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# Circular Economy and Sustainability in Information Systems: Criteria and Fuzzy AHP Analysis

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**Abstract.** This paper presents a multidimensional framework for evaluating the role of information systems in supporting circular economy principles, with a particular emphasis on sustainability, transparency, resource efficiency, and economic viability. Unlike previous studies that address these aspects in isolation and lack a comprehensive evaluation approach, this research integrates key criteria into a unified model, enabling systematic comparison and ranking of digital sustainability solutions. The framework is built upon six core groups of criteria: environmental sustainability, digital support for circular practices, resource efficiency, transparency and reporting, adaptability and scalability, and economic viability. A combination of qualitative literature analysis and multi-criteria decision-making methods (AHP and FAHP) was employed to structure and prioritize the criteria. While the proposed model contributes to the theoretical foundations of sustainable information systems, it also offers practical value for decision-makers aiming to implement data-driven circular business models. However, limitations such as the lack of empirical validation, sector-specific customization, and integration of temporal, security, and practitioner perspectives are acknowledged. Future research directions include testing the model in real-world settings, refining criteria weights through expert input, and expanding the framework to address industry-specific and contextual factors. The findings contribute to a more integrated and actionable approach to digital sustainability in both the public and private sectors.

**Keywords:** Circular economy · Information system · Fuzzy numbers · Fuzzy AHP.

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# 1 Introduction

In the contemporary business environment, marked by rapid technological advancement, digital transformation, and increasingly pronounced challenges related to climate change, the concepts of sustainable development and circular economy are emerging as key factors for the long-term stability and competitiveness of organizations [1, 2]. Global pressure to reduce negative environmental impact, alongside the need for more efficient resource management, has prompted companies to explore alternatives to the traditional linear model of production and consumption, which is based on the "take – make – dispose" principle. This approach has led to excessive depletion of natural resources, accumulation of waste, and increased greenhouse gas emissions, resulting in long-term consequences not only for the planet, but also for the sustainability of business operations.

The circular economy offers a response to these challenges by proposing an alternative model that involves closing the resource loop through strategies such as recycling, reuse, repair, remanufacturing, and designing products with extended life cycles. This approach not only contributes to the preservation of natural resources and the reduction of environmental footprints, but also enables the creation of additional value through innovation, efficiency, and responsible management throughout the entire product and service life cycle [3].

In this context, information systems (IS) play a pivotal role in enabling the principles of the circular economy [4]. Their function has evolved beyond merely supporting operational processes to becoming strategic platforms for collecting, processing, and analyzing data relevant to tracking environmental performance, material flows, energy consumption, and emission levels [5]. Systems such as ERP, CRM, SCADA, IoT networks, and advanced analytics technologies (including artificial intelligence, machine learning, and blockchain) empower organizations to make informed, real-time decisions that support sustainability objectives [6].

Digital solutions also facilitate detailed life cycle assessments (LCA), resource flow modeling, predictive analytics for inventory and production optimization, as well as the automation of recycling and reuse processes. Moreover, information systems support compliance with increasingly stringent regulatory frameworks and initiatives such as the EU Green Deal, ESG standards, and circular economy directives, thus enhancing organizational credibility, access to green financing, and overall business transparency [7].

By aligning information systems with sustainable development strategies, companies can achieve synergy among environmental, economic, and social goals. This integration not only reduces negative environmental impacts, but also paves the way for new business models, innovations, and market differentiation — potentially representing a significant competitive advantage. The aim of this paper is to examine how information systems can support the implementation of circular economy principles within business organizations, through the analysis of their role in resource optimization, process transparency, and sustainability monitoring and reporting. Additionally, the paper proposes the development of a framework for evaluating information systems based on clearly defined criteria, including environmental performance, digital maturity, cost-effectiveness, and regulatory compliance.

## 2 Literature overview

The concept of the circular economy (CE) is increasingly being examined in the context of digital transformation and information systems, as digital technologies enable the tracking, optimization, and transparency of resource flows. The traditional linear economy, based on the "take–make–dispose" model, is no longer sustainable—either environmentally or economically—which creates opportunities for leveraging information systems in support of sustainability.

Several recent studies highlight a strong connection between information technologies and the successful implementation of circular economy principles. Naveed et al. [1] identified key factors for the effective deployment of digital solutions in CE, emphasizing the importance of digital resource tracking, automation, and real-time data integration. Similarly, [7] proposes a conceptual framework for designing information systems that support sustainability, underscoring the significance of system integration and the scalability of digital tools.

The literature also highlights the importance of integrating ERP systems with Life Cycle Assessment (LCA) methodologies. Ferrari et al. [6] demonstrate how the combination of ERP and LCA enables dynamic tracking of a product's environmental impact throughout all stages of production and use. In this way, information systems are positioned as central instruments for making data-driven sustainable decisions.

However, several challenges remain. Yin et al. [5] point to institutional barriers and the need for organizational culture change in order for information systems to effectively support CE implementation. Moreover, the standardization of indicators for measuring circularity and sustainability remains an unresolved issue. In a study conducted by Moraga et al. [8], over 60 different indicators used in practice were identified, complicating cross-sector and cross-country comparisons and evaluations.

Additionally, most of the existing literature focuses on developed countries and large enterprises, while micro, small, and medium-sized enterprises (particularly in rural areas or developing countries) remain underrepresented. This highlights the need for future research on adapting information systems to smaller and resource-constrained environments [5, 9]

In light of these insights, it is evident that information systems hold significant potential to support the transition toward a circular economy. However, further investigation is needed into the practical aspects of their implementation, as well as the development of more universal frameworks for their evaluation within the context of sustainability.

## 3 Main Criteria for Circular Economy Sustainability

The starting factors influencing the development of circular economy were obtained from the literature overview, that is given in Section 2, followed by an expert discussion. The debate and consultation among the four experts/decision makers from the area of Economics (Macroeconomics, Faculty of Economics, 16 years of experience, working with the Regional development agency; Microeconomics, Faculty of Economics, 19 years of experience, working with Faculty of Economics), Sustainable Tourism (Faculty of Science and Mathematics, 11 years of experience, working with Faculty of Tourism and hotel management), and Ecology (Faculty of Science and Mathematics, 12 years of experience, working with Ministry of environmental protection and Research institute), based on their life and working experience, has led to the selection of six criteria [10]: Environmental Sustainability (S), Digital Support for Circular Practices (D), Resource Efficiency (R), Transparency and Reporting (T), Adaptability and Scalability (A), Economic Feasibility(E), as can be seen in Fig. 1.

**Fig. 1.** Criteria influencing Circular Economy.

### 3.1 Environmental Sustainability

Environmental sustainability represents a key criterion for evaluating information systems within the context of the circular economy, as any system that contributes to reducing negative environmental impacts directly supports the core goals of sustainable development. This includes processes and technologies that reduce greenhouse gas emissions, minimize waste, and optimize energy consumption. Information systems can enable the monitoring of energy performance—for instance, the energy usage of servers, cooling systems, and internal networks—thereby facilitating the identification of "bottlenecks" and opportunities for efficiency improvements. Hardware and infrastructure components that are recyclable or repairable extend the lifecycle of equipment, reducing the need for new raw materials [11]. Furthermore, software optimization and well-designed algorithms can lower computational demands, thereby decreasing energy consumption during task execution [12]. The integration of renewable energy sources, optimization of data center cooling, and adoption of "green" procurement and distribution practices for IT equipment can further reduce the ecological footprint of such systems. Environmental sustainability is also closely tied to regulatory frameworks, as many countries and regions have established standards for emissions, electronic waste recycling, and energy efficiency. Information systems that assist in meeting these standards offer a comparative advantage. Additionally, the ecological impacts of systems are often long-term in nature, meaning that investments in sustainability tend to pay off over time through reduced operational costs and energy consumption. However, it is equally important to consider potential drawbacks—such as the energy demands of data centers themselves, or the production and disposal of hardware—in order to design systems in a holistic and environmentally responsible manner [13].

### 3.2 Digital Support for Circular Practices

Digital support for circular practices implies that information systems serve not only operational purposes but also enable the monitoring of material flows, the optimization of production and operational processes, maintenance, recycling, and lifecycle management of products [11]. This includes tools such as ERP systems, inventory management platforms, IoT sensors, digital twins, blockchain for transparent supply chains, and real-time data analytics systems.

These tools allow for the identification of inefficiencies, the prediction of failures, the reduction of material and energy losses, and the increase in reuse rates. Digital product passports and systems for tracking components throughout use and service phases can extend product lifespans and facilitate recycling [14]. Sharing platforms, marketplaces for second-hand equipment, or resource redistribution systems also support the circular model.

However, it is critical that these systems be interoperable, use standardized data formats, and be designed to support flexible models—since different industries, regions, and organizational sizes have distinct requirements. Moreover, it is essential that these solutions remain accessible and that the costs of implementing digital support systems are affordable, particularly for smaller firms or those operating in rural areas.

Digital tools must also include mechanisms for data verification and reliability, enabling users to trust the accuracy of reporting and analytics. Finally, poorly implemented or fragmented digital practices may lead to "rebound effects" or unexpected increases in energy consumption, potentially offsetting the environmental benefits they are intended to deliver.

### 3.3 Resource Efficiency

Resource efficiency refers to the extent to which an information system enables the effective use of materials, energy, and other inputs without unnecessary losses. In practice, this means that systems should facilitate precise tracking of resource consumption, identification of redundancies or surpluses, and the reduction of waste in production and operational processes [13].

The reuse of components—through repair, remanufacturing, or the use of replacement parts—reduces the need for new raw materials [12]. Planning and analytics functions within systems can support inventory optimization, help prevent overstocking, and minimize material waste or over-ordering. Digital monitoring of material flows provides visibility into where materials are held, how they are used, and the proportions that are recycled or discarded—offering a measurable indicator of efficiency [14].

Resource efficiency is particularly critical in material-intensive sectors such as manufacturing, construction, and agriculture. Technologies such as IoT sensors, automation, and predictive analytics can anticipate failures and prevent breakdowns, thus reducing unplanned downtime and associated losses.

The implementation of circular flow models means that materials traditionally considered waste can be reintegrated into value chains through recycling or repair. Resource efficiency is closely linked to economic performance, as savings in materials and energy often translate into lower operational costs. Nonetheless, several challenges remain, including the collection of reliable data, the infrastructure needed for continuous monitoring, system maintenance, and the initial investment required to deploy the necessary technologies [12].

### 3.4 Transparency and Reporting

Transparency and reporting represent a critical component of sustainable business practices in the digital era, as they provide all relevant stakeholders — including investors, regulators, partners, and consumers — with insights into environmental performance, resource flows, and progress toward sustainability goals. In the context of information systems, this means that digital platforms must be capable of generating accurate, complete, and up-to-date reports aligned with internationally recognized standards such as the Global Reporting Initiative (GRI), Carbon Disclosure Project (CDP), and the Task Force on Climate-related Financial Disclosures (TCFD) [15].

High-quality ESG reporting enhances business transparency, reduces information asymmetry, and fosters trust among investors, consumers, and the wider public. Numerous studies have shown that companies with greater transparency in ESG practices achieve improved access to capital, receive higher ratings from agencies, and demonstrate greater resilience in periods of market volatility [16]. Moreover, public and open communication regarding environmental risks and impacts can serve as a foundation for more responsible decision-making and reputational gains.

However, despite its growing relevance, ESG transparency remains unevenly developed. Many companies tend to disclose only favorable data, while negative aspects are concealed or marginalized—often relegated to footnotes or poorly elaborated sections of reports [17]. Such practices hinder comprehensive assessments of environmental impacts and undermine confidence in the published information.

An additional challenge lies in the diversity of metrics and indicators used across organizations. Companies often apply different indicators, measurement units, and reporting frequencies, making cross-comparisons of ESG performance difficult. The lack of standardization complicates benchmarking, despite the increasing number of guidelines and regulatory initiatives.

To ensure credibility, information systems must include functionalities for both internal and external data verification, including audit trails, data assurance features, and options for independent third-party review. Data reliability becomes especially crucial when reports are used to support investment or regulatory decisions.

Within the context of evaluating information systems, this criterion can be assessed across several dimensions: whether the system enables ESG report generation; the comprehensiveness and timeliness of those reports; the degree of alignment with established regulations and standards; the level of support for automated data collection; and the accessibility of data to external stakeholders. Transparency is not merely a technical issue — it is a strategic imperative that underpins responsible governance and long-term sustainability.

### 3.5 Adaptability and Scalability

Adaptability and scalability refer to the ability of an information system to expand and adjust to changing conditions—whether in terms of scope, number of users, data volume, technology integration, industry sector, or geographic location—without a decline in performance or incurring excessive costs. A system should be modular and flexible, allowing for the integration of additional components (e.g., new sensors, analytics modules, or compliance standards) as the organization grows or the operating environment evolves. In rural areas or smaller enterprises, adaptability also implies ease of maintenance, low infrastructure requirements, and the ability to function under resource constraints. Scalability includes the system's ability to process increasing volumes of data, support a growing number of users, and maintain stability as operations expand. It should also be capable of supporting extended logistics networks or supply chains. Technical sustainability is another key aspect: the system's software and hardware should be upgradable, compatible with emerging technologies, and allow for regular updates and improvements. Furthermore, the system should be configurable for diverse regulatory, cultural, and infrastructural contexts—meaning the same system can be adapted to different conditions with minimal reengineering. Studies on "system of systems" architectures highlight that interoperability and scalability remain significant challenges in the broader deployment of green technological solutions [18].

### 3.6 Economic Feasibility

Economic feasibility addresses the cost–benefit relationship of an information system within the context of the circular economy—specifically, whether the investment is financially viable, how quickly it yields returns, how much it reduces operational costs, and what long-term or indirect benefits it offers. Costs may include hardware and software acquisition, system implementation, integration, operational maintenance, electricity consumption, employee training, and potential upgrade expenses [19]. Benefits can be direct—such as reduced material and energy consumption, lower waste management costs, and optimized logistics and inventory—but also indirect, including improved brand reputation, regulatory compliance, access to subsidies or green financing, enhanced consumer perception, and the enablement of new business models. The study [11] indicates that investments in digital technologies can significantly improve economic performance, provided that risks and costs are carefully managed. Literature reviews show that economic considerations are often a key barrier for small enterprises or organizations in rural areas, where initial investments may exceed available capacities. Return on investment (ROI) depends on several factors: the scale of system usage, resource efficiency, energy savings, waste reduction, and the system's operational lifespan. In many cases, the benefits only materialize after the system has stabilized, and the actual payback period may be longer than initially projected [20].

## 4 Methodology

The Analytic Hierarchy Process (AHP), developed by Thomas L. Saaty in the 1980s, has since been widely adopted as a robust decision-making method [21]. It enables the representation of comparative judgments using exact numerical values, typically natural numbers. A central advantage of AHP lies in its capacity to evaluate competing criteria, sub-criteria, and alternatives through a structured and hierarchical approach. This process blends logical analysis with intuitive judgment by decomposing complex decision problems into multiple levels — beginning with the overall goal, followed by a hierarchical breakdown of criteria and sub-criteria. The method facilitates pairwise comparisons among elements at the same hierarchical level while taking into account their relative influence on higher-level objectives. Parallel to this, fuzzy set theory, introduced by Lotfi Zadeh in 1965, has served as a foundational tool for handling uncertainty and vagueness in decision-making [22, 23]. Originally designed to support linguistic representation, the theory extends classical set theory by allowing elements to have degrees of membership, rather than binary inclusion. Within this framework, elements can belong to a set with varying levels of certainty, expressed as values between 0 and 1 via membership functions. A single fuzzy set may encompass multiple distinct membership functions, enabling decision-makers to model incomplete or imprecise information in a more nuanced and flexible manner.

### 4.1 Triangular fuzzy Numbers and Fuzzy AHP algorithm

In the sequel, basic properties on triangular fuzzy numbers will be given.

Let all fuzzy sets defined on the set of real numbers $R$ be represented as $F(R)$.

The number $A \in F(R)$ is a fuzzy number if there exists $x_0 \in R$ so condition $\mu_A(x_0) = 1$ holds, and $A_\lambda = \left[x, \mu_{A_\lambda}(x) \geq \lambda\right]$ is a closed interval for every $\lambda \in [0, 1]$. The membership function, a component of a triangle fuzzy number (TFN) $A$, is a function $\mu_A : R \to [0, 1]$, defined as

$$\mu_F(x) = \begin{cases} \frac{x-l}{m-l}, \; l \leq x \leq m, \\ \frac{u-x}{u-m}, \; m \leq x \leq u, \\ 0, \quad \text{otherwise}, \end{cases} \tag{1}$$

where inequality $l \leq m \leq u$ holds. Variables $l$, $m$ and $u$ are the lower, middle, and upper value, respectively, and when $l = m = u$, TFN becomes a crisp number. In the sequel, the triangular fuzzy number will be denoted by $\tilde{A} = (l, m, u)$. For the purpose of decision-making, some TFNs, their meaning and graphical representation will be stated: $\tilde{1} = (1, 1, 3)$ (Equal importance), $\tilde{2} = (1, 2, 3)$ (Absolutely weak dominance), $\tilde{3} = (1, 3, 5)$ (Extremely weak dominance), $\tilde{4} = (3, 4, 5)$ (Very weak dominance), $\tilde{5} = (3, 5, 7)$ (Fairly weak dominance), $\tilde{6} = (5, 6, 7)$ (Fairly strong dominance), $\tilde{7} = (5, 7, 9)$(Very strong dominance), $\tilde{8} = (7, 8, 9)$ (Extremely strong dominance), and $\tilde{9} = (7, 9, 9)$ (Absolutely strong dominance). Odd TFNs are presented in Fig. 2, while the even ones, serving as a intermediate values (AHP) were omitted.

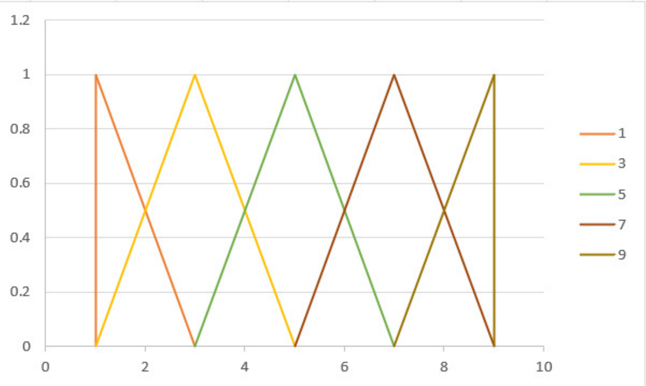

**Fig. 2.** Graphical representation of triangular fuzzy numbers.

For basic algebraic properties of TFNs and corresponding integral values given below, one can refer to [24–26].

Addition:

$$\tilde{A}_1 \oplus \tilde{A}_2 = (l_1, m_1, u_1) \oplus (l_2, m_2, u_2) = (l_1 + l_2, m_1 + m_2, u_1 + u_2), \tag{2}$$

Subtraction:

$$\tilde{A}_1 \ominus \tilde{A}_2 = (l_1, m_1, u_1) \ominus (l_2, m_2, u_2) = (l_1 - u_2, m_1 - m_2, u_1 - l_2), \qquad (3)$$

Multiplication:

$$\tilde{A}_1 \otimes \tilde{A}_2 = (l_1, m_1, u_1) \otimes (l_2, m_2, u_2) = (l_1 \cdot l_2, m_1 \cdot m_2, u_1 \cdot u_2), \qquad (4)$$

Reciprocal:

$$\tilde{A}_1^{-1} = (l_1, m_1, u_1)^{-1} = (\frac{1}{u_1}, \frac{1}{m_1}, \frac{1}{l_1}), \qquad (5)$$

Scalar multiplication:

$$k \cdot \tilde{A}_1 = k \cdot (l_1, m_1, u_1) = (k \cdot l_1, k \cdot m_1, k \cdot u_1). \qquad (6)$$

The most important steps, fuzzification and defuzzification, are presented below.

Using the triangular fuzzy numbers from the comparison matrix $\widetilde{D} = \left(\tilde{d}_{ij}\right)_{n \times n}$, applying

$$A = \sum_{i=1}^{n} \sum_{j=1}^{n} \tilde{d}_{ij} = \sum_{i=1}^{n} \sum_{j=1}^{n} \left(l_{ij}, m_{ij}, u_{ij}\right), \qquad (7)$$

and

$$A^{-1} = \left( \sum_{i=1}^{n} \sum_{j=1}^{n} \tilde{d}_{ij} \right)^{-1} = (\frac{1}{\sum_{i=1}^{n} \sum_{j=1}^{n} l_{ij}}, \frac{1}{\sum_{i=1}^{n} \sum_{j=1}^{n} m_{ij}}, \frac{1}{\sum_{i=1}^{n} \sum_{j=1}^{n} u_{ij}}), \qquad (8)$$

the value of the fuzzy synthetic extent is obtained as follows:

$$\widetilde{S}_i = \sum_{j=1}^{n} \tilde{d}_{ij} \otimes A^{-1} = \sum_{j=1}^{n} (l_{ij}, m_{ij}, u_{ij}) \otimes A^{-1}, \quad i = \overline{1, n}. \qquad (9)$$

Next, using

$$w_i = I_T^{\lambda}(\widetilde{S}_i) = \frac{1}{2}\left(\lambda u_i + m_i + (1 - \lambda) m_i\right), \, \lambda \in [0, 1], i = \overline{1, n}, \qquad (10)$$

the total integral value for the TFNs $\widetilde{S}_i$ is calculated.

The steps of the used algorithm are presented below. [27].

## 5 Results and Discussion

Firstly, the comparison matrix will be given, explaining the criteria rank and importance. According to the experts opinions, the criteria significance is presented in Fig. 3.

All the calculations were done in Microsoft Excel.

**Algorithm 1** Steps in the FAHP process.

```
Establish the main goal
Identify $Xi, Xij$                                   ▷ Criteria and sub-criteria
Construct **D**                                      ▷ The main Fuzzy correlation matrix
Calculate $CR$                                       ▷ Consistency ratio, $CI = \frac{\lambda_{max}-n}{n-1}$, $CR = \frac{CI}{RI}$
**if** $CR \geq 0.1$ **then**
    Adjust values
    **go to** 3                                      ▷ Recalculations, new fuzzy matrix
**else**
    Fuzzification, calculate $\widetilde{S}_i$              ▷ $\widetilde{S}_i = \sum_{j=1}^{n} \tilde{d}_{ij} \otimes A^{-1}, \quad i = \overline{1,n}$
    Defuzzification, calculate $w_i$                 ▷ $w_i = \frac{1}{2}\big(\lambda u_i + m_i + (1-\lambda) m_i\big)$, $\lambda \in [0,1]$
    Calculate $w_i^*$                                ▷ Normalization vector, $w_i^* = w_i \left(\sum_{i=1}^{n} w_i\right)^{-1}$
    $Xij$ ranking
**end if**
```

| | **S** | **D** | **R** | **T** | **A** | **E** |
|---|---|---|---|---|---|---|
| **S** | $\tilde{1}$ | $\tilde{3}$ | $\tilde{3}$ | $\tilde{5}$ | $\tilde{7}$ | $\tilde{7}$ |
| **D** | $\tilde{3}^{-1}$ | $\tilde{1}$ | $\tilde{1}$ | $\tilde{3}$ | $\tilde{5}$ | $\tilde{5}$ |
| **R** | $\tilde{3}^{-1}$ | $\tilde{1}^{-1}$ | $\tilde{1}$ | $\tilde{3}$ | $\tilde{5}$ | $\tilde{5}$ |
| **T** | $\tilde{5}^{-1}$ | $\tilde{3}^{-1}$ | $\tilde{3}^{-1}$ | $\tilde{1}$ | $\tilde{3}$ | $\tilde{3}$ |
| **A** | $\tilde{7}^{-1}$ | $\tilde{5}^{-1}$ | $\tilde{5}^{-1}$ | $\tilde{3}^{-1}$ | $\tilde{1}$ | $\tilde{1}$ |
| **E** | $\tilde{7}^{-1}$ | $\tilde{5}^{-1}$ | $\tilde{5}^{-1}$ | $\tilde{3}^{-1}$ | $\tilde{1}^{-1}$ | $\tilde{1}$ |

**Fig. 3.** The fuzzy comarison matrix for main group of criteria.

This matrix is consistent, since $CR = 0.025(CI = 0.032, \lambda_{max} = 6.158)$. The criteria with the highest weight is Environmental Sustainability (S), followed by (in the case of AHP) equally ranked criteria D and R, representing Digital Support for Circular Practices and Resource Efficiency, with the weight 0.199, being 2.13 times less important than the leading criteria. The least important criteria, with the equal weight of 0.042 in the AHP are Adaptability and Scalability (A) and Economic Feasibility (E). In the case of pessimistic FAHP ($\lambda = 0$) the leading criteria weight is equal 0.374, followed by criteria D and R with the corresponding weights 0.219 and 0.214. At the end of the ladder lie criteria A and E with the weights 0.047 and 0.042 respectively. For $\lambda = 1$ (optimistic case), criteria Environmental Sustainability is 1.55 more important than criteria Digital Support for Circular Practices, and 1.65 and 2.86 times more important than Resource Efficiency and Adaptability and Scalability. With the least important criteria, this qoutient is equal 9.23.

The weights of all criteria in the case of AHP and five cases of FAHP can be seen in Fig. 4 where the weights in the semi-pessimistic and semi-optimistic case of the FAHP can be seen. The corresponding fuzzy numbers obtained in the fuzzification process can be seen in Fig. 5.

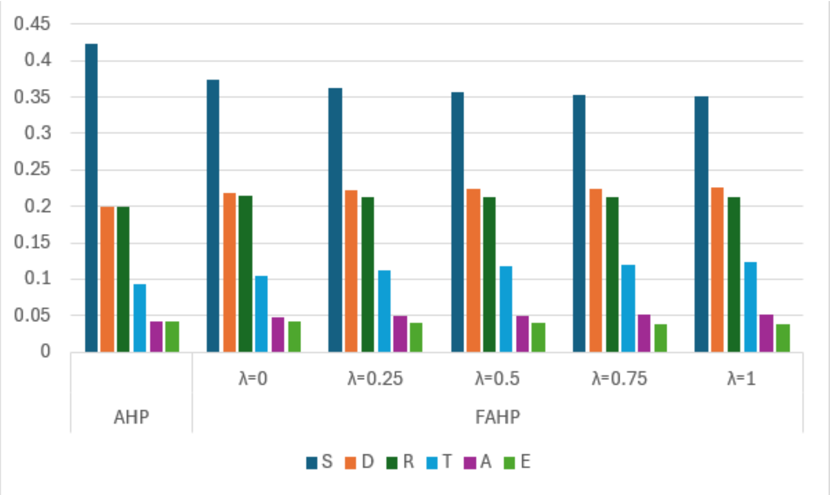

**Fig. 4.** Synthetic fuzzy numbers obtained in the defuzzification process.

Furthermore, the analysis of interdependencies among criteria through a visual model enhances the understanding of the systemic nature of sustainability within information systems, thereby enabling a more integrated approach to the planning, development, and evaluation of digital solutions. This study not only extends the existing theoretical foundations in the fields of information systems and sustainable development but also offers a practical tool to support organizations in systematically implementing data-driven circular business models.

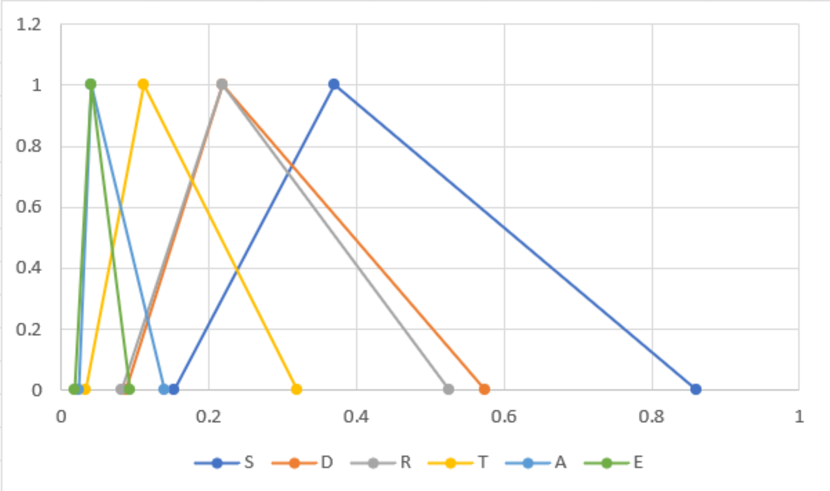

**Fig. 5.** The ranking of criteria in the case of AHP and FAHP.

The practical value of this manuscript lies in its potential to inform decision-making in real-world contexts, both for managers involved in the implementation of information systems and for policymakers aiming to promote sustainable digital transformation across the public and private sectors. Importantly, the proposed framework is adaptable to specific contexts, including small and medium-sized enterprises (SMEs) and rural communities, thus addressing a frequently overlooked dimension in the existing literature.

## 6 Conclusion

This study provides a multidimensional analysis of the role of information systems in supporting the implementation of circular economy principles, with a particular focus on sustainability, transparency, resource efficiency, and economic viability. In contrast to most previous studies that examine these domains in a fragmented manner and without a clear evaluation framework, this research integrates key criteria into a unified assessment model, enabling systematic comparison and ranking of solutions within the realm of digital sustainability. The scientific contribution of the study lies primarily in the definition and structuring of six core groups of criteria for evaluating the sustainability of information systems: (1) environmental sustainability, (2) digital support for circular practices, (3) resource efficiency, (4) transparency and reporting, (5) adaptability and scalability, and (6) economic viability. These groups are ranked based on their relative importance and impact, thereby facilitating a deeper understanding of the interactions within the system.

Although this study provides a theoretical framework for understanding and evaluating the contribution of information systems in the context of the circular economy and sustainable development, it is necessary to acknowledge several limitations that may affect the applicability and generalizability of the findings.

First, the proposed ranking model is based on a qualitative analysis of relevant literature and logical reasoning, supplemented by the use of quantitative multi-criteria decision-making methods such as AHP and FAHP. As a result, a certain degree of subjectivity is inherent in determining the relative importance of individual criteria, which could be more precisely defined through collaboration with industry experts. Second, the model has not yet been tested in real organizational settings, and its functionality and applicability therefore remain at a theoretical level. Empirical validation, through case studies, interviews with managers, or pilot implementations in specific companies, could significantly enhance its practical relevance and help identify potential challenges in implementation.

Moreover, the framework is not specifically tailored to particular industrial sectors or regional contexts, despite the fact that needs and priorities can vary significantly between, for example, the IT industry, agriculture, or construction. In addition, most of the regulatory and strategic guidelines included in the analysis are derived from the European context (e.g., EU regulations, ESG standards), which may limit the model's relevance in countries with different legislative and market conditions.

Another limitation lies in the model's omission of the temporal dimension of digital sustainability development. The relevance of individual criteria may shift depending on the implementation phase of the information system or the evolution of a company's business model. Furthermore, the study does not address aspects of data security and privacy, which are critical in digitized and interconnected information systems—especially within the context of sustainability and circular economy, where data plays a central role in tracking resource flows.

Finally, the study does not incorporate the perspectives and experiences of practitioners from relevant domains, such as IT managers, sustainability experts, software solution providers, and decision-makers in both the private and public sectors. Their input would be invaluable for further validating the proposed criteria and aligning them more closely with real-world market needs.

In light of these limitations, future research should focus on: Empirically testing the proposed model in real-world organizational contexts; Applying quantitative methods to determine the weights and priorities of criteria; Adapting the framework to specific industries and geographical regions; Expanding the model to include dimensions related to security and risk; and Incorporating practitioner perspectives through interviews, workshops, or surveys.

By addressing these areas, the model could evolve into a robust tool for both researchers and strategic decision-makers seeking to integrate information systems and circular economy principles in pursuit of sustainable and competitive business practices.

## References

1. Naveed, W., Ammouriova, M., Naveed, N. and Juan, A.A.: Circular economy and information technologies: identifying and ranking the factors of successful practices. Sustainability, 14(23), 15587 (2022). https://doi.org/10.3390/su142315587.
2. De Pascale, A., Arbolino, R., Szopik-Depczyńska, K., Limosani, M. and Ioppolo, G.: A systematic review for measuring circular economy: The 61 indicators. Journal of cleaner production, 281, 124942 (2021). https://doi.org/10.1016/j.jclepro.2020.124942
3. Riggs, R., Felipe, C.M., Roldán, J.L. and Real, J.C.: Information systems capabilities value creation through circular economy practices in uncertain environments: A conditional mediation model. Journal of Business Research, 175, 114526 (2024). https://doi.org/10.1016/j.jbusres.2024.114526
4. Vidmar, D., Marolt, M. and Pucihar, A.: Information technology for business sustainability: A literature review with automated content analysis. Sustainability, 13(3), 1192 (2021). https://doi.org/10.3390/su13031192
5. Yin, S., Jiang, M., Chen, L. and Jia, F.: Digital transformation and the circular economy: an institutional theory perspective. Industrial Management and Data Systems, 124(4), 1627–1655 (2024). https://doi.org/10.1108/IMDS-10-2023-0792
6. Ferrari, A.M., Volpi, L., Settembre-Blundo, D. and García-Muiña, F.E.. Dynamic life cycle assessment (LCA) integrating life cycle inventory (LCI) and Enterprise resource planning (ERP) in an industry 4.0 environment. Journal of Cleaner Production, 286, 125314 (2021). https://doi.org/10.1016/j.jclepro.2020.125314
7. Recker, J.: Designing information systems that support environmental sustainability: A framework-based review. Research Handbook on Information Systems and the Environment, 114–148 (2023). DOI: 10.4337/9781802201864.00012
8. Moraga, G., Huysveld, S., De Meester, S. and Dewulf, J.: Development of circularity indicators based on the in-use occupation of materials. Journal of Cleaner Production, 279, 123889 (2021). https://doi.org/10.1016/j.jclepro.2020.123889
9. Mayanti, B. and Helo, P.:Circular economy in supply chain management: a framework for database tool development to enhance sustainability. International Journal of Environmental Studies, 81(4), pp.1962-1979 (2024).
10. Mladenovic, M., Simjanovic, D. J., Ranđelovic, B. M., Dobricanin, S., Zdravkovic, N., Djokic, D. New Frontiers in Determining Criteria and Strategies in Rural Area Sustainable Development in Serbia: Fuzzy AHP Approach. World, 6(4), 141 (2025). https://doi.org/10.3390/world6040141
11. Li, Y., Dai, J. and Cui, L.: The impact of digital technologies on economic and environmental performance in the context of industry 4.0: A moderated mediation model. International Journal of Production Economics, 229, p.107777 (2020). https://doi.org/10.1016/j.ijpe.2020.107777
12. Kautish, S., Gurung, D.: Advancing Sustainable Computing: A Systematic Literature Review of Software, Hardware, and Algorithmic Innovations. ICCK Transactions on Sustainable Computing, 1(1), 1—19 (2025). https://doi.org/10.62762/TSC.2025.767094
13. William, B., Mabel, E.: Sustainable Digital Transformation: Exploring Energy-Efficient Computing and Circular Design Innovations (2025).
14. Cigu, E.: The Digital Economy's Contribution to Advancing Sustainable Economic Development. Administrative Sciences, 15(4), 146 (2025). https://doi.org/10.3390/admsci15040146

15. Lucia-Maria, U.: Implementing ESG reporting in public institutions: A case study of Romania's internal managerial control framework. Annals of'Constantin Brancusi'University of Targu-Jiu. Economy Series/Analele Universităţii'Constantin Brâncuşi'din Târgu-Jiu Seria Economie, (4) 241–247 (2024).
16. Zheng, Z.: The Impact of ESG Report Transparency on Investor Behavior. Advances in Economics, Management and Political Sciences, 129(1), 151–156 (2024). https://doi.org/10.54254/2754-1169/2024.18396
17. Schwoy, S.M., Dutzi, A. and Messing, J.: Silence is golden?–Analysing the transparency of ESG controversies in corporate reporting within the pharmaceutical and textile industry. Management Decision, 63(2), 665–707 (2025). https://doi.org/10.1108/MD-10-2023-1988
18. da Silva, A.C.A.G., Teixeira, G., de Campos, L.M.C., Bulcão-Neto, R.F. and Neto, V.V.G.: Systems-of-Systems for Environmental Sustainability: A Systematic Mapping Study. In 2025 20th Annual System of Systems Engineering Conference (SoSE) 1–6. (2025) IEEE. DOI: 10.1109/SoSE66311.2025.11083809
19. Cricelli, L. and Strazzullo, S.: The economic aspect of digital sustainability: A systematic review. Sustainability, 13(15), .8241 (2021). https://doi.org/10.3390/su13158241
20. Shabur, M.A.: Analyzing the challenges and opportunities in developing a sustainable digital economy. Discover Applied Sciences, 6(12), p.667 (2024). https://doi.org/10.1007/s42452-024-06298-y
21. Saaty, T.L.: The Analytic Hierarchy Process; McGraw-Hill International: New York, NY, USA, (1980)
22. Zadeh, L.A.: The concept of a linguistic variable and its application to approximate reasoning—II. Inf. Sci. 8, 301–357 (1975). https://doi.org/10.1016/0020-0255(75)90046-8
23. Zadeh, L.A.: The concept of a linguistic variable and its application to approximate reasoning—III. Inf. Sci. 9, 43–80 (1975). https://doi.org/10.1016/0020-0255(75)90017-1
24. Sun, C.C., 2010. A performance evaluation model by integrating fuzzy AHP and fuzzy TOPSIS methods. Expert systems with applications, 37(12), pp.7745-7754.
25. Wang, W.M., Lee, A.H. and Chang, D.T.: An integrated FA-FEAHP approach on the social indicators of Taiwan's green building. Global Business and Economics Review, 11(3-4), 304–316 (2009). DOI:10.1504/GBER.2009.031177
26. Kulak, O.; Durmuşoğlu, M.B.; Kahraman, C.: Fuzzy multi-attribute equipment selection based on information axiom. J. Mater. Process. Technol., 169, 337–345 (2005). https://doi.org/10.1016/j.jmatprotec.2005.03.030
27. Simjanovic, D. J., Zdravkovic, N., Vesic, N. O.: On the Factors of Successful e-Commerce Platform Design during and after COVID-19 Pandemic Using Extended Fuzzy AHP Method. Axioms, 11(3), 105 (2022). https://doi.org/10.3390/axioms11030105