of these variables, previous research does not pay enough attention to the relationship between EC analysis and the requirements of SD when CA is used as a mediator. This question is especially topical for the industrial sector as this sector has a great environmental impact and is quite vulnerable to environmental pressures (Santoso, 2025). This problem is especially difficult to implement in developing countries due to lack of specialized knowledge in environmental accounting and the absence of harmonized standards for the environmental accounting (Nguyen et al., 2024). Moreover, evidence from listed firms shows that sustainability committee and environmental performance jointly affect the disclosure of environmental costs (Budianto et al., 2025).

In this regard, the present study focuses on the case of industrial companies in Iraq where there is a problem of insufficient disclosure of the environmental information despite the necessity to inform the stakeholders about the environmental consequences of organisational activities. From the point of view of resource-based theory, environmental practices can be considered unique strategic resources that are able to contribute to the organizational value. Therefore, the aim of this study is to examine the role of EC in meeting the economic, social and environmental aspects of SD and to find out whether CA mediates this relationship. The main purpose of this study is to understand how these relationships can promote the success and sustainability of the industrial firms in today's environment.

This research is important for the field of managerial and accounting thought in the industrial environment. It is aimed at creating a framework for organisational decision-

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making that will help the company's managers to understand that the expenditure on environmental activities cannot be considered simply as a cost but as a strategic investment that increases the efficiency of the operations of the firm, strengthens the position of the investors, makes organizations competitive and contributes to comprehensive sustainability. Thus, environmental expenditure might bring benefits to the organization if managed strategically.

In order to fill this research gap, the following research question was developed: how does environmental cost management contribute effectively to the improvement of CA and meeting the SD objectives in industrial firms? The study will employ the quantitative research approach to investigate the relationships among the examined variables using the data from the group of industrial companies. Systematic methodology will be applied in order to ensure the reliability of the results with the use of statistical analysis of the gathered data. The structure of this study includes the following sections: literature review and hypotheses, methodology, presentation and discussion of the findings, conclusions.

LITERATURE REVIEW

Environmental Costs and Sustainable Development

The impact of the environmental cost on sustainable development goals has been studied by Kinyondo and Huggins (2021). According to the research results, environmental cost accounting contributes to enhanced resource efficiency and waste minimization. The mentioned results have special relevance to SDG 12, Responsible Consumption and Production, and SDG 13, Climate Action. The authors have also claimed that it was impossible to achieve SDG without using environmental strategies within organizations' activities as well as superficial enforcement of laws and regulations. In this way, it will be possible to create the necessary outcomes in order to protect the interests of future generations.

Methodologies for measuring environmental cost (EC) within the sustainability accounting framework have been explored by Sultan (2024). According to their findings, it is possible to achieve an approximately 25% improvement in environmental performance and approximately 30% improvement in institutional transparency due to EC inclusion in financial reporting. In this way, accurate EC disclosure will make it possible to improve managerial decision-making and serve as the necessary basis for actions related to sustainability. In a similar manner, Khatoon (2025) studied the correlation between EC and SD. According to their findings, EC identification and evaluation help firms predict and prevent future risks including resource depletion. In this way, EC will no longer be considered as financial burden but the CA source for sustainable growth of society.

Environmental expenditure and SD have been explored by May et al. (2023) in the study

focused on Materials Flow Cost Accounting (MFCA). As a result, it was found that MFCA helps companies to identify financial implications of their activities as well as reduce material and energy losses. These reductions help to enhance the environmental balance and thus promote SD. Faieq and Cek (2024) also examined the contribution of environmental accounting to enhancement of SD in industrial companies. According to their results, it is possible to achieve the necessary managerial decisions to use resources efficiently and minimize pollution. It leads to the promotion of economic and social aspects of SD and creation of CA due to higher product quality and lower expenses resulting from resource inefficiency.

Environmental accounting in the context of waste management has been studied by Mustika et al. (2023). As a result, it was found that the explicit identification of internal environmental failure costs and environment-related equipment maintenance costs helps to reinforce corporate social responsibility. At the same time, the transparent presentation of these costs gives the possibility to evaluate organization's commitment to SD from different perspectives. Environmental accounting as the strategy for EC and energy flows examination has been characterized by Maione et al. (2023). They found that environmental accounting helps to connect economic and social aspects of organizational activity. Identification of hidden costs gives the possibility to allocate resources for more environmentally responsible activities and thus create sustainable CA. The complex interaction between economic growth and sustainability has been studied by Anwarya (2022). According to the research results, higher expenditure on environmental protection helps to reduce the negative effect of economic growth on carbon emissions. Thus, it becomes clear that green financial policies are relevant for keeping environmental balance in the long term. The correlation between environmental performance of economic entities (in terms of pollution charges) and SD costs has been investigated by Bassetti et al. (2021). They found that the management of these costs is able to send positive signals to the lenders and thus lead to lower financing costs. In this way, investment in EC not only leads to the environmental benefit but also financial benefits.

The impact of environmental policies on greenhouse gas emission reduction and renewable energy consumption as the parts of sustainability has been evaluated by Li et al. (2022). According to their findings, the strictness of environmental policies helps to increase the speed of transition to the usage of clean energy and improve environmental quality. It creates a direct connection between the environmental management and ability of organizations to meet SD requirements in the long term. In turn, Chi et al. (2022) have studied the Emission Trading System (ETS) as the tool to achieve SD goals. It includes the identification and allocation of EC in different economic sectors. They found that the use of efficient pricing tools helps to allocate EC accurately and minimize economic losses. The research emphasizes the importance of combining the tools of environmental policy and financial management in order to

incentivize investments in environmentally friendly technologies. It helps to achieve international sustainability goals through reduction of social and EC.

Environmental Costs, Sustainable Development, Competitive Advantage

Saputra et al. (2023) proposed a conceptual framework according to which environmental accounting and, particularly, EC and their corresponding benefits are mediators connecting CA with SD. According to the results of analysis of the responses of 287 general managers, CA became recognized as a main determinant of SD. The results revealed that the use of environmental cost accounting motivates managers to apply sustainable practices which could help in finding the balance between environmental protection and economic development. Specifically, the authors argued that CA can promote the improvement of the mechanisms of environmental accounting that, in its turn, will increase the sustainable performance of firms. Al-Kahtani (2024) explored the relationships between corporate environmental responsibility, environmental strategy, and CA and the mediating role of environmental innovation in major industrial companies. It was found out that organizations responsible for environmental issues and able to integrate the idea of environment-friendly approach into their strategy could develop CA through cost reduction and creation of eco-friendly products. It was also stated that green innovation adoption was associated with high competitiveness of organizations showing how the management of environmental resources could lead to the accomplishment of long-term SD goals.

Shibin et al. (2020) explored the contribution of SD practices to the formation of the resource-based CA in SMEs. As a result, the research showed that the integration of SD programs into the main operations of organizations could help in increasing the efficiency and decrease the costs caused by resource wastage. Consequently, such changes could be used to develop a distinctive corporate reputation that would be difficult to replicate for competitors and which would become a part of CA. Sustainability was discussed by the authors not as a moral duty but as a strategic approach which could be applied in order to obtain the economic benefit and build loyal customers' base. Ayinla (2024) conducted the review of the inclusion of EC in the financial reports within the scope of SD. It was concluded that there is a shift from the peripheral treatment of the environmental issues to the consideration of EC as the main strategic issue. According to the authors, the recognition of EC as strategic investments and not merely the burden will help in increasing the CA. Greater transparency in this case allows making closer ties between the operations of organizations and SD goals and, at the same time, improving the perceptions of corporations among investors that, in its turn, could improve the market value and operational sustainability in competitive business environment. Azeem et al. (2025) studied the contribution of EC and environmental awareness to the environmental and financial performance of manufacturing companies where CA was considered as the mediator. The results have shown that proactive environmental strategy positively influences the CA and helps to

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provide companies with the unique market position. In its turn, CA is a link between the environmental commitments of firms and sustainable financial results.

Rohendi et al. (2024) focused on the relationship between social and EC disclosure and the company value where CA was considered as the mediator variable. According to the results of statistical analysis, it was stated that the disclosure of information about the management of EC and corporate environmental responsibilities was associated not only with the increase of company value but also with the formation of CA due to the improvement of the resource utilization efficiency and the confidence of stakeholders. Rolando (2024) explored the influence of green transformation and green business integration models on the implementation of environmental and technological projects aimed at the fulfillment of SD requirements. As a result, it was found out that the sharing and integration of resources and knowledge by manufacturing-industry partners could lead to the creation of CA and additional value of organization. Such approaches increased the efficiency of resource utilization and the allocation of EC associated with green innovations. Practically, it related to the growth of profits and assets and reduction of the number of emissions. Baquero (2024) studied the mediation of green innovation and EC in the achievement of sustainable CA. It was found out that companies which adopted green innovations to increase their environmental performance were more likely to develop sustainable CA. The solution of environmental problems, especially, through the reduction of the emission and energy consumption, provides the opportunity for the marketing of environmentally friendly products with high profit margin. Such practices could improve the brand recognition and competitiveness, helping the organization to develop sustainably.

Putri et al. (2021) explored the consideration of EC and their implications for the financial information and sustainability performance assessment of organizations. Special attention was paid to the identification, measurement, and disclosure of the costs associated with the treatment of the wastes. It was concluded that the recognition of the costs and their incorporation in the production costs is one of the important elements of effective environmental management. The greater visibility of the costs will help to improve the sustainability performance by providing the management of the organization with the better understanding of the EC hidden in conventional accounting systems. Afiat et al. (2023) explored the interaction between the environmental and financial costs in the context of sustainable business models in the energy industry. It was found out that the alignment of environmental and financial objectives within the single strategy could promote competitive profitability and decrease the negative environmental impacts. It was stressed that it was crucial to adopt sustainable practices, including the use of clean technologies and the assessment of the costs associated with the emission. In this way, it will be possible to pursue financial prosperity while performing the environmental responsibilities transforming sustainability from the mandatory requirement to the proactive business strategy which allows obtaining long-term added value.

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Safutra Sianipar et al. (2023) conducted a comprehensive literature review to explore the influence of the environmental cost accounting on the firm value. According to the results of the analysis, the treatment of EC as the strategic investments rather than the ordinary operating expenditures could help to increase the value of organizations. Such firms allocating the resources to manage the impacts on the environment and discloses this information will be better positioned to align their strategies with the goals of SD. Such alignment could help to generate value for the firms and society at large creating the CA based on the confidence of investors in the ability of the organizations to manage the environmental risks.

Taken together, the findings of the reviewed studies demonstrate the increasingly interconnected nature of EC, SD, environmental management, and CA. The literature generally indicates that systematic identification, measurement, disclosure, and management of EC can extend beyond environmental benefits by improving resource efficiency, operational performance, corporate value, stakeholder confidence, and market competitiveness. At the same time, the reviewed evidence suggests that CA can function as an important mechanism through which environmental practices and EC management are translated into broader sustainable outcomes. Nevertheless, the existing literature does not fully establish how EC management contributes to the achievement of the different dimensions of SD through CA, particularly within industrial companies. Based on the preceding literature and the findings reported in these studies, the following hypotheses are therefore proposed:

Hypothesis: *There is a statistically significant effect of environmental cost analysis on the fulfilment of SD dimensions in industrial companies.*
Hypothesis: *There is a statistically significant effect of environmental cost analysis on the enhancement of CA in industrial companies.*
Hypothesis: *There is a statistically significant effect of CA on the achievement of the SD dimensions within industrial companies.*
Hypothesis: *CA, as a mediating variable, takes part in the enhancement of the impact of environmental cost analysis on the SD dimensions in industrial companies.*

RESEARCH METHODOLOGY

Sample of the Study

The study population comprised industrial companies listed on the Iraqi Stock Exchange. From this population, ten companies were purposively selected, and a total of 60 employees were recruited from the selected companies. The sampling process was based on specific eligibility criteria established to enhance the reliability and relevance of the findings. First, each selected company was required to publish annual reports or sustainability reports and to provide clear disclosure of its EC within its financial statements or accompanying notes. Such disclosure could relate to prevention costs,

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assessment costs, or failure costs. Second, the companies were required to undertake industrial activities associated with a substantial environmental impact, thereby ensuring that the analysis of EC was relevant to their operational context. Companies that failed to satisfy these requirements were excluded from the study. This included organisations that did not provide the required environmental cost disclosures as well as companies experiencing prolonged operational interruptions. Following the application of these criteria, ten companies were retained as the final study sample. The selected companies represented a range of industrial activities, including the chemical, textile, and construction industries.

Variable Measuring

The existing research makes use of an integrated framework, with the following three main variables. Such a research framework has been developed to measure the degree to which EC analysis impacts the achievement of SD, and to find out whether there is any mediating effect of CA in the relationship between the mentioned variables. Variable operationalization is carried out in order to guarantee the validity and accuracy of further statistical analysis, while keeping in mind the coherence between the concepts used and real life of companies.

Environmental Costs

Environmental cost (EC) is defined as the economic responsibilities that are created by industries in terms of environmental protection, control, or correction of the environmental impact of their business operations. In the current research, EC is conceptualized using five major indicators that categorize these costs in terms of their purposes and effects on organizational performance. The mentioned indicators comprise environmental prevention costs, environmental evaluation costs, internal environmental failure costs, external environmental failure costs, and EC intensity (Mustika et al., 2023).

Sustainable Development

In the industrial setting, sustainable development (SD) can be described as the ability of the organization to achieve economic development alongside meeting its environmental and social obligations, thus ensuring sustainability. In this paper, sustainable development is operationalized using three core components namely economic, environmental and social (Fahmie et al., 2025; Justita & Riyanto, 2022).

Competitive Advantage

Competitive advantage (CA) refers to how much an industry-based company can achieve superiority through cost-effectiveness, profitability, productivity, market presence, and innovation. It involves the capability of an organization to improve its market position through creating competitive advantages that distinguish its

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performance from the performance of its competitors. Competitive advantage, in the current research, is measured based on five dimensions, namely cost advantage, profitability advantage, productivity advantage, market share advantage, and innovation/differentiation advantage (Linh, 2024; Nguyen et al., 2024).

RESULTS

Testing Model Validity

Several statistical techniques were applied to assess the adequacy and quality of the measurement model. The evaluation focused on establishing the internal consistency and convergent validity of the study constructs, namely the economic, environmental, and social dimensions, together with CA and EC. To evaluate these measurement properties, Cronbach's alpha, composite reliability, rho_A, and average variance extracted (AVE) were employed.

Table 1: Construct Reliability and Convergent Validity of the Measurement Model

Construct	Cronbach's α	rho_A	Composite Reliability	AVE
Economic Dimension	0.756	0.761	0.859	0.670
Environmental Dimension	0.486	0.507	0.719	0.473
Social Dimension	0.783	0.827	0.873	0.697
Competitive Advantage (CA)	0.811	0.841	0.869	0.573
Environmental Costs (EC)	**0.826**	**0.842**	**0.877**	**0.591**

Note: AVE = Average Variance Extracted. Thresholds: α and composite reliability ≥ 0.70; AVE ≥ 0.50. The environmental dimension falls below threshold on α, rho_A and AVE; see Section 4.1.

As seen in Table 1, the Cronbach's alpha coefficients of the study variables vary between 0.486 and 0.826. The coefficient for the economic dimension is 0.756, while the respective coefficients for the social dimension, CA, and EC are 0.783, 0.811, and 0.826. The mentioned above values exceed the accepted threshold of 0.70, which means that there is adequate internal consistency across the measurement indicators for the mentioned above constructs. Meanwhile, the environmental dimension showed the following value – 0.486. This low value indicates insufficient internal consistency across the measurement indicators of this construct when measured by the means of Cronbach's alpha.

However, Cronbach's alpha is not the only criterion that can be applied when assessing the reliability of the constructs used in structural equation modelling through PLS. Due to the fact that Cronbach's alpha can give a conservative estimate of internal consistency, other criteria should also be taken into account, specifically, rho_A and composite reliability coefficients. The values of rho_A vary between 0.507 and 0.842. To be more precise, the coefficient for the economic dimension is 0.761, while for the social dimension, CA, and EC the respective coefficients are 0.827, 0.841, and 0.842. These values indicate an acceptable level of internal reliability for the mentioned above

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constructs. At the same time, the coefficient for the environmental dimension is 0.507, which signals about relatively poor internal consistency of the mentioned above construct's indicators.

The results concerning composite reliability are more positive. The values vary from 0.719 to 0.877, while the coefficient for the economic dimension is 0.859, the coefficient for the environmental dimension is 0.719, for the social dimension – 0.873, for CA – 0.869, and for EC – 0.877. It should be noted that all coefficients exceed the accepted threshold of 0.70. It means that the composite reliability results show an acceptable level of internal reliability across all study variables, including the environmental dimension. The convergent validity was then assessed by means of average variance extracted (AVE), which is the proportion of the variance of the measurement indicators accounted for by the respective construct. As a result, the AVE values are 0.670 for the economic dimension, 0.697 for the social dimension, 0.573 for CA, and 0.591 for EC. Each of these values exceeds the accepted threshold of 0.50, which means that convergent validity was proven for these constructs.

However, the AVE value for the environmental dimension is 0.473 and is slightly below the 0.50 threshold. Hence, according to the conventional criterion, the environmental dimension does not fully meet the criterion of convergent validity. However, the deviation from the threshold is rather small, besides, the composite reliability of 0.719 for the environmental dimension is within the acceptable range. Hence, the result in itself does not mean that the environmental dimension should be excluded immediately. On the contrary, the indicators constituting the environmental dimension require additional analysis to check if any item affects the result significantly.

Overall, the results of the analysis of the measurement model indicate that the majority of constructs demonstrate sufficient reliability and convergent validity. However, the environmental dimension requires additional analysis before making the conclusion about the possible exclusion of the second indicator, which outer loading is below 0.70. Figure 1 shows the measurement model together with the outer loadings of all measurement indicators and coefficient of determination (R^2) for each endogenous construct. As one can see from Figure 1, the values of R^2 indicate the extent to which the model's explanatory variables explain the variation in the endogenous constructs. For CA, R^2 is 0.277, which means that EC explains 27.7% of the variance of CA, while 72.3% is explained by other factors that are not included into the model.

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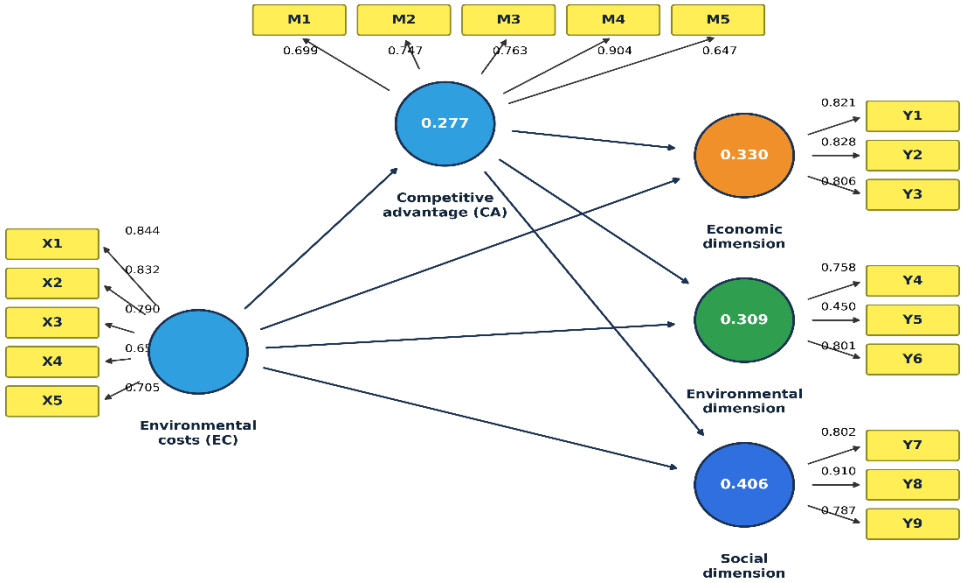


Figure 1: Measurement Model with Outer Loadings and Coefficients of Determination

Regarding the economic dimension of SD, the coefficient of determination was 0.330, which means that the specified model variables explained 33.0% of the variance of the economic dimension, while the rest 67.0% is caused by other factors that are not considered in the model. Similarly, the environmental dimension provided R^2=0.309, which means that the model variables explained 30.9% of the variance of the environmental dimension and the rest 69.1% is caused by other determinants not included in the model. The highest coefficient of determination among all SD dimensions is the one of the social dimensions, and it equals 0.406. It means that the variables included in the model explained 40.6% of the variance of the social dimension, while the rest 59.4% might be due to other factors not considered in the model. In general, the R^2 values varied between 0.277 and 0.406, and they mean that the model has acceptable explanatory power.

The comparison of the coefficients showed that the highest explanatory power of the model has been provided for the social dimension, then comes the economic dimension and the least explanatory power is for the environmental dimension. The lowest R^2 among the endogenous constructs belongs to the CA. Despite the acceptable explanatory power, some unexplained variance shows that there might be some other determinants of the model variables, and they might be financial, operational, administrative, and environmental related to the characteristics and actions of industrial companies.

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Testing the Relationship among Variables

Direct Effects

Table 2 presents the results of the structural path analysis and the statistical significance of the hypothesised relationships among CA, EC, and the three dimensions of SD. The findings for each structural path are discussed below. For the path from CA to the economic dimension (CA → economic dimension), the T-statistic was 1.349, with a P-value of 0.178. Since the P-value exceeds the significance threshold of 0.05, the relationship between CA and the economic dimension is not statistically significant. Thus, the results do not provide sufficient statistical evidence to conclude that variations in CA are associated with significant changes in the economic dimension of SD among the companies under study. Accordingly, the hypothesis proposing a significant effect of CA on the economic dimension is not statistically supported. For the relationship between CA and the environmental dimension (CA → environmental dimension), the T-statistic was 1.517 and the P-value was 0.130. As the P-value is greater than 0.05, this path does not reach statistical significance. The findings therefore indicate that CA does not have a statistically significant effect on the environmental performance of the companies examined. Consequently, the hypothesis proposing a significant relationship between CA and the environmental dimension is not supported statistically.

In contrast, the path from CA to the social dimension (CA → social dimension) produced a T-statistic of 2.367 and a P-value of 0.018. Because the P-value is below the 0.05 significance level, the relationship is statistically significant. This finding demonstrates that CA has a statistically significant effect on the social dimension of SD. Hence, changes in CA are significantly associated with variations in the social dimension among the companies included in the study. The hypothesis proposing a significant effect of CA on the social dimension is therefore statistically supported. Regarding the relationship between EC and the economic dimension (EC → economic dimension), the analysis produced a T-statistic of 2.049 and a P-value of 0.041. Since the P-value is below 0.05, the path is statistically significant. The results consequently demonstrate a significant effect of EC on the economic dimension of SD. This finding suggests that greater attention to the identification, measurement, and analysis of EC is associated with changes in the economic performance indicators of the companies under investigation. Accordingly, the hypothesis proposing a significant effect of EC on the economic dimension is statistically supported.

The path from EC to the environmental dimension (EC → environmental dimension) yielded a T-statistic of 2.496 and a P-value of 0.013. The P-value is below the 0.05 significance threshold, confirming that the relationship is statistically significant. The findings therefore indicate that EC have a significant effect on the environmental dimension of SD. One possible interpretation is that systematic management and analysis of costs associated with environmental activities can contribute to improving

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environmental practices and outcomes within industrial companies. Accordingly, the hypothesis proposing a significant effect of EC on the environmental dimension is statistically supported. Similarly, the relationship between EC and the social dimension (EC → social dimension) was statistically significant, with a T-statistic of 2.821 and a P-value of 0.005. As the P-value is below 0.05, the results provide evidence of a significant effect of EC on the social dimension of SD. This relationship may be associated with the role of EC management in addressing the environmental consequences of industrial activities, which can, in turn, support social responsibility practices and greater attention to employees and surrounding communities. Therefore, the hypothesis proposing a significant effect of EC on the social dimension is statistically supported. Finally, the path from EC to CA (EC → CA) recorded a T-statistic of 3.832 and a P-value of 0.000. The T-statistic for this relationship was the highest among all paths reported in Table 2. Given that the P-value is below the 0.05 significance threshold, the relationship between EC and CA is statistically significant. The findings consequently demonstrate that EC have a significant effect on CA among the companies examined. This result suggests that the systematic analysis and management of EC can contribute to more efficient resource utilisation, lower levels of waste, and enhanced competitive capability. Thus, the hypothesis proposing a significant effect of EC on CA is statistically supported.

Table 2: Direct Effects of the Structural Model

Path	β	t	p	Decision
CA → Economic Dimension	0.265	1.349	.178	Not Supported
CA → Environmental Dimension	0.286	1.517	.130	Not Supported
CA → Social Dimension	0.325	2.367	.018	Supported
EC → Economic Dimension	0.389	2.049	.041	Supported
EC → Environmental Dimension	0.349	2.496	.013	Supported
EC → Social Dimension	0.404	2.821	.005	Supported
EC → CA	**0.526**	**3.832**	**< .001**	**Supported**

Note: β = Standardised Path Coefficient, obtained from the structural model reported in Figure 2. Significance assessed at $p < .05$.

Indirect Effects

Table 3 reports the results of the indirect-effect analysis examining whether CA mediates the relationships between EC and the three dimensions of SD. For the first mediation path (EC → CA → economic dimension), the T-statistic was 1.034, with a P-value of 0.302. As the P-value exceeds the 0.05 significance threshold, the indirect effect of EC on the economic dimension through CA is not statistically significant. Accordingly, the findings provide insufficient statistical evidence to establish a mediating role for CA in the relationship between EC and the economic dimension.

The second mediation path, represented by EC → CA → environmental dimension, produced a T-statistic of 1.289 and a P-value of 0.198. Since the P-value is greater than

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0.05, the indirect effect of EC on the environmental dimension through CA is not statistically significant. Thus, the results do not provide statistically significant evidence that CA mediates the relationship between EC and the environmental dimension. For the third mediation relationship (EC → CA → social dimension), the analysis yielded a T-statistic of 1.542 and a P-value of 0.124. Again, the P-value exceeds the 0.05 significance level, indicating that the indirect effect of EC on the social dimension through CA is statistically insignificant. Therefore, there is no sufficient statistical evidence to confirm that CA mediates the relationship between EC and the social dimension. Taken together, none of the three indirect paths achieves statistical significance. Consequently, the hypothesis proposing that CA mediates the relationship between EC and SD is not statistically supported. These findings also emphasise the need to distinguish between direct and indirect effects when assessing the role of CA within the proposed model. Although EC demonstrated significant direct relationships with the SD dimensions, the absence of significant indirect effects through CA suggests that achieving SD through EC management may depend on additional intermediary mechanisms. Potential mechanisms for further investigation include environmental innovation, operational efficiency, and organisational reputation.

Table 3: Indirect (Mediating) Effects of Competitive Advantage

Path	β (Indirect)	t	p	Mediation
EC → CA → Economic Dimension	0.139	1.034	.302	Not Supported
EC → CA → Environmental Dimension	0.150	1.289	.198	Not Supported
EC → CA → Social Dimension	**0.171**	**1.542**	**.124**	**Not Supported**

Note: Indirect β computed as the product of the constituent direct paths reported in Table 2 (e.g., 0.526 × 0.265 = 0.139). No indirect path reaches significance at $p < .05$.

To provide an overall assessment of the structural model, Table 4 presents the proportion of variance explained for each endogenous construct, together with the decomposition of the total effect of EC on the social dimension. The social dimension is the only SD dimension for which CA demonstrates a statistically significant direct effect.

Table 4: Derived Model Assessment Statistics

Statistic	Symbol	Value	Interpretation
Explained Variance, CA	R^2	0.277	Weak to Moderate
Explained Variance, Economic Dimension	R^2	0.330	Moderate
Explained Variance, Environmental Dimension	R^2	0.309	Moderate
Explained Variance, Social Dimension	R^2	0.406	Moderate; Highest in Model
Total Effect, EC → Social Dimension	c	0.575	Direct 0.404 + Indirect 0.171
Share of Total Effect Mediated	**VAF**	**29.7%**	**Below 20–80% Band; No Mediation**

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Figure 2 illustrates the structural model, presenting the standardised path coefficients alongside their corresponding p-values.

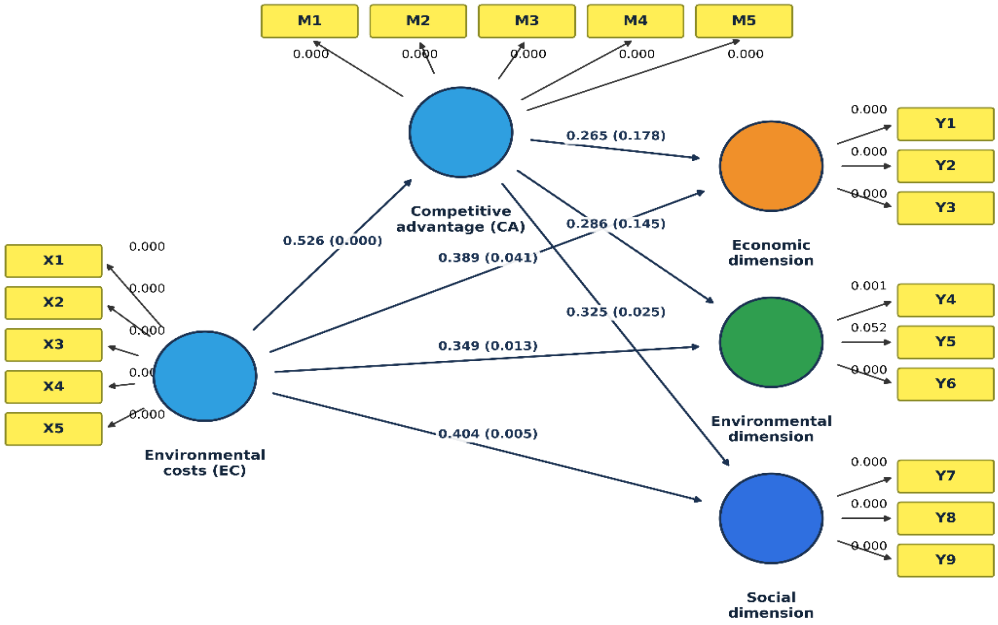


Figure 2: Structural Model of Environmental Costs and Sustainable Development with Competitive Advantage as Mediator

CONCLUSION

The research results revealed that EC positively influences the process of SD and produces considerable impacts in terms of economic, environmental and social dimensions. Measuring and analyzing EC is possible for industrial enterprises that allows detecting the amount of environmental expenses, improving resource utilization and lowering the amount of waste and environmentally related costs in order to ensure sustainable performance. Moreover, EC have considerable impacts on CA that is positively influenced due to the implementation of effective management of environmental activities. Such impacts include improvements in operational efficiency, lower waste and environmentally related costs, better reputation of the enterprise among its customers and community. The influence of CA on SD is different depending on the dimensions. CA produces no considerable impacts on economic or environmental dimension but influences social one considerably. It means that CA is not always able to enhance all the aspects of sustainable development, although the improvement in such aspect as organizational continuity, relations with employees and community, and social responsibility are possible. In general, the findings of the research confirm that EC is a vital tool for ensuring SD and CA. The research results proved that there was a difference in the relationship between CA and SD in terms of three dimensions that confirms the necessity of evaluation of SD in terms of economic, environmental and

social dimensions. Finally, the mediation analysis showed that CA did not mediate the relationship between EC and SD dimensions. Despite the significant impacts of EC on CA and SD, the impacts of EC on SD via CA were insignificant.

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