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THE ROLE OF MULTI-CRITERIA DECISION-MAKING IN IMPROVING CIRCULAR ECONOMY PERFORMANCES: EUROPEAN CONTEXT

Abstract

This paper evaluates circular-economy performance across selected European countries using Eurostat indicators: resource productivity, waste generation (excluding major mineral wastes), waste per capita, recycling rate, and municipal waste per capita using two MCDM methods: PROMETHEE and ARAS. The methodological design enables ranking of alternatives, visualization of trade-offs among criteria, and identification of dominance directions. Findings consistency has shown Sweden as the top performer (maximum utility and the highest aggregate score), whereas Western Balkan countries lag due to lower recycling rates and higher per-capita waste. Several mid-developed economies exhibit stable profiles and can serve as reference models. Policy implications emphasize scaling recycling capacity, improving resource productivity, strengthening waste-management systems, and aligning with the EU framework through targeted funding and improved institutional coordination.

Key words: *circular economy, performances, MCDM, PROMETHEE, ARAS*

JEL classification: *C44, Q33, Q56*

УЛОГА ВИШЕКРИТЕРИЈУМСКОГ ОДЛУЧИВАЊА У ПОБОЉШАЊУ ПЕРФОРМАНСИ ЦИРКУЛАРНЕ ЕКОНОМИЈЕ: ЕВРОПСКИ КОНТЕКСТ

Апстракт

Овај рад процењује перформансе циркуларне економије у одабраним европским земљама користећи Евростат индикаторе: продуктивност ресурса, генерисање отпада (без главних минералних отпада), отпад по глави становника, стопу рециклаже и комунални отпад по глави становника употребом две методе вишекритеријумског одлучивања: PROMETHEE и ARAS. Методолошки оквир омогућава рангирање алтернатива, визуелизацију компромиса међу критеријумима и идентификацију смерова доминације.

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Конзистентност резултата указује на то да је Шведска водећа земља (максимална корисност и највиши збирни скор), док земље Западног Балкана заостају због ниже стопе рециклаже и већег отпада по глави становника. Средње развијене економије показују стабилне перформансе и могу послужити као референтни модели. Импликације за креаторе политика укључују јачање рециклажних капацитета, повећање продуктивности ресурса, унапређење управљања отпадом и усклађивање са оквиром ЕУ кроз циљано финансирање и бољу институционалну координацију.

Кључне речи: *циркуларна економија, перформансе, вишекритеријумско одлучивање, PROMETHEE, ARAS*

Introduction

The circular economy (CE) represents a fundamental shift away from the linear “take–make–dispose” model of production and consumption. Instead, it prioritizes keeping products, materials, and components in use for as long as possible through closed-loop systems. The innovative approach of circular economy (CE) involves the reuse and recycling of resources, which return the waste materials to the production flows in order to optimize products, services, processes, and functions within a system. Core principles include (Awan & Sroufe, 2022; Obiuto et al., 2024; Solomon et al., 2024): (a) designing for durability to prevent premature obsolescence, (b) minimizing waste at the design stage, (c) extending product lifetimes via refurbishment, renovation, modification, or performance upgrades and remanufacturing, restoring used goods to near-new condition through disassembly, (d) cleaning, part replacement, and testing.

Far from being purely conceptual, these principles provide a practical blueprint for businesses to transition toward more sustainable models by reframing “waste” as a resource and embedding circular thinking across the entire life cycle. This system’s approach aligns with broader sustainability agendas, especially the UN SDGs, such as SDG 12 (Responsible Consumption and Production) and SDG 9 (Industry, Innovation, and Infrastructure) which promote innovation to recover resources and reduce environmental harm (Papamichael et al., 2024; Raman et al., 2024). Integrating CE principles into industrial processes is now essential amid rising environmental pressures, supply-chain volatility, and more discerning consumers, where one of the biggest challenges can be identified as the necessity of meeting the growing needs of the urban population while ensuring economic, environmental and social sustainability of the society. As firms confront resource scarcity and climate change, circular strategies offer new ways to create, deliver, and capture value, most notably by reducing reliance on virgin, non-renewable inputs. Practices like remanufacturing recapture value from returns and end-of-life products, while green manufacturing embeds environmentally beneficial methods to lower energy use, emissions, and waste, leading to vital economic growth. Policymakers must identify appropriate instruments to target existing problems and constraints. Even resource-intensive sectors such as mining are applying circular methods to address long-standing sustainability issues (Ghaithan et al., 2023; Remeikienė et al., 2025).

Operators are using Industry 4.0, enabled smart logistics and IoT sensors, AI, and real-time analytics, to trace materials, optimize operations, and facilitate the reuse and recycling of valuable by-products even developing digital (smart) agriculture (Kamali Saraji et al. 2025; Vaezinejad et al. 2025). These intelligent systems both improve efficiency and shrink carbon footprints by reducing energy demand and enabling more efficient resource flows and finally could improve export which is the most important for the country's competitiveness (Han et al., 2023; Chi et al, 2023). By designing loops that return materials and components to production, companies can curb depletion of finite resources, preserve capital, and strengthen environmental credibility. The EU's circular economy frameworks emphasize linking digitalization with well-structured policies to reduce single-use materials and encourage product-service models (Popović et al, 2025). The convergence of CE principles with digital technologies thus signals a transformative move toward industrial systems that are more sustainable, low-carbon, and resource-efficient (Woschank & Zsifkovits, 2021). The assessment of the performance of the circular economy in this research will be based on the application of MCDM methods in the case of the ranking of selected European countries (Peyravi et al, 2024; Mesa, 2023). Namely, after certain literature findings, the research methodology will be presented based on the analysis of circular economy indicators as the main criteria in the performance ranking of European countries (Figueiredo & Figueiredo, 2025). A comparative presentation of MCDM methods such as PROMETHEE and ARAS, along with their advantages and limitations, will analyze the leading countries in the field of circular economy, their influence on policymakers, as well as their importance in the implementation of circular economy postulates.

1. Theoretical Background

The transition to a circular economy and the associated challenges require rapid, innovative solutions that ultimately contribute to an environmentally sustainable future, given that the amalgamation of the circular economy and the Industry 4.0 concept has produced an entirely new economic environment (Xie et al., 2022). The necessary shift to a circular economy is widely recognized as a complex and immense challenge that stimulates intensive debate and diverse approaches to transformation. Cities and regions, key drivers of the circular economy, must urgently reconsider how to accelerate and improve this transition process. As part of this comprehensive transition, innovative approaches to process evaluation, capacity building, financing, and regulation are essential for optimizing the current linear system. Such optimization may include the adoption of green and clean production techniques, changes in value-chain relationships, the identification of relevant synergies, and the optimization of cross-sectoral processes. These technologies can help develop durable and sustainable products, drive new circular business models, and support the infrastructure needed to scale up the circular economy (Walzberg et al., 2020). Multi-criteria decision-making (MCDM) is a way to help decision-makers rationally choose among multiple options where several conflicting objectives are present. It is often used when: (a) There is a combination of criteria that are clearly not directly comparable; and (b) Multiple stakeholder perspectives influence the decision being made.

The qualitative element of multi-criteria analysis concerns working with stakeholders to explore their perspectives. The quantitative element concerns the use of models to represent stakeholder preferences and the performance of different options. MCDM is described as a normative, or prescriptive, approach to decision analysis, rather than a descriptive one. It indicates which decision should be made if the decision-maker is consistent with the stated preferences. MCDA seldom captures all modifications associated with a decision. This means it should be viewed as a support tool for decision-makers, not as a comprehensive solution to decision-making. The views of different stakeholders must be taken into account in order to make good decisions within organizations. This means that one of the first actions is to identify an adequate set of stakeholders who provide the necessary diversity of perspectives relative to the complexity of the problem. Preferences are inherently subjective, which means that precautions must be taken to ensure a valid MCDM outcome (Meng et al., 2025). A particularly useful technique is to examine how seemingly impartial positions relate to relevant strategic objectives. All criteria in an MCDM problem can be classified into two categories. Criteria to be maximized fall into the category of "benefit" (or performance) criteria, though they need not literally be profit measures, while criteria to be minimized fall into the category of "cost" criteria.

The ideal solution to an MCDM problem would maximize all benefit criteria and minimize all cost criteria. There are two types of MCDM methods, compensatory and non-compensatory:

a) Compensatory methods allow trade-offs among criteria. A slight decrease in one criterion is acceptable if it is offset by an improvement in one or more other criteria.
b) Non-compensatory methods do not allow trade-offs among criteria. An unfavorable value on one criterion cannot be compensated by favorable values on other criteria; each criterion must stand on its own. Comparisons are therefore made on a criterion-by-criterion basis.

The purpose of MCDM is to help decision-makers select the most suitable alternative from a set of options while considering multiple criteria simultaneously (Theilig et al., 2024). This approach recognizes that decisions are rarely based on a single factor and aims to provide a comprehensive analysis that reflects the complexity and multidimensional nature of decision problems. The purpose of MCDM is to acknowledge that decision problems often involve conflicting objectives and to provide a structured framework for evaluating and comparing alternatives based on their performance against the identified criteria. The key objectives of MCDM can be summarized as follows:

- Comprehensive evaluation - MCDM aims to provide a holistic assessment of alternatives by considering multiple criteria. It takes into account both quantitative and qualitative factors relevant to the decision problem, ensuring a more comprehensive and balanced evaluation.
- Trade-off analysis - MCDM recognizes that decision problems often involve trade-offs among criteria. By explicitly considering trade-offs, decision-makers can gain insight into the implications of different choices and make informed decisions aligned with their goals and preferences.
- Stakeholder involvement - MCDM methods often involve the participation of stakeholders in the decision-making process. By incorporating the

preferences and perspectives of different stakeholders, MCDM promotes inclusiveness, transparency, and accountability in decision-making.

- Structured decision process - MCDM provides a structured framework and systematic approach to decision-making. It involves a sequence of steps, problem formulation, criteria identification, alternative evaluation, and ranking, that help decision-makers navigate complex decision problems logically and coherently.
- Decision support - MCDM methods serve as decision-support tools, providing decision-makers with valuable insights, information, and analyses to facilitate the decision process. They help decision-makers make more informed and rational choices by considering a broader range of factors and perspectives.

By providing a systematic approach and incorporating stakeholder preferences, MCDM methods enable decision-makers to navigate complex decision problems and choose alternatives that are best aligned with their objectives and priorities, thereby shaping balanced and optimized circular models (Walzberg et al., 2020). Using MCDM methods, decision-makers can manage complex decision problems more effectively, leading to more informed and balanced decisions. The multi-criteria decision-making process typically involves several key steps that guide decision-makers through the evaluation and selection of alternatives based on multiple criteria. Although specific details may vary depending on the chosen MCDM method, the following steps provide a general overview of the MCDM process (Wang et al., 2024):

1. Problem formulation - Clearly define and articulate the decision problem. This includes identifying the objectives, criteria, and constraints of the decision. The decision-maker should have a clear understanding of what needs to be achieved and the context in which the decision is being made.
2. Criteria identification - Identify and define the criteria to be used in evaluating alternatives. Criteria may be quantitative or qualitative and should be relevant to the decision problem. It is important to ensure that the criteria are comprehensive, non-redundant, and mutually exclusive.
3. Alternative generation - Generate a set of feasible alternatives that could potentially solve the decision problem. Creativity and domain knowledge are essential for identifying a diverse range of alternatives. The number of alternatives should be manageable yet sufficiently representative to allow meaningful comparison.
4. Evaluation and measurement of criteria - Evaluate and measure each criterion for every alternative. This step involves collecting data or information regarding the performance of alternatives on each criterion. The data may be quantitative (numerical values) or qualitative (scores or rankings). Various techniques, such as surveys, expert judgment, or data-analysis methods, can be used for quantification.
5. Weighting and normalization - Once criteria have been evaluated, assign weights representing the relative importance of each criterion. Weighting reflects the decision-maker's preferences and priorities. Normalization may also be performed to standardize criterion values, ensuring they are on the

same scale and comparable.

6. Selection of a decision method - Choose an appropriate MCDM method or approach. The choice depends on the nature of the decision problem, the available data, and the decision-maker's preferences. Common MCDM methods include the Analytic Hierarchy Process (AHP), the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS).
7. Alternative ranking and selection - Using the chosen MCDM method, rank or prioritize the alternatives based on their performance across the criteria. The method aggregates criterion evaluations, taking into account the assigned weights and preferences. The outcome is a ranked list of alternatives indicating their relative suitability or preference.
8. Sensitivity analysis - Conduct sensitivity analysis to assess the robustness and stability of results. This involves examining the impact of changes in criterion weights or alternative scores on the ranking. Sensitivity analysis helps to understand the influence of uncertainty and variability on the final decision.
9. Decision implementation - After alternatives have been ranked and selected, proceed with implementing the chosen alternative. This may include further planning, resource allocation, and monitoring to ensure that decisions are effectively put into practice.

This may include further planning, resource allocation, and monitoring to ensure effective implementation. It is important to note that the MCDM process is iterative and may involve revisiting steps to refine the problem formulation, criteria, or evaluations based on feedback and additional analyses. MCDM methods offer several advantages that make them valuable decision-making tools, but they also have limitations that should be considered. Key advantages and limitations include (Taherdoost & Madanchian, 2023):

- Consideration of multiple criteria - MCDM methods allow decision-makers to consider and evaluate multiple criteria simultaneously, enabling a more comprehensive and holistic assessment of alternatives that reflect the different dimensions of the decision problem.
- Transparency and accountability - MCDM methods provide a transparent and documented process for decision-making. Criteria, weights, and evaluation procedures are explicitly defined, allowing decision-makers to justify and communicate their decisions to stakeholders.
- Flexibility and adaptability - MCDM methods can be adapted to different decision contexts and tailored to specific evaluation needs. They can handle both quantitative and qualitative criteria, enabling decision-makers to incorporate diverse types of information into the decision process.
- Sensitivity analysis - MCDM methods often support sensitivity analysis, allowing decision-makers to assess the robustness of results. Sensitivity analysis helps identify the impact of changes in criterion weights, scores, or preferences on the final ranking, improving understanding of uncertainty and decision stability.
- Subjectivity and bias - MCDM methods rely on subjective judgments and preferences of decision-makers. The accuracy and consistency of these

judgments may vary, leading to potential biases and subjectivity in the decision process.

- Data availability and quality - MCDM methods heavily depend on data for criterion evaluation. Obtaining accurate and reliable data for all criteria can be challenging, particularly in complex decision problems. Incomplete or inaccurate data can affect the validity and reliability of results.
- Complex decision contexts - MCDM methods may struggle with decision problems involving a very large number of criteria and alternatives. The complexity of computations and interpretation of results can be challenging, requiring additional effort and expertise.
- Simplifying assumptions - MCDM methods often require simplifying assumptions to facilitate computation and comparison. These assumptions may oversimplify the decision problem, overlooking important combinations and interactions among criteria and potentially affecting result accuracy.
- Limited treatment of uncertainty - MCDM methods generally do not explicitly account for uncertainty and risk. While sensitivity analysis can provide insights into robustness, it may not capture all sources of uncertainty, limiting the ability to make fully informed decisions in uncertain environments.
- Lack of a universal method - No single MCDM method is universally applicable to all decision problems. The choice of a method depends on the characteristics of the decision problem, available data, the decision-maker's preferences, and the desired level of complexity. Selecting an appropriate method requires careful consideration and expertise.

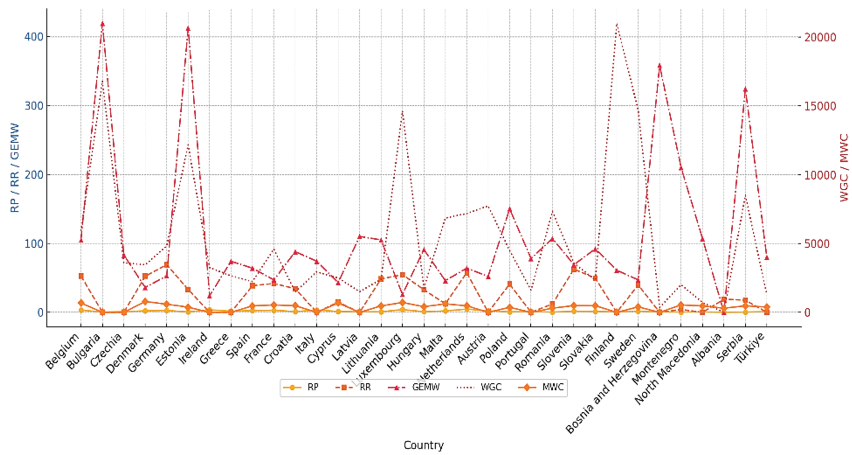
2. Research Design and Methodology

The diversity of multi-criteria decision-making (MCDM) methods provides an exceptionally valuable analytical framework for assessing indicator performance within the circular economy. These methods, grounded in the consideration of multiple criteria and objectives, enable decision-makers to systematically evaluate alternatives, set priorities, and formulate actions that foster a sustainable circular transition (Garcia-Bernabeu et al., 2020). Based on a review of the relevant literature, the author concludes that all indicators should carry equal importance in the subsequent analysis. Specifically, determining the weighting coefficients of the criteria (indicators) for further analysis is one of the key aspects of MCDM, as it evaluates each criterion's contribution to the construction of the multi-criteria model (Rađenović & Veselinović, 2017). Through a comparative analysis of two MCDM methods, the study will rank the country with the optimal environment for developing the postulates and principles of the circular economy and for improving existing performance. Accordingly, drawing on the experience of the top-ranked country, the other countries in the model should receive guidance for shaping their own trajectories in circular-economy development. The data required for this analysis were collected from the Eurostat database and refer to the performance values of circular economy indicators for the most recent year available. Based on the most recently available data from the Eurostat database, 33 countries were analyzed using the following circular economy indicators developed according to the methodology of the applied database:

- Resource productivity (Eurostat, a),
- Generation of waste excluding major mineral waste per GDP unit (Eurostat, b),
- Waste generation per capita (Eurostat, c),
- Recycling rate of municipal waste (Eurostat, d),
- Generation of municipal waste per capita (Eurostat, e).

Below is a descriptive statistics chart showing the trends of the above indicators for the most recent available years (Figure 1). The chart displays various indicators related to waste management and resource productivity. It points to significant oscillations in waste generation, while the parameters related to recycling and resource productivity are relatively stable. These fluctuations may stem from seasonal changes, economic activity, or regional differences in waste management. In interpreting the chart, indicators with optimal behavior are those that exhibit stability without large oscillations and remain within reasonable bounds.

Figure 1: Descriptive statistics for analyzed indicators according to last available data



*Note: RP- Resource productivity; GEMW- Generation of waste excluding major mineral wastes per GDP unit; WGC- Waste generation per capita; RR- Recycling rate of municipal waste; MWC- Generation of municipal waste per capita

Source: Authors' calculations

For this reason, in the multi-criteria model, identical weights are assigned to all indicators ($w_i = 0.2$), indicating their equal importance in contributing to the implementation of circular economy principles. One of the best-known methods within the MCDM approach is PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation), developed in 1982 by Jean-Pierre Brans. Its implementation in the Visual PROMETHEE Academic software environment involves three steps (Visual PROMETHEE Academic, 2025):

- First, a fuzzy preference relation is constructed for each individual criterion, which entails quantifying the intensity of preference of one alternative over another.
- Next, a global preference is formed at the level of the entire set of alternatives, aggregating all individual preferences.

- The third step is the construction of the ranking, i.e., ordering the alternatives based on their overall preferential values.

Within the analysis, the decision-maker defines a preference function R_i for each criterion, thereby forming a fuzzy preference relation denoted S_i (a, b), which reflects the extent to which alternative a is preferred to alternative b for the given criterion. This approach enables precise ranking of options depending on the weights and preferences defined by the analyst or decision-maker (Rađenović & Rajić, 2025):

$$S_i: AxA \rightarrow [0,1];\ S_i(a,b) = P_i\big(f_i(a) - f_i(b)\big) = P_i(d) \tag{1}$$

For each alternative from the set A, inflows and outflows are calculated based on the Phi (+, −) coefficient, which ranges from −1 to +1. The values of this coefficient reflect the degree to which one alternative dominates others in the overall set. Functionally, Phi (+, −) is analogous to the Pearson correlation coefficient, the higher its value, the greater the degree of dominance of the alternative. Parameters defined in this way enable the decision-maker to make a structured, transparent, and objective decision in a multi-criteria environment on the basis of quantitative and qualitative preferences (Brans et al., 1986):

$$\Phi^+(a) = \frac{1}{n-1}\sum_{x \in A} S(a,x) \tag{2}$$

$$\Phi^-(a) = \frac{1}{n-1}\sum_{x \in A} S(x,a) \tag{3}$$

In addition to PROMETHEE, the analysis also applied the ARAS method (Additive Ratio Assessment System), developed by Zavadskas and Turskis. Unlike other multi-criteria decision-making methods, ARAS is based on a utility function, through which the performance of each alternative is calculated and compared (Zavadskas & Turskis, 2010). In the aggregation process, the values of the weighted normalized matrix for each alternative A_i and the reference point A_0 are summed (Marjanović et al., 2019). In this way, the overall performance index S_i is obtained, as well as the index of the optimal alternative S_0. After normalization and optimization of the data, the utility index U_i is also derived, which enables the final ranking (Jovčić et al., 2020):

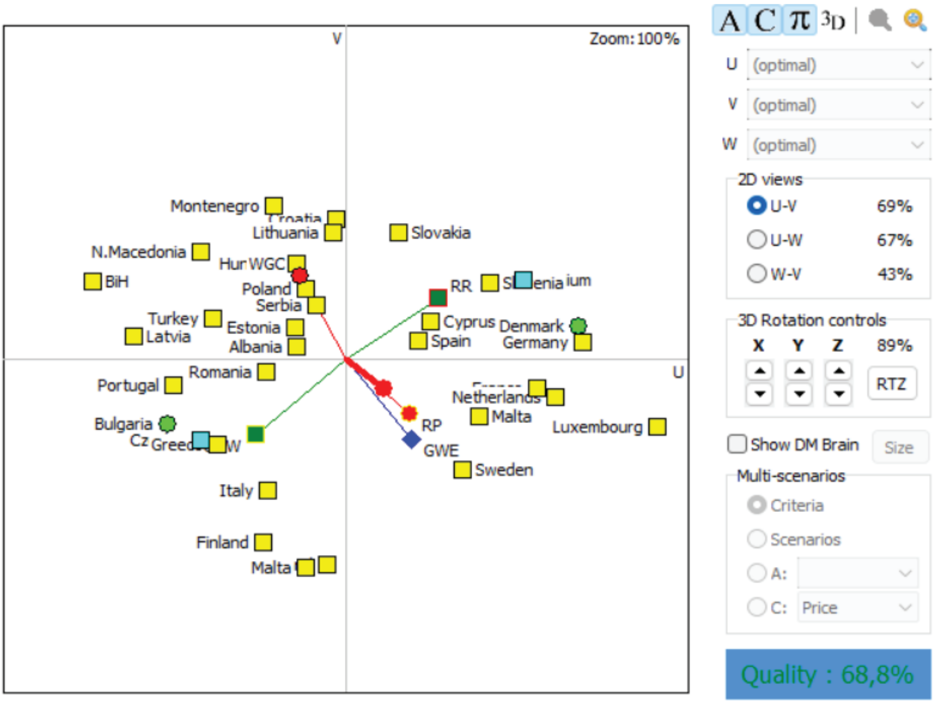
$$S_i = \sum_{j=1}^{n} y_{ij},\ U_i = \frac{S_i}{S_{i\,max}} \times 100\% \tag{4}$$

3. Results and Discussion

The following graphic presents the GAIA (Geometrical Analysis for Interactive Aid) matrix, which is used for multi-criteria decision analysis (Figure 2). This space enables the visualization of trade-offs between alternatives (countries) and criteria (indicators), grouping alternatives into “mini-clusters” by quadrants (Rađenović & Rajić, 2024). The vectors in the plot represent the direction and importance of each indicator, while the projections of countries relative to the vectors indicate their position in the circular economy. Germany, Denmark, and Spain show strong alignment with the indicators Recycling Rate (RR) and Resource Productivity (RP), whereas Serbia, Estonia, and Albania lie closer to the negative sides of the vectors, suggesting a need for interventions and policy improvements. In this context, multi-criteria methods such as PROMETHEE, combined with the GAIA tool, provide powerful visual insights into relationships between different indicators and alternatives (countries). The GAIA matrix offers a clearer understanding of how individual countries perform across multiple criteria, knowledge that is essential for strategy-making in the circular economy. In the GAIA chart shown, alternatives (countries) are depicted as yellow squares, while criteria are represented as vectors. The GAIA vector (red arrow) symbolizes the direction of the optimal compromise among all criteria, and the best alternative is located near that vector. GAIA analysis provides insight into: (a) Countries that are leaders in advancing the circular economy; (b) Criteria that exert the greatest influence on overall performance; (c) Clustering of countries by similarity, which can support the creation of regional strategies; (d) Linkages among indicators that help target measures with the highest impact.

The quality of the GAIA model is 68.8%, meaning that the two dimensions (U and V) explain almost 70% of the total variance in the data. This represents a sufficient level of reliability for drawing practical conclusions. GAIA analysis is a powerful decision-support tool in the domain of the circular economy. Based on the results, it is possible to formulate targeted policy measures and waste-management strategies. Countries with lower performance can use insights into the strengths of other countries as guidance for improvement. The GAIA method enables a visual understanding of complex interrelationships in a multi-criteria environment, crucial for making sustainable decisions in environmental planning. France, the Netherlands, Germany, and Malta are positioned closer to the GAIA vector and to the criteria RP and GWE. This indicates that these countries display balanced performance in terms of resource productivity and waste generation efficiency per unit of GDP. Serbia, Albania, Romania, and Estonia are located in the second quadrant, closer to the negative direction of the GAIA vector and indicators such as WGC, pointing to lower performance and higher waste generation per capita. Slovenia, Slovakia, and Sweden show an association with the Recycling Rate (RR), suggesting relatively high recycling rates. Italy and Finland are situated isolated from the main group, which may indicate a specific performance pattern not aligned with most other countries.

Figure 2: GAIA matrix



Source: Authors' calculations

The Western Balkan and Eastern European countries must improve resource productivity and expand recycling capacities in order to approach the optimal performance values of the circular economy. The "red stick" clearly indicates that countries such as the Netherlands, Luxembourg, and Sweden are leaders in the circular economy, and that development strategies should move in that direction. The most important priorities for improving performance are reducing waste per capita, increasing the recycling rate, and optimizing resources in production. The "red stick" (Decision stick) is a key element of the analysis:

- The direction and length of the stick indicate the preferred direction for optimizing the decision based on all criteria considered.
- It is oriented toward countries with better circular-economy performance, such as the Netherlands, Luxembourg, and Sweden.
- This means that the optimal strategy for improving circular-economy performance follows the path of countries with high resource productivity and effective waste-management systems.
- Countries that are farther from the stick's direction (Serbia, Bosnia and Herzegovina, Albania, North Macedonia) deviate significantly and have weaker circular-economy performance.

Applying the ARAS method and analyzing the values in the resulting table, it was determined that Sweden is the top-ranked country in terms of the selected circular-economy indicators. This position is the result of high values in both the overall performance index and utility, which sets Sweden apart as the most successful example of good practice within this research framework (Table 1).

Table 1: ARAS ranking results

Countries	Region	Si	Ui
Belgium	Western Europe	1754.05	8.33
Bulgaria	Eastern Europe	6737.03	32.00
Czech Republic	Central Europe	17204.34	81.71
Denmark	Scandinavia	3682.14	17.49
Germany	Central Europe	4330.49	20.57
Estonia	Baltics	5541.80	26.32
Ireland	Western Europe	12981.90	61.66
Greece	South Europe	3275.68	15.56
Spain	South Europe	2726.63	12.95
France	Western Europe	2802.12	13.31
Croatia	South Europe	5223.73	24.81
Italy	South Europe	2084.38	9.90
Cyprus	South Europe	3019.33	14.34
Letonia	Baltics	3223.11	15.31
Lithuania	Baltics	1611.93	7.66
Luxembourg	Western Europe	3015.19	14.32
Hungary	Central Europe	15423.64	73.25
Malta	South Europe	2289.79	10.88
Netherlands	Western Europe	7525.31	35.74
Austria	Central Europe	7774.15	36.92
Poland	Central Europe	7782.23	36.96
Portugal	South Europe	5047.70	23.97
Romania	Eastern Europe	1691.18	8.03
Slovenia	Central Europe	7758.45	36.85
Slovak Republic	Central Europe	4196.18	19.93
Finland	Scandinavia	2960.89	14.06
Sweden	Scandinavia	21054.94	100.00
Bosnia and Herzegovina	Western Balkan	15147.53	71.94
Montenegro	Western Balkan	716.46	3.40
North Macedonia	Western Balkan	2758.66	13.10
Albania	Western Balkan	1290.58	6.13
Serbia	Western Balkan	313.90	1.49
Türkiye	South-eastern Europe	9312.93	44.23

Source: Authors' calculations

Conclusion

The results obtained using the PROMETHEE and ARAS methods indicate a high degree of consistency in identifying the best- and worst-performing countries in terms of circular-economy performance. Sweden, as the leading country in the circular economy, emerges as a clear leader under both methods. In the PROMETHEE GAIA diagram, Sweden is positioned in the positive direction of the preference vector, confirming its dominant position. Likewise, within the ARAS methodology, it attains the maximum utility value as well as the highest overall score. At the other end of the spectrum, Western Balkan countries such as Serbia, Albania, and Montenegro show significantly lower values in both models. Low utility levels and placement in the lower-left quadrant of the GAIA space suggest the need for interventions in waste management, recycling, and efficient resource use. The results also indicate that medium-developed countries such as Hungary, the Czech Republic, and Ireland exhibit stable and balanced performance, suggesting their potential use as reference models for developing countries. The PROMETHEE method, as an advanced visual and analytical tool, enables the mapping of country performance through spatial relationships and directions of dominance. Its advantage lies in its ability to represent interactions among criteria, though it requires the subjective definition of preference functions. Conversely, the ARAS method offers transparent ranking based on established relative utilities, but tends to accentuate extreme values. Combining both methods in this study provides deeper insights and supports informed recommendations for future circular-economy policy. It is recommended to adopt hybrid analytical approaches that integrate visualization, ranking, and clustering to better capture regional and national specificities. In addition, improving institutional coordination, alignment with the EU legal framework, and the application of circular-economy indicators should be priorities in future initiatives of Western Balkan countries. The evaluation of the effectiveness of PROMETHEE and ARAS for assessing circular-economy performance is based on several parameters, including the ability to differentiate among alternatives, transparency in interpreting results, and flexibility in application to different data types.

In conclusion, multi-criteria decision-making methods provide decision-makers with valuable tools for evaluating and comparing alternatives based on multiple criteria. Decision-makers should be aware of the limitations and exercise caution when applying MCDM methods, ensuring that the chosen method aligns with the decision problem and taking into account expert judgment and sensitivity analysis to improve result robustness. MCDM methods continue to evolve with ongoing research and advances in the field. As decision-making becomes increasingly complex and multidimensional, MCDM methods provide a valuable framework for making informed decisions that account for multiple criteria and stakeholder preferences. By leveraging the strengths of MCDM methods and mitigating their limitations, decision-makers can enhance the quality and effectiveness of their decision processes. Decision-making is an essential technique, and the application of these methods has increased, offering a range of useful tactics for providing decision support. The MCDM method has the capacity to identify and more precisely resolve various conflicting interests.

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SUSTAINABLE DEVELOPMENT OF ENTREPRENEURS IN PROFESSIONAL, SCIENTIFIC, INNOVATIVE, AND TECHNICAL ACTIVITIES OF THE REPUBLIC OF SERBIA

Abstract

M-sector entrepreneurs engage in professional, scientific, innovative, and technical activities crucial for the development and implementation of technologically advanced work programs. The paper aims to determine the trend in business indicators among entrepreneurs in sector M and to identify the participation of entrepreneurs in this sector in overall entrepreneurial activities from 2010 to 2023. It can be concluded that the turnover and gross added value of entrepreneurs in sector M show a tendency to grow during the observed period; however, the oscillatory trend in the percentage participation of these indicators in total entrepreneurial activities is also noticeable. The number of entrepreneurs and employment in the M sector is growing with certain oscillations. The same indicators show a growing trend of percentage participation in total entrepreneurial activities.

Key words: *entrepreneurs, sector M, business indicators, technological entrepreneurship*

JEL classification: *L26, O30*

ОДРЖИВИ РАЗВОЈ ПРЕДУЗЕТНИКА У СТРУЧНИМ, НАУЧНИМ, ИНОВАЦИОНИМ И ТЕХНИЧКИМ ДЕЛАТНОСТИМА РЕПУБЛИКЕ СРБИЈЕ

Апстракт

Предузетници сектора М обухватају предузећа из области стручне, научне, иновационе и техничке делатности које су значајне за развој и примену технолошких напредних програма рада. Циљ рада је да утврди

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тренд кретања пословних индикатора предузетника у сектору М, као и да идентификује учешће предузетника овог сектора у укупним предузетничким активностима у периоду од 2010. до 2023. године. На основу резултата, може се закључити да промет и бруто додата вредност предузетника у сектору М показују тенденцију раста у посматраном периоду, али је приметан и осцилирајући тренд процентуалног учешћа ових показатеља у укупним предузетничким активностима. Бројност предузетника и запосленост у сектору М расте уз одређене осцилације. Исти показатељи бележе растући тренд процентуалног учешћа у укупним предузетничким активностима.

Кључне речи: *предузетници, сектор М, пословни резултати, технолошко предузетништво*

Introduction

Businesses must keep up with accelerated industrial development because it affects the development and competitiveness of economies competing within the boundaries of global technological development (Motiei, 2023). The issue of implementing higher technologies that require the development of specific entrepreneurial competencies among individuals has always been an actual but still insufficiently researched topic in the literature (Artyushenko, 2024). Technological progress is seen as one of the good means of taking advantage of market imperfections (Petti & Zhang, 2011). Accordingly, it is considered a challenge for entrepreneurs to use these technological changes to create new products and services and accelerate their launch on the market (Petti & Zhang, 2011). As the need to monitor technological achievements is a necessity in entrepreneurship, the subject of the paper is the companies of Sector M - professional, scientific, innovative, and technical enterprises. Accordingly, the paper aims to determine the trend of business indicators of entrepreneurs in sector M, as well as to identify the participation of entrepreneurs in this sector in overall entrepreneurial activities from 2010 to 2023.

The literature review identified several insufficiently researched issues. First, companies from sector M with intensive technological development come into the focus of researchers and state policy makers. Previous research has analyzed the operations and results of accounting firms (Lee & Cheng, 2018), management consulting firms (Gabbianelli & Pencarelli, 2024), and marketing firms (Mdangaya Mtange & Deya, 2024), but the summarized results of M-sector entrepreneurs are not sufficiently presented. Considering the growing trend of entrepreneurs' orientation toward technological entrepreneurship (Nikraftar et al., 2022) and the development potential of M-sector entrepreneurs, which is especially important for emerging countries, the study focuses on the analysis of M-sector entrepreneurs over thirteen years. Also, previous research focused on technological leadership was conducted among enterprises (Petti & Zhang, 2011; Petti & Zhang, 2013), while this study exclusively focuses on the entrepreneurs' business indicators. Secondly, previous research has indicated that technological progress and company performance are in a positive relationship (Petti & Zhang, 2011; Xin-gang & You, 2018). The drivers of technological progress are scientific, innovative, and technical enterprises, so the study focuses on the analysis of the achieved results of M-sector entrepreneurs, with the main goal of observing their growth trend.

The paper contains an introduction and four parts. The second part of the paper describes the results of previous research on the importance of entrepreneurship development for the economy and explains the importance of professional, scientific, and technical enterprises through technological entrepreneurship. In the third part of the paper, the sample is described, and an overview of the development of sector M is given. The fourth part of the paper analyzes the obtained results observed according to two aspects: the entrepreneur's business indicators and the participation of entrepreneurs of sector M in overall entrepreneurial activities. In the fifth part of the paper, the obtained results are discussed, along with the practical implications and limitations of the research.

1. Literature Review

1.1. Entrepreneurship as a Determinant of Sustainable Development

Entrepreneurship is often seen as a driving factor for economic development through the creation and commercialization of innovations, new ideas, and new technologies (Nikraftar et al., 2022). Entrepreneurs often focus on knowledge „from different sources, to encourage innovation and thus create added value for consumers" (Krstić & Jovanović Vujatović, 2022, p. 26). These activities will increase the competitiveness of the company (Prdić & Kuzman, 2023). Entrepreneurship is "largely focused on respective behaviors and decisions, exploration and exploitation of opportunities, as well as development and implementation of resources, which is necessary for the formation of a profitable business" (Nikraftar et al., 2022, p. 79, Janošik et al., 2024). The three key dimensions of entrepreneurial orientation are risk-taking, innovation, and proactivity (Libingi & Bbenkele, 2024). Risk-taking implies "gambling" with something that has value for the entrepreneur. Innovation focuses on constantly searching for new connections between phenomena to discover new ideas and improve existing products and processes. The proactive orientation of the entrepreneur is directed towards the organization's future, the changes that will happen, or the creation of changes itself.

Researchers highlight entrepreneurs as the main drivers of economic development (Motiei, 2023) since they create new business opportunities and influence the employment rate and income level (Nikraftar et al., 2022). The key to an entrepreneur`s success is a focus on increasing innovation performance and innovative processes with a special focus on technological innovation (Hwang & Choi, 2024), which leads to increased "competitive advantage and sustainable activities in international business environment" (Nikraftar et al., 2022, p. 79). Additionally, entrepreneurial activity is vital in ensuring socioeconomic and political stability (Artyushenko, 2023). The role of entrepreneurs in conditions of economic destabilization and lack of financial resources is also significant – with specific support, entrepreneurs can quickly and rationally stimulate the development of economic competition (Artyushenko, 2023). Premović et al. (2024, p. 59) particularly emphasize the role of small and medium-sized enterprises and entrepreneurs in developing economies since they "contribute significantly to gross added value, affect financial stability, and in crisis are a stabilizer, often a driver of economic development".

Entrepreneurship development is “a dominant goal of developing countries to eliminate unemployment, to develop economic growth, to heighten market mobility, to use innovation and technology” (Motiei, 2023, p. 275). In the structure of the Serbian sector of small and medium-sized enterprises and entrepreneurs (SMEE), entrepreneurs contain 74.6% of the number of enterprises, employ 27.3% of the total number of employees in SMEE, realize 18.1% of the turnover of SMEE, and 24% of the gross added value of SMEE (Burzanović, 2024).

The entrepreneurship development and its contribution to economic development largely depend on entrepreneurial skills and competencies. Entrepreneurial competencies can be defined as initiative, willingness to take reasonable risks, ability to generate and implement new ideas, and responsibility for decisions taken (Artyushenko, 2023). Key competencies are the basis for the development of entrepreneurial thinking, leadership qualities, communication skills, and the ability to solve complex problems (Artyushenko, 2024). The opportunity-based view of entrepreneurship highlights the importance of cultivating entrepreneurial skills and traits for exploring and identifying opportunities to best understand the process of using them (Libingi & Bbenkele, 2024). This theory is continued by the experiential learning theory, which promotes learning as a transformation of experience to create the knowledge necessary to use perceived opportunities (Libingi & Bbenkele, 2024).

Considering the contribution of entrepreneurship to the comprehensive development of developing countries, it is useful to note the limitations that this sector faces. Raza et al. (2024, p. 1) identify “market-related challenges, financial constraints, limitations in human capital, institutional barriers, sociocultural factors, technological shortcomings, and infrastructural challenges” as important obstacles to entrepreneurial development. Motiei (2023) considers that limited financing, especially in developing countries, is a key limiting factor of entrepreneurial development, while Chowdhury (2007) identifies the lack of good skills needed to start and run a business as a key constraint. Nikraftar et al. (2022) discuss technological factors that have limited the progress of entrepreneurs, including a lack of interaction and technical skills, wrong choice of technology, lack of knowledge of new technologies, and inadequate human capital. SMEs in Serbia face difficulties in accessing finance, high operating costs, and insufficient connectivity with the international market (Fedajev et al., 2022).

Entrepreneurship and sustainable development are interconnected through three fundamental dimensions—economic, social, and environmental. Economic sustainability is achieved through innovation and competitiveness; social sustainability arises from employment creation and social responsibility; and environmental sustainability depends on efficient resource use and ecological awareness (Hall et al., 2010).

According to the Triple Bottom Line (TBL) approach (Elkington, 1998), enterprises must simultaneously pursue profit (economic value), people (social equity), and planet (environmental protection). Entrepreneurial orientation-defined by innovativeness, proactiveness, and risk-taking (Lumpkin & Dess, 1996)-serves as a mechanism that integrates these three aspects into the company’s strategic behavior. In this sense, sustainable entrepreneurship is more than just starting a business; it represents an approach to creating and implementing innovations that have positive social and environmental impacts while maintaining economic viability (Hockerts & Wüstenhagen, 2010).

Accordingly, the connection between sustainable business and entrepreneurship is reflected in the following segments:

- Innovation as a sustainability driver – Entrepreneurial firms that continuously innovate are more capable of developing environmentally friendly technologies, reducing waste, and optimizing production processes.
- Strategic orientation toward sustainability – Enterprises with an entrepreneurial orientation tend to incorporate sustainability goals into their core strategies, which leads to stronger market positions and improved stakeholder relations.
- Human capital and organizational learning – Entrepreneurial leadership promotes a culture of continuous learning, creativity, and employee engagement, which are prerequisites for long-term sustainability.
- Socio-environmental value creation – Sustainable entrepreneurship contributes not only to financial performance but also to community development, social inclusion, and environmental protection.

1.2. Entrepreneurs in Professional, Scientific, Innovative, and Technical Activities

The development of the entrepreneurial spirit also plays a significant role in industries with high innovation and technological capabilities (Nikraftar et al., 2022). Recent research indicates that the focus is increasingly on technological entrepreneurship and activities that have the potential to advance modern business trends (Miletić et al., 2025). Nikraftar et al. (2022, p. 77) believe that "the development of technology plays a significant role in economic growth and development", and accordingly, M-sector companies will be viewed through the prism of technological entrepreneurship. Technological opportunities provide these companies with an incentive to conduct and commercialize scientific, innovative, and technical research at a high level. Technological entrepreneurship "is defined as a style of business leadership that involves identifying high-potential, technology-intensive commercial opportunities, gathering resources such as talent and capital, and managing rapid growth and significant risk using principled decision-making skills" (Motiei, 2023, p. 274-275). In scientific, professional, innovative, and technical enterprises, entrepreneurs "use technology as their driving factor in transforming resources into goods and services, creating an environment conducive to industrial growth" (Motiei, 2023, p. 277).

Numerous companies and institutions are increasingly investing "in the knowledge and education of their employees, offering them numerous programs for the acquisition and improvement of various knowledge and skills" (Premović et al., 2024, p. 60). These activities also contribute to the future economic development (Ognjanović & Kahrović, 2023). Therefore, it can be concluded that educational institutions provide significant support in encouraging the entrepreneurial economy and entrepreneurial abilities of individuals. Entrepreneurship education is especially important for young people in Serbia since more than half of the employees work in SMEs (Premović et al., 2024). The entrepreneurial education program should include (Artyushenko, 2023): acquisition of basic theoretical knowledge about entrepreneurship; introduction of practical business projects where students will develop their start-ups and acquire the skills of their management; functioning of business incubators that will effectively provide comprehensive support to the most promising start-ups. All of the above are being developed to enable entrepreneurs to identify and use technological and innovative opportunities for the creation of new or significantly improved products and their successful commercialization (Petti & Zhang, 2011).

Professional, scientific, innovative, and technical entrepreneurs are focused on identifying intensive business opportunities, obtaining necessary resources, and managing growth and possible risks with the ultimate goal of using these opportunities to create value (Petti & Zhang, 2011). According to the theory of information asymmetry, some researchers believe that the value of high-tech companies is based on R&D activities (Chen et al., 2023). Jovanović et al. also agree with this (2024), proving that investment in R&D activities affects the company's patent activity. In other words, "inventions and technological development are essential for value creation and competitiveness, but it is the discovery of technological opportunities and their commercial exploitation that makes the difference" (Petti & Zhang, 2011, p. 9). This is the basis of technological entrepreneurship: transforming promising innovations and technologies into value (Petti & Zhang, 2011). Based on the above, it can be concluded that entrepreneurs from the field of scientific, innovative, and technical activities are specialized in finding and identifying new opportunities through high-tech research and development programs, supporting technology for creating innovations and their technical feasibility.

The entrepreneurial structure within Sector M is distinguished by a high level of human capital intensity. Entrepreneurs are usually highly educated professionals who rely on expertise, creativity, and innovation rather than on physical capital (Krstić et al., 2016; Lee & Cheng, 2018). Such enterprises are often small or medium-sized but play a disproportionate role in generating added value, technological advancement, and employment in advanced economies (European Commission, 2022).

Professional and scientific entrepreneurs act as intermediaries between research institutions and the market, transforming scientific knowledge into commercially viable solutions (Audretsch & Link, 2019). They often engage in applied research, technological consulting, and product development, thereby stimulating innovation ecosystems at regional and national levels (Cooke, 2007). Innovation-driven entrepreneurship in this sector is also associated with a higher degree of digitalization, international collaboration, and participation in global value chains (Zhou & Wu, 2018).

From an economic perspective, entrepreneurs in professional and technical services contribute substantially to GDP growth and export potential, as their outputs are typically knowledge-intensive services with high value-added content (European Commission, 2022). According to the OECD (2023), this sector has become one of the fastest-growing components of the modern service economy, driven by the rising demand for expert knowledge in areas such as engineering design, IT consultancy, R&D, and sustainability management.

Moreover, these entrepreneurs play a pivotal role in enhancing organizational competitiveness by supporting innovation processes in other sectors. For instance, engineering and consulting firms help manufacturing enterprises integrate advanced technologies, improve energy efficiency, and comply with environmental standards (Gabbianelli & Pencarelli, 2024). Thus, professional and scientific entrepreneurship indirectly promotes sustainable business practices across the economy.

Despite their importance, entrepreneurs in this sector often face structural challenges, such as limited access to financing, regulatory complexity, and skills shortages in advanced technological fields (Nikraftar et al., 2022). In emerging economies, additional barriers include weak links between academia and industry, low investment in R&D, and insufficient institutional support for innovation. These constraints can limit the scalability and internationalization of professional and scientific enterprises, despite their high innovation potential.

As economies move toward sustainability and digital transformation, the role of professional, scientific, and innovative entrepreneurs becomes increasingly strategic. By integrating sustainability principles into consulting, engineering, and research activities, these enterprises can help accelerate the transition toward a green and circular economy (Petti & Zhang, 2011). Strengthening cooperation between universities, research centers, and entrepreneurial firms is therefore essential for improving knowledge transfer and fostering sustainable innovation.

Very few studies analyze the contribution of technological entrepreneurship to the growth and development of companies. Nikraftar et al. (2022, p. 76) conclude "that the key factors affecting the success of the technological entrepreneurship process in nanotechnology were classified into five general categories: organizational, environmental, institutional, individual, and technology factors". Motiei (2023, p. 283) concludes that the key factors that influence technological entrepreneurship "are increasing the productivity of goods and services, supporting entrepreneurship, increasing the efficiency of monetary policies that are in the first level". Chen et al. (2023) prove that scientific innovation is positively and significantly related to the successful listing of technical attributes. The development of technology-intensive enterprises from the M sector is necessary for emerging countries, so the study focuses on the analysis of the achieved results of entrepreneurs and their participation in overall entrepreneurial activities.

1.3. Key Aspects of Entrepreneurship in the Republic of Serbia

Entrepreneurship in Serbia represents a dynamic but still developing segment of the national economy (Ivanović-Đukić et al., 2012). In 2023, there were almost 249,000 registered entrepreneurs, employing around 266,000 workers, and generating revenues exceeding 2.3 trillion dinars (approximately 20 billion euros). The geographical distribution shows a concentration of entrepreneurial activity in Belgrade (28.6%) and Vojvodina (25.1%), while Šumadija and Western Serbia account for 28.4%, and Southern and Eastern Serbia 17.9% (World Bank Group, 2023).

The sectoral structure of entrepreneurship highlights the dominance of wholesale and retail trade (around 17% of entrepreneurs), followed by professional, scientific, technical, and innovative activities (16.9%), manufacturing (14.1%), construction (10.7%), and transport and storage (8.7%). Despite this relatively diversified base, entrepreneurship remains vulnerable to fluctuations, as shown by the 21,712 newly registered entrepreneurs in the first half of 2024, which marks a decline compared to the previous year, while more than 11,000 entrepreneurial ventures are closed annually (Serbia Business, 2024).

The startup ecosystem, particularly in Belgrade and Novi Sad, has recently gained international recognition. Its total value reached USD 1.116 billion in 2023, representing a 66% year-on-year growth. These ecosystems are ranked first in the Western Balkans and tenth in Central and Eastern Europe, with strengths in available talent and above-average female participation. The average age of founders in Serbia is 35 years, younger than the European and global average, and female entrepreneurs make up 31.2% of the total, with a large share being highly educated (Startup Genome, 2023).

Nevertheless, challenges remain significant. The number of startups decreased by about 20% in 2025, reflecting difficulties in sustaining early-stage businesses and scaling them beyond initial funding rounds. Many entrepreneurs still rely heavily on grants and operate with limited international ambitions. Moreover, while Serbia has a strong technical talent pool, gaps persist in areas such as market expansion, business development, and sales (The Digital Serbia Initiative, 2025). Taken together, these findings suggest that entrepreneurship in Serbia has established a strong quantitative base and promising ecosystems, yet it continues to face structural challenges related to sustainability, scaling, and diversification. Policies that support innovation financing, internationalization, and entrepreneurial education-particularly for women and younger founders-will be essential for further strengthening the sector.

2. Methods

2.1. Data Source and Sample Description

Given the importance of technological development for entrepreneurship, this paper focuses on Sector M – professional, scientific, innovative, and technical enterprises. The aim is to determine the trend of business indicators of entrepreneurs in Sector M and to identify their participation in overall entrepreneurial activities in Serbia from 2010 to 2023. The study uses secondary data from the Statistical Office of the Republic of Serbia – specifically, the annual reports Entrepreneurs in the Republic of Serbia for the period 2010–2023.

Previous studies have analyzed accounting firms (Lee & Cheng, 2018), management consulting firms (Gabbianelli & Pencarelli, 2024), and marketing firms (Mdangaya Mtange & Deya, 2024), but the summarized results of M-sector entrepreneurs are not sufficiently presented. Considering the growing orientation toward technological entrepreneurship (Nikraftar et al., 2022) and its development potential-especially in emerging countries-this study focuses on the analysis of M-sector entrepreneurs over thirteen years.

The sample includes entrepreneurs from sector M in the Republic of Serbia. According to the Decree on the Classification of Activities (2010), sector M includes professional, scientific, innovative and technical activities, i.e., accounting and legal activities, management activities and consultancy related to management, architectural and engineering activities, scientific R&D, advertising and market research, and other professional, scientific and technical activities. One recommendation for increasing productivity among Serbian entrepreneurs is to focus on developing innovative activities (Ognjanović et al., 2025). The business results of these entrepreneurs were analyzed and monitored for the period from 2010 to 2023, and the data were taken from the report "Entrepreneurs in the Republic of Serbia" for each year individually.

2.2. Indicators and Analytical Approach

The analysis is based on four key business indicators:

1) Number of entrepreneurs;
2) Number of employees;
3) Turnover;
4) Gross added value.

The indicators were observed annually to identify trends and relative participation of M-sector entrepreneurs within total entrepreneurial activities in Serbia. Percentage shares were calculated to determine the contribution of Sector M to the national entrepreneurial landscape.

Accordingly, the results of the study should answer the following research questions:

1) What is the trend of business indicators of entrepreneurs in sector M in the observed period?

2) What is the participation of entrepreneurs of the M sector in the total entrepreneurial activities according to the entrepreneurs' business indicators in the observed period?

3. Results

In the M sector in 2023, 23657 companies were registered in Serbia, which generated 469972.1 million RSD of gross added value, investments of 33125.2 million RSD, and employed 135300 workers (Statistical Yearbook, 2024). In the EU, the professional, scientific, and technical activity in 2021 had 4.8 million companies, generated 681.8 billion euros in added value, 1433338 € in net turnover, and employed 11.6 million people, which accounts for 7.4% of total employment (Eurostat, 2024). The labor productivity of the professional, scientific, and technical activities in the EU in 2021 was 58700 € per employee, while the average personnel costs per employee were 52300 € (Eurostat, 2024). Leogrande (2024) states that the average value of professional, scientific, and technical companies increased by 83.18% in OECD countries from 2005 to 2022.

3.1. Business Indicators of Entrepreneurs in Sector M

A summary of the business results of sector M entrepreneurs is shown in Table 1. Entrepreneurs were observed for the period from 2010 to 2013 according to the achieved business indicators: number of entrepreneurs, number of employees, turnover, and gross added value. According to the results obtained, it can be concluded that the number of entrepreneurs in this sector is growing year by year, except in 2023. Employment in sector M shows oscillations in the observed period: until 2015, it records alternating growth and decline, after which employment grows until 2022 and then again shows a tendency to fall. Employment is almost 30% higher in 2023 compared to 2010. The value of turnover is growing in the observed period. In 2023, the turnover is higher by 592%, which indicates a growing trend in entrepreneurial activities regardless of fluctuations in the number of employees. The value of gross value added also shows an exceptional growth, except in 2020. It is assumed that this result is a reflection of the COVID crisis. In the case of this indicator, a high percentage of growth was identified in 2023 compared to 2010 - 417%.

Table 1: Business indicators of entrepreneurs in sector M: Professional, scientific, innovative, and technical activities (2010-2023)

Year	Number of entrepreneurs	Number of employees	Entrepreneur's turnover (in millions of RSD)	Gross added value of entrepreneurs (in millions of RSD)
2010	24.365	13.494	35.881	17.935
2011	25.367	11.533	41.542	21.858
2012	26.119	12.227	48.173	25.149
2013	25.832	11.773	49.889	26.039
2014	27.002	12.041	50.012	28.118
2015	27.844	14.214	55.450	31.211
2016	29.845	15.339	61.585	34.665
2017	32.323	16.328	69.963	39.350
2018	35.055	17.609	83.659	46.993
2019	37.884	18.389	97.111	54.834
2020	41.566	19.764	95.510	53.654
2021	42.789	20.575	117.251	65.885
2022	46.174	18.576	131.062	74.792
2023	42.097	17.531	212.452	114.693

Source: Entrepreneurs in the Republic of Serbia from 2010 to 2023, Statistical Office of the Republic of Serbia, Belgrade

The movement of business indicators of the entrepreneurs in sector M for the observed period can also be shown graphically. Figure 1 shows the trend in the number of companies and employment, while Figure 2 shows the trend in turnover and gross added value.

Figure 1: Trends in the number of and entrepreneurs and employment in M sector

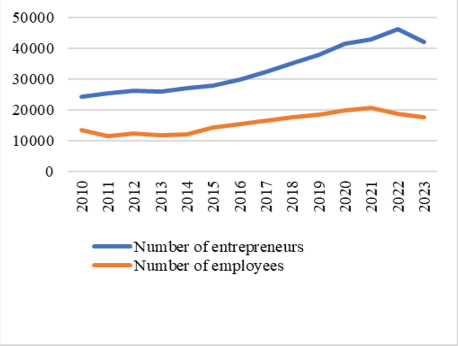
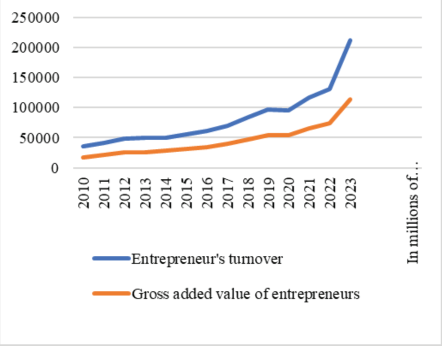


Figure 2. Trends in entrepreneur`s turnover and gross added value in M sector



Source: Processing of data collected from the reports "Entrepreneurs in the Republic of Serbia" (2010-2023)

3.2. Participation of Sector M Entrepreneurs in Overall Entrepreneurial Activities

The analysis of the M-sector entrepreneurs can also be monitored based on the value of the participation of business indicators in the total entrepreneurial activities. The analysis covers the same period, from 2010 to 2023, and is based on the data presented in the reports Entrepreneurs in the Republic of Serbia for each observed year. The percentage participation was calculated for each observed indicator by comparing the value of the indicators achieved by the entrepreneurs of sector M with the value of the indicators for all entrepreneurs for each observed year (Table 2).

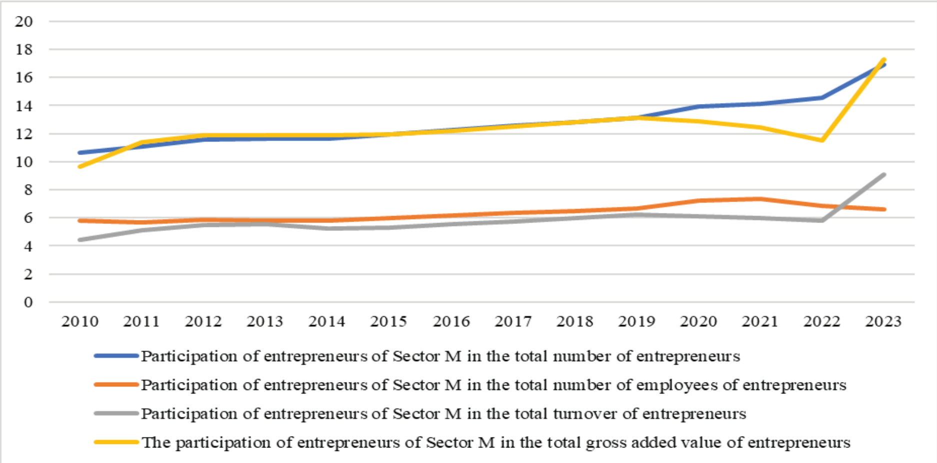
Table 2: Participation of M-sector entrepreneurs in total entrepreneurial activities according to business indicators (2010-2023)

Year	Participation of entrepreneurs of Sector M in the total number of entrepreneurs	Participation of entrepreneurs of Sector M in the total number of employees of entrepreneurs	Participation of entrepreneurs of Sector M in the total turnover of entrepreneurs	The participation of entrepreneurs of Sector M in the total gross added value of entrepreneurs
2010	10.65	5.81	4.46	9.68
2011	11.10	5.67	5.14	11.36
2012	11.55	5.89	5.46	11.88
2013	11.63	5.79	5.52	11.86
2014	11.66	5.80	5.22	11.91
2015	11.96	6.01	5.33	11.94
2016	12.25	6.19	5.52	12.20
2017	12.56	6.33	5.76	12.51
2018	12.84	6.48	6.00	12.79
2019	13.14	6.65	6.24	13.11
2020	13.94	7.25	6.10	12.88
2021	14.11	7.34	6.00	12.43
2022	14.56	6.83	5.81	11.53
2023	16.91	6.61	9.10	17.30

Source: Entrepreneurs in the Republic of Serbia from 2010 to 2023., Statistical Office of the Republic of Serbia, Belgrade.

The percentage share of observed business indicators of entrepreneurs of sector M can also be shown graphically by year (Figure 3).

Figure 3: Percentage share of business indicators of M-sector entrepreneurs in total entrepreneurial activities



Source: Processing of data collected from the reports "Entrepreneurs in the Republic of Serbia" (2010-2023).

If we observe at the number of entrepreneurs, their percentage share in the total number of entrepreneurs is growing in the period from 2010 to 2023. Participation in the total employment of M-sector entrepreneurs shows a tendency to grow, except for a slight decrease in 2022 and 2023. The percentage share in the total turnover of entrepreneurs achieves a slight growth until 2020, where it records a slight decline until 2023. The share of this indicator records above-average growth in 2023. An almost identical trend was recorded in the case of the participation of M-sector entrepreneurs in gross added value. Growth was identified until 2020, then a decline occurred over the next three years, and in 2023, this indicator would have above-average growth.

4. Discussion

The research results can be used to interpret the research questions. Namely, if we observe the trend of business indicators of entrepreneurs in the M sector, we can conclude that the number of entrepreneurs and employment will grow until 2021 and 2022, respectively, and then decline. Such results are in line with the conclusion of Jaško et al. (2023), which also indicates changes in the number of entrepreneurs and employment among entrepreneurs in Serbia. The same authors interpret this result as the fact that the Serbian entrepreneurial ecosystem is facing challenges that are higher than average. Worryingly, the number of entrepreneurs is falling in 2023 in the M sector, which is not typical considering that technology entrepreneurship is in its infancy. On the other hand, the share of M-sector entrepreneurs in the total number of entrepreneurs shows constant growth in the observed period. Such results indicate the competitiveness of professional, scientific, innovative, and technical entrepreneurs compared to other activities in Serbia. Second, the reduction in the number of employees can be interpreted in the sense of technological development - the introduction of modern technology and the digitalization of business processes reduce the need for entrepreneurs for the labor force. In the obtained results, it is also noticeable that the share of M-sector employment in the total employment of entrepreneurs does not show major fluctuations. These results lead to the conclusion that despite the reduction in the number of employees, the turnover of entrepreneurs in sector M is increasing, which indicates the development potential of scientific, innovative, and technical entrepreneurs.

Third, the remaining two observed indicators, turnover and gross added value, show a clear growth trend in the observed period. Pechlaner et al. (2004) reach similar findings, stating that turnover growth contributes to company growth. Such results are encouraging, especially for future investments, since the growth of turnover heralds the growth of cash flow (Ibrahimi & Meghouar, 2019). On the other hand, it is worrying that the participation of turnover and gross value added of the M sector in the total entrepreneurial results achieved a drastic decline in 2022, bearing in mind the potential of scientific, innovative, and technical entrepreneurship. As a possible explanation for such results, Pechlaner et al. (2004) state the lack of growth capital and qualified employees.

Practical implications. The growing trend of turnover and gross value added among M-sector entrepreneurs indicates the existence of means to overcome one of the key problems faced by Serbian entrepreneurs - the lack of financial resources. It is recommended that entrepreneurs accumulate part of the realized turnover value and gross added value to use for all future investments and business expansions. However, unfavorable trends were identified in terms of the number of entrepreneurs and employment in the M sector, as well as a decrease in the estimated share of turnover and gross value added in 2022 in the total entrepreneurial activity. First of all, it is necessary to find the factors that caused the drop in results. Potential causes include the lower attractiveness of scientific, innovative, and technical entrepreneurship since it requires specialized entrepreneurial skills, abilities, knowledge, and experience, for which not all entrepreneurs are trained. Such results can also explain the lower percentage participation of turnover and gross value added in total entrepreneurial activities. Entrepreneurs must also monitor the trend of employment, which shows oscillations in the observed period. This may be the result of the application of modern technology that replaces the workforce, but entrepreneurs of professional, innovative, and technical activities must always keep in mind that the knowledge, experience, and skills of employees cannot be replaced by machines.

Research limitations and recommendations for future research. The research provides an insight into the trend of the results of entrepreneurs of sector M without analyzing the nature of the relationship between these results and some other business factors. Therefore, it is recommended that future studies additionally explore the impact of sociological, economic, environmental, and technological business factors on the results of the entrepreneur's work. It is also recommended that the number of entrepreneurs' indicators that are monitored expand (financial performance, customer satisfaction performance, investment performance, etc.). Another limitation refers to the fact that the study does not provide insight into the reasons for the oscillating trend of turnover and gross value-added participation in overall entrepreneurial activities. The recommendation for future studies is to analyze the factors that lead to such oscillations and to what extent the observed factors can be under the control of the entrepreneur.

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INTEGRATING SUSTAINABILITY PERFORMANCE INDICATORS INTO DIGITAL MATURITY MODELS: A SYSTEMATIC LITERATURE REVIEW

Abstract

Digital transformation and sustainability have emerged as two dominant and interrelated strategic imperatives for contemporary organizations. However, existing digital maturity models predominantly focus on technological capabilities while largely overlooking sustainability performance outcomes. This study addresses this gap by systematically reviewing the literature on integrating sustainability performance indicators into digital maturity models. A systematic literature review was conducted following Kitchenham's protocol and the PRISMA framework, covering peer-reviewed journal articles published between 2016 and 2026 and retrieved from the Web of Science and Scopus databases. The review synthesizes conceptual and empirical contributions, identifies commonly applied environmental, social, and governance (ESG) indicators, and examines methodological approaches for integration. The findings reveal three dominant integration approaches: combined maturity models, parallel assessment frameworks, and embedded dimensional models. Environmental indicators are most frequently operationalized, while social and governance dimensions remain comparatively underdeveloped. The analysis also highlights persistent challenges related to limited empirical validation, lack of standardization, data availability constraints, and SME applicability. The study contributes by providing a structured synthesis of integration mechanisms and proposing a conceptual foundation for integrated digital–sustainability maturity assessment, offering guidance for researchers and practitioners seeking to advance holistic organizational evaluation frameworks.

Key words: *digital transformation, maturity models, sustainable performance*

JEL classification*: M15, Q56*

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ИНТЕГРИСАЊЕ ПОКАЗАТЕЉА ОДРЖИВИХ ПЕРФОРМАНСИ У МОДЕЛЕ ДИГИТАЛНЕ ЗРЕЛОСТИ: СИСТЕМАТСКИ ПРЕГЛЕД ЛИТЕРАТУРЕ

Апстракт

Дигитална трансформација и одрживост постале су два доминантна и међусобно повезана стратешка императива савремених организација. Међутим, постојећи модели дигиталне зрелости претежно су усмерени на технолошке капацитете, док у великој мери занемарују концепт одрживих перформанси. Овај рад настоји да одговори на наведени јаз кроз систематски преглед литературе о интеграцији показатеља одрживих перформанси у моделе дигиталне зрелости. Систематски преглед литературе спроведен је применом Kitchenham протокола и PRISMA оквира, обухватајући рецензиране научне радове објављене у периоду 2016–2026. године и идентификоване у базама Web of Science и Scopus. Преглед синтетизује концептуалне и емпиријске доприносе, идентификује најчешће коришћене еколошке, социјалне и управљачке (ESG) индикаторе и анализира методолошке приступе њиховој интеграцији. Резултати указују на три доминантна приступа интеграцији: комбиноване моделе зрелости, паралелне оквире процене и моделе са уграђеном димензијом одрживости. Еколошки индикатори су најзаступљенији, док су социјална и управљачка димензија релативно слабије развијене. Анализа такође идентификује одређене изазове који се односе на ограничену емпиријску валидацију, недостатак стандардизације, ограничења у доступности података и примењивост у малим и средњим предузећима. Рад доприноси пружањем структуриране синтезе механизама интеграције и предлагањем концептуалне основе за процену интегрисане дигитално-одрживе зрелости, нудећи смернице истраживачима и практичарима за развој холистичких оквира организационе евалуације.

Кључне речи: *дигитална трансформација, модели зрелости, одрживе перформансе*

Introduction

There are two megatrends that have transformed the business landscape: digital transformation and the sustainability imperative, which have put pressure on organizations worldwide to increase their digital capabilities and simultaneously address environmental degradation, social inequality, and governance accountability (Singh et al., 2025; Šimberová et al., 2022). These dual challenges have catalyzed scholarly and practitioner interest in frameworks that can holistically assess organizational readiness and performance across both dimensions (Fortier et al., 2025; Martínez-Peláez et al., 2024).

While digital maturity and sustainability performance have traditionally been assessed as two separate areas using different frameworks and metrics, digital maturity models tend to focus on technological infrastructure, digital capabilities, business process transformation, and the creation of an innovation-oriented organizational culture (Merdin et al., 2022), whereas sustainability assessment frameworks tend to focus on environmental indicators (e.g., emissions and resource consumption), social metrics (e.g., employee well-being and community engagement), and governance practices (e.g., ethical leadership and transparency) (Sell, 2024).

Nevertheless, the increasing recognition of the interdependence between digitalization and sustainability has resulted in the development of integrated approaches, which acknowledge that digital technologies can enhance sustainability performance, while sustainability objectives can simultaneously shape and direct digital transformation strategies (Martínez-Peláez et al., 2024; Fatemi, 2024; Fortier et al., 2025).

The integration of sustainable performance indicators into digital maturity models represents a paradigm shift toward comprehensive organizational assessment (Fortier et al. 2025; Münnich et al., 2025) because sustainability considerations can inform more responsible and resilient digital transformation strategies (Eisner et al. 2022; Nicolau & Petcu, 2026), and digital technologies can be enablers of sustainability goals (Fatemi, 2024). Recent research shows that firms that pursue „twin transformation" or the simultaneous advancement of sustainability and digital agendas outperform firms that handle these imperatives separately (Fatemi, 2024).

This review synthesizes findings from over 30 highly relevant peer-reviewed journal articles published between 2016 and 2026, and provides researchers, practitioners, and policymakers with a comprehensive review of current knowledge, methodological approaches, and strategic pathways for advancing integrated assessment frameworks, contributing to both academic discourse and practical application in identifying best practices, persistent challenges, and charting directions for future research and development.

Despite the growing body of literature on digital maturity models and sustainability performance assessment, the integration of these two domains remains theoretically fragmented and methodologically inconsistent. Existing studies either integrate sustainability in a limited manner within digital frameworks or treat digitalization only as an enabling factor for sustainability outcomes. This study addresses this gap by systematically mapping existing models, critically comparing their integration mechanisms, and providing a clearer pathway for future research and practical implementation. Accordingly, the primary objective of this study is to systematically examine how sustainability performance indicators are incorporated into digital maturity models, identify dominant integration approaches, and synthesize existing conceptual and empirical contributions. To contextualize this research gap and establish a conceptual basis for the systematic review, the following section outlines the theoretical foundations related to digital maturity models, sustainability performance indicators, and the emerging twin transformation paradigm. Based on the identified research gap, the central research question guiding this study is: How are sustainability performance indicators integrated into digital maturity models, and what dominant approaches characterize this integration?

The remainder of the paper is structured as follows. The next section presents the theoretical background, outlining key concepts related to digital maturity models, sustainability performance indicators, and the twin transformation paradigm. This is followed by the methodology section, which describes the systematic literature review design and research procedures. The subsequent section presents the thematic analysis and synthesis of key findings from the reviewed studies. Finally, the paper concludes with a discussion of implications, limitations, and directions for future research.

1. Theoretical Background

1.1. Digital Maturity Models: Evolution and Concepts

Digital maturity models offer a structured approach to analyzing the digital capabilities of an organization and determining future growth opportunities. While originally rooted in early capability maturity models (CMM) that focused on evaluating software development processes, today, they have evolved into more holistic frameworks that examine strategy, culture, technology, and operations (Merdin et al., 2022). Digital maturity models typically evaluate organizations on a variety of dimensions, such as technological infrastructure (hardware, software, connectivity), digital competencies (employee skills, digital literacy), business process transformation (automation, optimization), data governance (data collection, analysis, and utilization), innovation capacity (experimentation, agility), and digital leadership (vision, managerial support) (Quenum et al., 2025).

The progression of digital maturity models parallels wider changes in organizational technology adoption patterns, from initial emphasis on information technology infrastructure and simple digitization of manual processes, to the more advanced capabilities of artificial intelligence, Internet of Things (IoT) integration, cloud computing, and data analytics (Lichtenthaler, 2020; Sira, 2025). While digital maturity models typically are applied to technology and the ability of an organization to adopt digital tools, research has shown that technological maturity is not sufficient to drive comprehensive organizational performance (Kahrović, 2021). In this regard, digital business transformation is viewed as an organizational process that involves the application of digital technologies but also requires a transformation of business models, operational processes, and strategic directions of the enterprise (Kahrović & Avdović, 2023). Thus, integrating sustainability metrics (economic, social, and environmental) into digital maturity frameworks allows for more holistic assessments of how digital transformation contributes to organizational performance and to its overall sustainable performance. Recent empirical research further confirms that technological quality and the achieved technological level of economic entities significantly influence sustainable business operations, positioning technological capability as a key determinant of long-term organizational sustainability (Miletić et al., 2025). However, understanding the role of sustainability within digital maturity assessment requires a clear conceptualization of sustainability performance measurement itself, which is discussed in the following subsection.

Digital maturity assessment serves a number of organizational functions, including being diagnostically useful to provide a baseline understanding of current capabilities and gaps relative to an industry benchmark or strategic goal, prescriptively useful to help prioritize resource allocation and digital initiatives, and strategically useful to align digital investments with business objectives and competitive positioning.

However, traditional digital maturity models have been criticized for being too narrowly focused on technological capabilities and not paying enough attention to the broader organizational and societal impacts (Djebbouri et al., 2025; Tiron-Tudor et al., 2024). In addition, empirical analyses suggest that most existing digital maturity models remain predominantly descriptive and linear, lack strong theoretical grounding, and are rarely empirically validated, thus demonstrating limited scientific robustness and prescriptive value (Kruljac & Knežević, 2019).

1.2. Sustainability Performance Indicators: The ESG Framework

Sustainability performance measurement has evolved from early environmental compliance metrics to more holistic ESG frameworks, which measure the multidimensional impacts of organizations on the environment, society, and governance (Singh et al., 2025). Within this framework, *environmental indicators* are typically operationalized through metrics that quantify resource intensity and ecological impact. These commonly include direct and indirect greenhouse gas emissions across operational boundaries, patterns of energy use and efficiency, water consumption profiles, waste treatment, and material recovery practices, as well as biodiversity and circularity-related initiatives. Such indicators are often aligned with internationally recognized reporting architectures including Global Reporting Initiative - GRI, Carbon Disclosure Project - CDP, and Task Force on Climate-related Financial Disclosures - TCFD (Babkin et al., 2021; Fan, 2025; Li et al., 2025; Radivojević et al., 2018). The *social indicators* focuses on how organizations manage relationships with internal and external stakeholders. Key measures frequently encompass occupational safety conditions, workforce development initiatives, equality and inclusiveness policies, responsible labor standards, protection of fundamental human rights, community-oriented programs, customer trust and data protection practices, and socially responsible supply chain management (Nasiri et al., 2022; Tiron-Tudor et al., 2024). *Governance indicators* capture organizational structures, policies, and practices that ensure accountability, transparency, and ethical conduct and include metrics like board composition and independence, executive compensation alignment, shareholder rights, business ethics and anti-corruption measures, regulatory compliance, and risk management frameworks, all of which are becoming integral to environmental and social performance (Sell, 2024, Al Jabri & Lahrech, 2026). While ESG frameworks provide structured mechanisms for evaluating sustainability performance, recent research increasingly emphasizes the need to integrate these metrics with digital transformation processes, giving rise to the concept of twin transformation discussed below.

1.3. The Convergence Imperative: Twin Transformation

The concept of „twin transformation" has emerged to describe the strategic integration of digital transformation and sustainability transition (Martínez-Peláez et al., 2024; Fortier et al., 2025). Multiple factors drive this convergence. First, digital technologies offer powerful tools for monitoring, controlling, and assessing sustainability performance. IoT sensors enable real-time environmental monitoring, artificial intelligence optimizes resource consumption, blockchain enhances supply chain transparency, and data analytics identify sustainability improvement opportunities (Nicolau & Petcu, 2026). Second, as businesses realize that adopting technology must be in line with their commitments to social responsibility and the environment, sustainability factors are becoming more and more important in shaping digital transformation strategies (Fatemi, 2024; Martínez-Peláez et al. in 2024). Sustainability is increasingly recognized not merely as a compliance requirement but as a driver of value creation, as integrating environmental and social considerations into business models enhances long-term competitiveness and stakeholder value (Milenković et al., 2025).

Several theoretical frameworks support twin transformation. The resource-based view theory states that the integrated digital-sustainability capabilities can be considered valuable, rare, and difficult to imitate resources that provide a competitive advantage (Al Jabri & Lahrech, 2026). According to stakeholder theory, businesses must balance the interests of different stakeholders,such as social and environmental ones, with their financial objectives. Finally, institutional theory explains how regulatory pressures, normative expectations, and mimetic processes lead to organizational adoption of integrated assessment frameworks that incorporate digital maturity and sustainability performance (Damnjanović et al., 2025; Jamwal et al., 2025; Li et al., 2025). Building upon these theoretical foundations, the study proceeds with a systematic literature review designed to identify, compare, and synthesize existing approaches for integrating sustainability indicators into digital maturity models.

2. Methodology

The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement (Page et al., 2021) and Kitchenham's protocol (2004) serve as the foundation for this study's systematic literature review. This strategy promotes methodological transparency, reproducibility, and thorough coverage of the relevant literature. Using the PICO model to formulate research questions, creating a structured search strategy across the Web of Science and Scopus databases, applying stringent inclusion and exclusion criteria, and formally evaluating the quality of eligible studies to ensure methodological rigor are the four main steps in the review process. Every stage is intended to reduce bias and improve the reliability of the results.

2.1. Research Questions

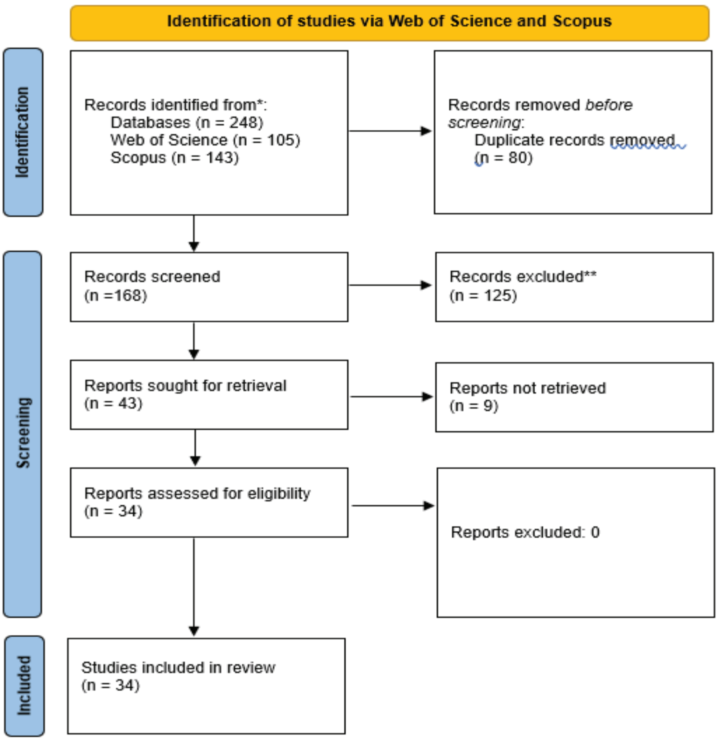
In order to systematically address the objectives of this study, the research questions were formulated using the PICO model, a widely recognized framework originally introduced by Richardson et al. (1995) for structuring systematic reviews and decomposing clinical questions into searchable components. PICO, which stands for Population, Intervention, Comparison, and Outcomes, provides a clear and rigorous approach for defining the scope of an investigation. In the context of this research, the *population* (P) comprises organizations across industries undergoing digital transformation and sustainability transitions. The *intervention* (I) refers to integrated digital maturity models that incorporate sustainability and ESG performance indicators. The *comparison* (C) involves traditional assessment approaches in which digital maturity and sustainability performance are evaluated separately through distinct frameworks. The *outcomes* (O) include organizational performance improvement, alignment between digital and sustainability strategies, transparency and accountability, and greater long-term resilience.

This literature review aims to explore what is known about the integration of sustainability performance indicators into digital maturity models, specifically (1) which conceptual and empirical frameworks exist for integrating sustainability into digital maturity assessment, (2) which environmental, social, and governance (ESG) indicators are most frequently used, (3) how sustainability indicators are methodologically integrated, and (4) what industry contexts and empirical applications support the development and implementation of integrated digital sustainability maturity models.

2.2. Search Strategy

This literature review employed a comprehensive and systematic search strategy to identify relevant scholarly publications examining the integration of sustainable performance indicators into digital maturity models (Martínez-Peláez et al., 2024). The search was carried out through the electronic databases Web of Science (WoS) and Scopus. According to Benavides et al., (2020, p. 3), "they are the most relevant scientific information platforms that access the scientific databases and the most significant publication of the different areas of knowledge" (p. 3). The structured search strategy employed to identify articles used the strings "digital maturity*" AND "sustainable performance*" and was conducted on 15 January 2026.

Figure 1: Search and selection strategies



The initial search retrieved 248 records (105 from WoS and 143 from Scopus). All references were imported into Zotero reference management software, where 80 duplicate entries papers were removed. After deduplication and quality checks, 34 unique records were retained for the screening phase. This structured search approach ensured that the selected studies systematically address the research questions and maintain methodological rigor.

2.3. Study Selection

Following the initial search, rigorous inclusion and exclusion criteria were applied to ensure the review focused on the most relevant and high-quality studies. Inclusion criteria specified: (1) peer-reviewed journal articles published in academic journals; (2) publication dates between 2016 and 2026, capturing the most recent decade of research; (3) substantive focus on digital maturity models, sustainability performance indicators, or their integration; (4) empirical studies, conceptual frameworks, or systematic reviews; and (5) English language publications. Exclusion criteria eliminated: (1) conference proceedings, book chapters, dissertations, and grey literature; (2) publications outside the specified time range; (3) studies lacking substantive discussion of either digital maturity or sustainability indicators; (4) purely technical papers without organizational or strategic focus; and (5) duplicate publications.

2.4. Quality Assessment

Kitchenham (2004) suggests that study quality relates to the extent to which bias is minimized and internal and external validity are maximized. Assessing the quality of primary studies is crucial in a systematic review for several reasons: to refine inclusion and exclusion criteria, to explore whether quality differences explain variations in findings, to weigh the importance of individual studies during synthesis, to guide the interpretation of results, and to strengthen recommendations for future research (p. 10).

In this review, the quality assessment was conducted during the eligibility evaluation phase. Studies were included only if they were published in journals indexed in the Journal Citation Reports 2024, which ensures that all sources meet rigorous international standards of academic quality. Articles were also expected to focus on fundamental aspects of digital maturity and sustainable performance, ensuring that only recent, peer-reviewed, high-impact studies contributed to the synthesis of findings; this approach ensured that the review would be of high methodological rigor and would minimize bias, which would ultimately increase the credibility and reliability of results.

The extracted data were organized into a comprehensive paper table with enriched columns capturing: (1) frameworks and models used, describing specific digital maturity models, sustainability frameworks, or integrated models; (2) sustainability indicator types, categorizing environmental, social, and governance metrics; and (3) integration approaches and methodologies, detailing how sustainability indicators were incorporated into maturity assessment frameworks.

Thematic analysis was conducted to extract common patterns, trends, and relationships in the literature, grouped papers based on themes such as framework types, indicator categories, integration methodologies, industry applications, and research gaps, compared frameworks, methodological approaches, and empirical findings, and synthesized findings across studies to provide a holistic understanding of the current knowledge, best practices, and research gaps in this area. The application of this methodological procedure resulted in a structured body of literature that was subsequently analyzed thematically, with the key findings presented in the following section.

3. Results and Discussion

3.1. Current Frameworks Integrating Sustainability into Digital Maturity

A review of the literature shows that frameworks that incorporate sustainability considerations into digital maturity assessment fall into three main categories: combined maturity models, parallel assessment frameworks, and embedded dimensional models (Fortier et al., 2025; Sell, 2024). To enhance clarity and reduce fragmentation in the presentation of findings, Table 1 provides a structured synthesis of these approaches, outlining their conceptual logic, integration mechanisms, and representative studies.

Table 1: Dominant Approaches to Integrating Sustainability into Digital Maturity Models

Integration Approach	COMBINED MATURITY MODELS	PARALLEL ASSESSMENT FRAMEWORKS	EMBEDDED DIMENSIONAL MODELS
Conceptual Logic	Digital and sustainability maturity assessed within a unified and structurally integrated framework	Digital maturity and sustainability performance assessed separately and analytically linked	Sustainability incorporated as an intrinsic dimension within digital maturity structures
Sector	SMEs; Manufacturing; Supply chains	Industrial ecosystems; Manufacturing; Industry 4.0 firms	Construction; General business; Industry 5.0; Smart cities
ESG Coverage	E (strong); S (moderate); G (variable)	E; S; G (separate projections)	E (strong); S (moderate); G (limited)
Methodological Type	Conceptual + empirical validation	Quantitative empirical (survey; modelling; PCA)	Design science; conceptual + sector case applications
Typical Integration Mechanism	Composite indices; weighted aggregation; ESG mapping	Correlation analysis; PCA; regression modelling	ESG indicators embedded into maturity dimensions
Representative Studies	Tiron-Tudor et al. (2024); Münnich et al. (2025); Fatemi (2024); Fortier et al. (2025); Trequattrini et al. (2025); Demir et al. (2022)	Babkin et al. (2021); Jamwal et al. (2025); Gladysz et al. (2024)	Sell (2024); Merdin et al. (2022); Han (2025); Djebbouri et al. (2025); Diaz Schery et al. (2025); Santana et al. (2019)

As shown in Table 1, combined maturity models represent the most structurally integrated approach, while parallel and embedded models reflect varying degrees of methodological coupling between digital and sustainability assessment. The following sections elaborate on each category in greater detail.

Combined Maturity Models represent the most integrated approach, treating digital and sustainability maturity as interconnected dimensions within a unified assessment framework. The Synergetic Digital Sustainable Development Maturity Model (SDSDMM) is an example of a combined maturity model developed for SMEs in Eastern Europe. The SDSDMM captures both digitalization and sustainability dimensions through a user-friendly tool validated via focus group sessions with experts who confirmed its transparency and practicality (Tiron-Tudor et al., 2024). Similarly, Münnich et al. (2025) developed a combined digitalization-sustainability maturity model for SMEs that systematically maps ESG metrics to digital maturity levels, validated through expert feedback and 37 case evaluations. Fatemi (2024) proposed a weighted maturity model for assessing digital–sustainability synergy within the twin transformation paradigm, applying composite scoring logic validated through multiple case applications. Fortier et al. (2025) developed an integrated framework for manufacturing SMEs that structurally embeds sustainable performance indicators within digital maturity assessment. Trequattrini et al. (2025) introduced a composite digital–sustainability readiness index linking ESG metrics to digital maturity levels through weighted scoring validated in SME contexts. The Smart and Sustainable Supply Chain Readiness and Maturity Model (S3RM) represents another significant combined framework, specifically designed for supply chain contexts. The S3RM employs a triple-bottom-line approach encompassing smartness dimensions (availability, integrity, adaptability) and sustainability dimensions (social, environmental, economic). The model calculates a composite Smart and Sustainable Readiness and Maturity Index by averaging sustainability scores' summation and smartness scores' multiplication, validated through automotive industry case studies (Demir et al., 2022).

Parallel Assessment Frameworks maintain separate but coordinated evaluation of digital maturity and sustainability performance. Babkin et al. (2021) developed a methodology for assessing industrial ecosystem maturity that extends the traditional ESG framework with a fourth projection: digital maturity. This approach employs principal component analysis and hierarchical agglomerative clustering to assess six maturity levels (very high, advanced, basic, elementary, zero, and minus one), demonstrating positive and significant correlations across all four assessment projections. The methodology was validated on Russia's national industrial ecosystem and metallurgy/mining sector. Jamwal et al. (2025) demonstrated positive associations between Industry 4.0 maturity and sustainability outcomes using quantitative modelling. Gladysz et al. (2024) assessed Industry 4.0 maturity and sustainability dimensions separately while identifying interdependencies.

Embedded Dimensional Models incorporate sustainability as an intrinsic dimension within digital maturity frameworks. Sell (2024) developed a maturity model for evaluating data-driven sustainability management that encompasses eight technical and organizational dimensions derived from theory and practitioner insights through design science research. The model progresses from basic implementation to real-time integration and cloud connectivity, emphasizing the role of data culture in sustainability management. Several frameworks target specific industry contexts (Gladysz et al., 2024; Criveanu, 2026). Han (2025) introduced an updated digital maturity assessment model for construction companies that directly correlates digital maturity levels to ESG performance enhancements. Diaz Schery et al. (2025) established a framework linking Building Information Modeling (BIM) maturity with Industry 4.0 and sustainability paradigms for construction digital transformation. Santana et al. (2019) developed a Sustainability Maturity Model (SMM) for smart cities using ISO 37122 sustainability indicators, following the CMMI maturity indices and COBIT process controls.

3.2. Types of Sustainable Performance Indicators Used

The literature suggests that many sustainability indicators are integrated into digital maturity models, but there is considerable variation in specificity, measurement approaches, and emphasis across the ESG dimensions.

Environmental indicators are the most prevalent sustainability metrics and reflect the climate change and resource depletion challenges facing organizations (Eisner et al., 2022; Fan, 2025; Li et al., 2025), and the most commonly cited environmental indicators include: 1. *Energy and Emissions*: Energy consumption and efficiency, renewable energy adoption, carbon intensity, and carbon emissions (Scope 1, 2, and 3) are mentioned in most frameworks (Babkin et al., 2021), and carbon emissions and energy efficiency metrics were included in the industrial ecosystem maturity assessment (Maghawry et al., 2025). 2. *Resource Management*: Water consumption and efficiency, waste generation and recycling rates, circular economy practices, and material efficiency are among the commonly cited metrics (Demir et al., 2022; Münnich et al., 2025). 3. *Environmental Impact*: Biodiversity impacts, pollution levels, environmental compliance, and ecosystem services metrics are included in more comprehensive frameworks (Sell, 2024).

While less emphasized than environmental metrics in most frameworks, *social indicators* address organizational relationships with employees, customers, suppliers, and communities: 1. *Employee Welfare*: Occupational health and safety, employee training and development, work-life balance, and employee satisfaction metrics are commonly included; Tiron-Tudor et al. (2024) included social dimensions such as employee welfare in the SDSDMM framework, Babkin et al. (2021) included social metrics as one of four assessment projections in their industrial ecosystem maturity model. 2. *Diversity and Inclusion*: Gender diversity, ethnic diversity, pay equity, and inclusive workplace practices appear; Demir et al. (2022) included social responsibility metrics in the sustainability dimensions of the S3RM model. 3. *Stakeholder Engagement*: Customer satisfaction, community engagement, stakeholder dialogue, and social impact assessment metrics appear; Sell (2024) highlighted the need for sustainability communication that is tailored for specific stakeholder groups. 4. *Supply Chain Social Responsibility*: Labor practices in supply chains, human rights due diligence, supplier diversity, and fair trade practices appear; Demir et al. (2022) incorporated supply chain social responsibility into the S3RM model validated through automotive industry applications.

Governance indicators focus on organizational structures, policies, and practices ensuring accountability, transparency, and ethical conduct: 1. *Board and Leadership*: Board composition and independence, executive compensation alignment, leadership diversity, and succession planning metrics appear in comprehensive ESG frameworks.

Babkin et al. (2021) included corporate governance as one of the core ESG projections in their maturity assessment methodology. 2. *Ethics and Compliance*: Business ethics policies, anti-corruption measures, regulatory compliance, whistleblower protections, and ethical supply chain practices feature prominently. Cenholt & Presser (2025) developed an ESG-Capability Maturity Model (ESG-CMM) that bridges ESG metrics with capability maturity frameworks, emphasizing governance accountability. 3. *Transparency and Reporting*: Sustainability reporting quality, data transparency, third-party verification, and stakeholder communication metrics appear increasingly. Sell (2024) emphasized the importance of transparent sustainability reporting and the challenges of formulating appropriate sustainability KPIs. 4. *Risk Management*: Climate risk assessment, social risk management, cybersecurity governance, and integrated risk frameworks appear in advanced maturity models (Sira, 2025; Koldovskiy et al., 2025). Sivaiah et al. (2025) developed a maturity-based adoption model for sustainability reporting in SMEs that emphasizes governance and transparency.

The literature reveals significant variation in indicator specificity. Some frameworks employ broad, qualitative indicators (e.g., „environmental performance", „social responsibility"), while others specify quantitative metrics with clear measurement protocols (e.g., „tons of CO2 equivalent emissions per unit of production", „percentage of renewable energy in total energy consumption"). This variation reflects different framework purposes, target audiences, and data availability constraints.

3.3. Integration Approaches and Methodologies

The literature reveals diverse methodological approaches for integrating sustainability indicators into digital maturity models, ranging from simple additive scoring to sophisticated weighted composite indices and embedded dimensional frameworks.

The most common integration method is to combine digital maturity and sustainability scores through weighted aggregation (Babkin et al., 2021; Fortier et al., 2025; Trequattrini et al., 2025), which involves assigning weights to different indicator categories based on their relative importance (Trequattrini et al., 2025), with the weighting scheme determined through expert judgment, AHP, or empirical validation (Trequattrini et al., 2025), allowing organizations to tailor the framework to their contexts and strategic priorities. A weighted maturity model for assessing digital-sustainability synergy in twin transformation (Fatemi, 2024) is another example of the weighting method applied to maturity dimensions that was validated by multiple case applications and deemed flexible and practical. Demir et al. (2022) used a mathematical integration method to calculate the S3RM index by averaging the summation of sustainability scores and the multiplication of smartness scores.

The parallel assessment with correlation analysis, which has separate pathways for digital maturity and sustainability performance and examines relationships between them, shows that all four assessment projections (environmental, social, governance, and digital maturity) are positively and significantly correlated, and that digital maturity advancement will lead to improvements in other dimensions, thus yielding insights into synergies and trade-offs without forcing artificial integration (Babkin et al. 2021). Industry 4.0 maturity and sustainability outcomes are also positively correlated, with the best sustainability performance achieved by firms that are more mature in Industry 4.0 (Jamwal et al. 2025).

Embedded dimensional integration treats sustainability as an intrinsic dimension within digital maturity frameworks rather than a separate assessment domain. Sell (2024) developed a maturity model with eight technical and organizational dimensions that inherently incorporate sustainability considerations. For example, the data handling dimension progresses from basic implementation to real-time sustainability data integration and cloud connectivity. This approach ensures that sustainability is considered at every stage of digital maturity progression. Merdin et al. (2022) developed a digital maturity model for Turkish businesses that includes environmental elements as one of seven core dimensions alongside strategy, customers, employees, process management, technology and data management, organizational culture, and innovation. This embedded approach treats sustainability as a fundamental component of digital maturity rather than an add-on consideration (Djebbouri et al., 2025).

Maturity Level Mapping explicitly defines sustainability performance expectations at each digital maturity level. Münnich et al. (2025) systematically mapped ESG metrics to digital maturity levels, specifying the sustainability capabilities expected at each stage of digital advancement. For example, organizations at basic digital maturity levels might track simple environmental metrics manually, while those at advanced levels employ real-time IoT-enabled monitoring and AI-driven optimization. Han (2025) directly mapped digital maturity levels to ESG performance improvements in construction companies, demonstrating how digital capabilities enable progressively sophisticated sustainability management. This approach provides clear roadmaps for organizations seeking to advance both digital and sustainability maturity simultaneously.

Validation Approaches vary significantly across frameworks, with important implications for framework credibility and practical utility: 1. *Case Study Validation*: Multiple frameworks employ single or multiple case studies to demonstrate practical applicability. Münnich et al. (2025) validated their combined model through 37 SME case evaluations. Demir et al. (2022) conducted automotive industry case studies to validate the S3RM model. Case studies provide rich contextual insights but limited generalizability. 2. *Expert Panel Validation*: Several frameworks employ expert judgment to validate indicator selection, weighting schemes, and maturity level definitions. Tiron-Tudor et al. (2024) validated the SDSDMM through focus group sessions with experts who confirmed its transparency and practicality. Münnich et al. (2025) incorporated expert feedback into their systematic indicator selection process. Expert validation enhances face validity but may reflect expert biases. 2. *Empirical Data Validation*: Advanced frameworks employ objective performance data to validate relationships between digital maturity and sustainability outcomes. Trequattrini et al. (2025) validated their composite index with empirical evidence from industrial SMEs. This approach provides the strongest evidence of framework validity but requires access to comprehensive organizational data.

3.4. Industry Applications and Case Studies

The literature reveals diverse industry applications of integrated digital-sustainability maturity frameworks, with significant concentration in manufacturing, supply chain management, construction, and smart cities. Manufacturing and

Industrial SMEs represent the most extensively studied context, reflecting both the sector's significant environmental footprint and the critical role of SMEs in economic development. Münnich et al. (2025) applied their combined digitalization-sustainability maturity model to 37 SME case evaluations across diverse manufacturing sectors. The study demonstrated that SMEs face unique challenges in resource-constrained digital transformation while simultaneously addressing sustainability imperatives. Fortier et al. (2025) specifically focused on integrating sustainable performance into digital maturity models for manufacturing SMEs, recognizing their distinct needs compared to large enterprises.

Tiron-Tudor et al. (2024) developed the SDSDMM specifically for SMEs in Eastern Europe operating within Industry 5.0 contexts. The framework addresses challenges in SME awareness, understanding, and resource constraints while providing a user-friendly assessment tool. The focus on Eastern European SMEs highlights regional variations in digital-sustainability maturity and the need for context-specific frameworks.

Babkin et al. (2021) applied their industrial ecosystem maturity assessment methodology to Russia's national industrial ecosystem and metallurgy/mining sector. The results showed that Russia's industrial ecosystem maturity level was "basic" with prospects for advancement to "advanced," while the metallurgy and mining ecosystem achieved "advanced" maturity. This application demonstrates the framework's utility for national-level industrial policy and sector-specific strategic planning.

Given the extensive environmental and social impacts of supply chains, Supply Chain Management emerges as a key application domain. The S3RM model was validated by Demir et al. (2022) through automotive industry supply chain case studies to show how the framework can recognize strengths, weaknesses, opportunities, and threats for supply chain operations, with the automotive application being especially relevant due to the complex global supply chains of the sector and the high sustainability challenges.

Another example is the digital sustainable maturity grid for supply chains that Silva et al. (2022) introduced, which integrates ESG metrics into definitions of maturity levels without empirical testing, but provides a conceptual basis for the assessment of supply chain sustainability, acknowledging that organizational sustainability performance is becoming more dependent on extended value chain management beyond direct operations.

Another major application domain is Construction Industry, which reflects large environmental impacts of the construction industry and the ongoing digitization of the construction industry using Building Information Modeling (BIM) and other technologies, Han (2025) developed an extended digital maturity assessment model for construction companies and directly mapped digital maturity levels to ESG performance improvements based on the construction-specific framework addressing the construction industry characteristics such as project-based organization, fragmented value chains, and regulatory complexity.

Diaz Schery et al. (2025) bridged BIM maturity with Industry 4.0 and sustainability paradigms, recognizing that construction digital transformation must integrate sustainability considerations from the outset. The framework embeds social and economic sustainability indicators into BIM maturity assessment, though it lacks empirical case validation.

Smart Cities represent an emerging application domain where digital technologies and sustainability imperatives naturally converge. Santana et al. (2019) developed a Sustainability Maturity Model (SMM) for smart cities based on ISO 37122 sustainability indicators. The framework was inspired by CMMI maturity indices and COBIT process controls, demonstrating how established maturity model methodologies can be adapted to urban sustainability contexts. A case study in a hypothetical city validated the framework's ability to classify cities by maturity level based on standardized sustainability indicators.

Cross-Sector Insights from comparative analysis of industry applications: First, frameworks need to be sector-specific, taking into account industry characteristics, regulatory environments, and stakeholder expectations; second, SMEs have different challenges than large enterprises, so tools should be simplified and resource requirements lower; third, a supply chain and ecosystem perspective is becoming more relevant, as it is recognized that organizational sustainability depends on extended value networks; and fourth, validation approaches are different by sector, with manufacturing and supply chain studies requiring more rigorous empirical validation than in the case of construction and smart city applications.

3.5. Challenges and Gaps in Current Research

Despite significant progress in integrating sustainability indicators into digital maturity models, the literature reveals persistent challenges and research gaps that limit framework effectiveness and adoption.

Lack of Standardization emerges as the most fundamental challenge. The literature reveals proliferation of diverse frameworks with limited convergence on common dimensions, indicators, or maturity level definitions. This fragmentation creates several problems. Organizations struggle to select appropriate frameworks for their contexts. Benchmarking across organizations and sectors becomes difficult or impossible. Longitudinal tracking of progress is complicated when frameworks evolve or organizations switch between frameworks. Regulatory and reporting alignment is hindered when frameworks do not map to established standards like GRI, SASB, or TCFD. Tiron-Tudor et al. (2024) acknowledged that their SDSDMM framework, while validated through focus groups, provides limited indicator detail and sector focus. Similarly, multiple studies note the absence of unified assessment standards that would enable cross-organizational and cross-sector comparison (Fortier et al., 2025; Silva et al., 2022).

Limited Empirical Validation represents a significant methodological gap. Many proposed frameworks lack rigorous empirical testing, relying instead on conceptual development, expert validation, or single case studies. Silva et al. (2022) explicitly acknowledged that their digital sustainable maturity grid for supply chains lacks empirical testing. Diaz Schery et al. (2025.) noted the absence of empirical case validation for their BIM-sustainability integration framework. Fortier et al. (2025) recognized limited empirical validation of their integrated framework for manufacturing SMEs. This validation gap creates uncertainty about framework reliability, validity, and practical utility. Organizations may hesitate to invest resources in implementing frameworks without strong evidence of their effectiveness. Researchers cannot build cumulative knowledge when frameworks remain untested or tested only in limited contexts.

Practical limitations: Data Availability and Quality Constraints (Sell 2024) make it difficult to collect sustainability background data across the whole product life cycle and to design suitable sustainability KPIs, especially for Scope 3 emissions, supply chain social indicators, and long-term environmental impacts; many organizations (especially SMEs) do not have the data infrastructure, measurement systems, and reporting capabilities to undertake sustainability assessments; and digital maturity limitations (low maturity organizations do not have the technological capabilities to collect and analyze sustainability data) creates a circular dependency: sustainability assessment needs digital capabilities, and digital maturity assessment needs sustainability considerations.

Sector-Specific Adaptation Difficulties limit framework transferability across industries. While some frameworks claim broad applicability, effective implementation typically requires substantial customization to address sector-specific characteristics, regulatory requirements, and stakeholder expectations. Han (2025) developed a construction-specific framework recognizing that generic models inadequately address industry particularities. Demir et al. (2022) validated their S3RM model in automotive supply chains but acknowledged limited generalizability to other sectors. The tension between framework generalizability and sector specificity remains unresolved. Highly generic frameworks may lack practical utility, while sector-specific frameworks limit knowledge transfer and comparative analysis across industries.

SME-Specific Challenges receive significant attention but remain incompletely addressed. Multiple studies recognize that SMEs face distinct challenges including limited financial resources, constrained human capital, lower digital maturity baselines, limited sustainability expertise, and reduced stakeholder pressure compared to large enterprises (Fortier et al., 2025; Münnich et al., 2025; Tiron-Tudor et al., 2024). However, most frameworks remain complex and resource-intensive, limiting SME adoption. Quenum et al. (2025) developed a self-audit tool for SME digital maturity assessment that embeds sustainability indicators, but noted limited empirical validation and sector detail. The challenge of creating frameworks that are simultaneously comprehensive, rigorous, and accessible to resource-constrained SMEs remains largely unresolved.

Integration Methodology Gaps persist despite diverse approaches. The literature lacks clear guidance on optimal integration methodologies for different contexts. Should sustainability be embedded as dimensions within digital maturity models, assessed in parallel with correlation analysis, or combined through weighted composite indices? What weighting schemes are most appropriate? How should trade-offs between digital advancement and sustainability performance be managed? Fatemi (2024) proposed a weighted maturity model but acknowledged that optimal weighting schemes remain context-dependent and require further research. The mathematical integration approach employed by Demir et al. (2022) averaging sustainability scores' summation and smartness scores' multiplication represents an innovative but untested methodology requiring validation across diverse contexts.

Temporal Dynamics and Longitudinal Assessment: Most frameworks focus on a point-in-time assessment rather than temporal dynamics, learning curves, or longitudinal progression. Organizations require direction on the expected timeline for maturity advancement, the sequencing of digital and sustainability initiatives, and how to manage transition periods. There is limited evidence in the literature as to how organizations move through maturity levels over time or what intervention strategies are most effective at accelerating advancement.

Emerging Technology Integration remains underdeveloped. While frameworks acknowledge the importance of advanced technologies like artificial intelligence, blockchain, and IoT for sustainability management, they provide limited guidance on how these technologies should be incorporated into maturity assessment. Sell (2024) emphasized real-time integration and cloud connectivity but did not fully specify how emerging technologies should be evaluated within maturity frameworks.

Global South and Emerging Economy Contexts receive insufficient attention. Most frameworks are developed and validated in European, North American, or developed Asian contexts. Maghawry et al. (2025) addressed emerging economy contexts through their CBAM digital readiness index but noted limited validation and sector-specific case studies. The applicability of existing frameworks to emerging economies with different institutional environments, resource constraints, and sustainability priorities remains largely unexplored. Taken together, these findings highlight both the progress achieved and the persistent limitations in the development of integrated digital–sustainability maturity frameworks, forming the basis for the concluding discussion and future research directions.

Conclusions and Implications

This study provided a comprehensive review of the literature on integrating sustainability performance indicators into digital maturity models, based on the analysis of 30 highly relevant peer-reviewed journal articles published between 2016 and 2026. The findings indicate that this research field is rapidly evolving, driven by the growing importance of digital transformation and increasing pressure on organizations to improve sustainability outcomes. As a result, the concept of „twin transformation", referring to the simultaneous advancement of digital capabilities and sustainability performance, has emerged as a key strategic priority for modern organizations.

The analysis demonstrates a clear shift in the literature toward integrated assessment frameworks that treat digital maturity and sustainability as interdependent dimensions rather than separate organizational domains. The most advanced models apply combined maturity frameworks, parallel evaluation approaches supported by correlation analysis, or embedded sustainability dimensions within digital maturity structures. However, substantial diversity remains in terms of integration methodologies, indicator selection, and validation techniques. Environmental indicators continue to dominate most frameworks, while social and governance dimensions are often less developed, highlighting the need for a more balanced and holistic assessment approach in future research.

This study makes several important theoretical contributions. First, it systematizes a fragmented body of research by providing a structured synthesis of how sustainability performance indicators are incorporated into digital maturity models. Second, it develops a conceptual categorization of dominant integration approaches, thereby clarifying the structural differences among combined, parallel, and embedded maturity frameworks. Third, by examining methodological patterns and validation practices, the study identifies key theoretical gaps that hinder the development of standardized and comparable digital–sustainability maturity assessments. In doing so, the paper strengthens the conceptual foundation of the twin transformation paradigm and provides a basis for the development of more coherent and integrative assessment models.

Methodologically, the study contributes by applying a rigorous systematic literature review protocol, ensuring transparency, replicability, and analytical consistency in mapping integration mechanisms across diverse research contexts.

From a practical perspective, the findings offer actionable insights for managers, policymakers, and organizational decision-makers seeking to align digital transformation initiatives with sustainability objectives. The identified integration approaches provide structured pathways for incorporating ESG indicators into digital maturity assessments, enabling organizations to move beyond technology-centric evaluation toward more comprehensive performance measurement systems.

The study also highlights critical implementation challenges, including limited data availability, lack of standardized metrics, and constraints faced by small and medium-sized enterprises (SMEs). By identifying these barriers, the paper informs practitioners about key considerations in designing and implementing integrated digital–sustainability strategies. Moreover, the findings suggest that integrated maturity frameworks can support evidence-based policymaking and the development of regulatory instruments that promote responsible and sustainable digital transformation.

Despite significant progress, several persistent challenges limit the broader applicability of integrated frameworks. The most critical issues include the lack of standardization across models, limited empirical and longitudinal validation, and the underrepresentation of emerging economies and Global South contexts. Future research should prioritize the development of unified and comparable assessment standards, the execution of rigorous longitudinal studies, and the incorporation of advanced technologies such as artificial intelligence and big data analytics into sustainability assessment processes. Furthermore, greater emphasis is needed on refining social and governance indicators and integrating circular economy and regenerative sustainability principles into digital maturity frameworks. Overall, integrating sustainability into digital maturity models is evolving from a conceptual aspiration into a strategic necessity. As organizations navigate increasing technological complexity and sustainability pressures, integrated maturity frameworks are becoming essential tools for enhancing long-term competitiveness, accountability, and organizational resilience.

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FINANCING DEVELOPMENT OF ORGANIC AGRICULTURE: EXPERIENCES OF SERBIA

Abstract

A precise strategic vision of development, an adequate basis in the normative framework, as well as financial support (incentives) are necessary for the achievement of sustainable rural development. The aim of the research is to analyze the amount, structure and share in the agricultural budget of incentives for sustainable rural development in the period 2013–2023, as well as to assess the effectiveness of these incentives on the development of organic production in the Republic of Serbia. The paper used descriptive statistics methods, desk research method, methods of analysis and synthesis, as well as descriptive and comparative methods. The author concludes that in the Republic of Serbia, incentives for sustainable rural development are continuously paid from the state (agricultural) budget, that incentives for organic production had a dominant share in their structure in the analyzed period (2013–2023), but that organic production has not been developed in accordance with natural resources and allocations from the state (agricultural) budget. The paper also analyzes the experiences of the Republic of Croatia regarding financial support for the development of ecological and sustainable agriculture and makes proposals for the introduction of new types of incentives within the framework of agricultural policy measures in the Republic of Serbia.

Key words: *agricultural budget, incentives for sustainable rural development, incentives for organic production, development of organic production, Serbia*

JEL classification: *R11, Q57*

ФИНАНСИРАЊЕ РАЗВОЈА ОРГАНСКЕ ПОЉОПРИВРЕДЕ: ИСКУСТВА СРБИЈЕ

Апстракт

Прецизна стратешка визија развоја, адекватна основа у нормативном оквиру, као и финансијска подршка (подстицаји) неопходни су за остваривање одрживог руралног развоја. Циљ истраживања је анализа износа, структуре и учешће подстицаја за одрживи рурални развој у аграрном буџету у периоду 2013–2023, као и процена ефикасности ових подстицаја на развијеност органске производње у Републици Србији. У раду су коришћене методе дескриптивне статистике, метод истраживања за столом, методе анализе

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и синтезе, као и дескриптивни и компаративни метод. Аутор закључује да се у Републици Србији подстицаји за одрживи рурални развој континуирано исплаћују из државног (пољопривредног) буџета, да су подстицаји за органску производњу имали доминантно учешће у њиховој структури у анализираном периоду (2013–2023), али да органска производња није развијена у складу са природним ресурсима и издвајањима из државног (пољопривредног) буџета. У раду се, такође, анализирају искуства Републике Хрватске у вези са финансијском подршком за развој еколошке и одрживе пољопривреде и дају предлози за увођење нових врста подстицаја у оквиру мера пољопривредне политике у Републици Србији.

Кључне речи: *аграрни буџет, подстицаји за одрживи рурални развој, подстицаји за органску производњу, развој органске пољопривреде, Србија*

Introduction

The strategic goals of sustainable rural development in Serbia are defined in the Agriculture and Rural Development Strategy for the period 2014–2024. Their essence is to ensure the agricultural and rural development and the growth of farmers' living standards, with "sustainable resource management and environmental protection" (Strategy, 2014). Also, in the document (Serbia and Agenda 2030), the goals of sustainable rural development are defined, within which "environmental protection and the fight against climate change" are particularly emphasized. In order to combat climate change, a special Law on Climate Change (Law, c) was adopted. All the mentioned documents are of strategic importance for ensuring sustainable rural development in the Republic of Serbia.

Sustainable rural development in the Republic of Serbia has been financed from the agricultural budget since 2005 (Radović & Jeločnik, 2021). The legal framework for this source of financing is defined in accordance with the Law on Incentives in Agriculture and Rural Development (Law, a). The financial framework for incentives for sustainable rural development is defined on an annual basis, by regulations, as well as for other types of incentives. Financing for sustainable rural development in the Republic of Serbia should be implemented from the IPARD 3 program. More precisely, from Measure 4 of this program. Measure 4 of the IPARD 3 program is still in the accreditation process. It is expected that it will soon be accredited, as well as that a public call for potential applicants will be published immediately after the accreditation.

Organic agriculture is the most widely used concept of sustainable agricultural production in the Republic of Serbia. Organic agricultural production, as a special type of sustainable agricultural production, has been developing in the Republic of Serbia since the 1980s. The Law on Organic Production (Law, a), which was adopted in 2010, defined the legal basis for the development of this production more precisely than the previous law. This enabled faster development of this type of sustainable agricultural production in the Republic of Serbia. For example, from 2010 to 2019, the total number of producers in the organic production system increased 45 times (Radović & Jeločnik, 2021). The research question that the author will attempt to answer in this paper is whether the resources that evidently exist in Serbia for the development of organic agricultural production, are being adequately used.

The starting point for the research in this paper is the results of the research by Tomaš-Simin et al. (2019), who concluded in their research that “organic farming in Serbia is legally a well-regulated area, but still not developed to the necessary and possible extent” (p. 265). Considering that the research results of the cited authors were published seven years ago, the aim of the research in this paper is to determine whether the above statement is still true.

Therefore, the paper analyzes the legal framework, financial incentives from the agricultural budget for sustainable rural development, and primarily for organic production. In the research, the author uses official statistical documents, i.e. reports from the Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia, as the only available and authoritative ones in the field of organic agriculture.

The paper, also, analyzes the experiences of the Republic of Croatia. Agriculture in Serbia and Croatia has similar economic importance. Specifically, the share of gross added value created in agriculture in the gross domestic product in 2023 was 5.5% in Serbia, and 3.36% in Croatia. In both countries, the structure of agricultural entities is dominated by family farms, and the average size of agricultural holdings is similar. In 2023, it was 7 ha in Croatia, and 6.4 ha in Serbia (Radović et al., 2025). However, when analyzing the development of organic, i.e. ecological agriculture, the author notice that it is more developed in Croatia compared to Serbia. Specifically, in 2023, 4% of the total number of farms in Croatia practiced organic farming, and only 1.3% in Serbia (Radović et al., 2025). In addition, the Republic of Croatia is a member of the European Union, so it applies agricultural policy measures harmonized with the EU Common Agricultural Policy, which can also be a guideline for the Republic of Serbia, as a country in the process of European integration.

1. Literature Review

For the purpose of sustainable development, and within it – the sustainable development of agriculture, the United Nations has adopted the Sustainable Development Goals (SDG), and the European Union has implemented the long-term planning document “The European Green Deal” (Boix-Fayos & De Vente, 2023; Filipović et al., 2025). In the literature, there are also views that sustainable rural development, the green transition and the fight against climate change should be in the scope of the “responsibility of every national economy” (Đuričin et al., 2024, p. 24).

For sustainable development, the use of renewable energy sources (Bathaei & Štreimikienė, 2023; Madžar et al., 2025) and environmental protection (Filipović, 2024) are important. Also, it is of great importance that all economic activities are carried out in a sustainable manner. Above all, this refers to agriculture (Adisa et al., 2024; Shang, Xie, 2024; Saleem et al., 2024; Adefila et al., 2024) and tourism (López-Sanz et al., 2021; Turtureanu et al., 2025). Agricultural development should be carried out in a sustainable manner with the aim of more efficient use of natural resources, food safety and increased living standards for farmers (FAO, 2016; Stanojević et al., 2022).

Organic agricultural production is part of sustainable development (Glamočlija et al, 2015; Vapa-Tankosić et al., 2023; Khan et al., 2024; Reimer et al., 2024; Bocean, 2025; Yerkinbayeva et al., 2025) "based on an essential connection between agriculture and nature" (Mihailović & Brzaković, 2018, p. 127). A group of authors (Katić et al., 2008) points out that this production "ensures the harmony of environmental protection requirements and production based on natural processes" (p. 271), and Kovačević (2021) states that "organic products are the path to competitive and sustainable agriculture (p. 31).

Clark (2020) points out that "organic agriculture has experienced remarkable growth in recent decades as societal interest in environmental protection and healthy eating has increased" (p. 12). The group of authors (Wu & Marette, 2020) and (Zollet & Lall-Maharjan, 2021) emphasize the significance of well-defined regulations for organic production development.

The European Union's budget allocates funds for financing sustainable rural development (Marković, 2015; Walenia, 2022; Kalinowska et al., 2022; Romanchuk et al., 2024). Financing of agriculture and rural development in Serbia has been realized from the agricultural budget since 1996, when this financial instrument was constituted (Pejanović & Radović, 2011; Radović, 2015; Radović, 2024). Agricultural policy measures often changed in the previous period, but their essence remained the same (Radović et al., 2024).

For sustainable development of agriculture in Serbia is of particular importance that incentives for organic production were introduced in 2005 and since then they have been paid continuously from the agricultural budget (Radović et al., 2023). Roljević-Nikolić et al. (2017) state that, the intensive development of organic agriculture in the EU is the result of continuous and stable financial support from the EU agricultural budget, while "in Serbia not only the amount of support changes from year to year, but also the types of support" (p. 334).

2. Methodology and Data Sources

The aim of the research in this paper is to assess the effectiveness of incentives for sustainable rural development on the development of organic production in the Republic of Serbia. To this end, the paper analyzes the amounts and structure of incentives for sustainable rural development, as well as their share in the agricultural budget in the period 2013–2023 in the Republic of Serbia. In order to assess the effectiveness of the aforementioned incentives, the author analyzed trends in the development of organic plant and livestock production in the Republic of Serbia in the period 2013–2023. More precisely, in order to assess the effectiveness of the incentives, the increase/decrease in areas in organic plant production and the number of animals in organic livestock production in the period 2013–2023 is analyzed. Also, the effectiveness of incentives for organic agricultural production was also analyzed based on the share of arable land used in the organic plant production system relative to the total arable land in the Republic of Serbia in the final year of the analyzed period (2023). In addition, the analysis considered the share of individual species of domestic animals within the organic livestock production system in relation to the total number of animals of the same species in 2023.

The initial hypothesis on which the research is based is that financial incentives, although paid continuously from the agricultural budget, do not have an adequate impact on the development of organic agriculture in Serbia. The paper used the desk research method, descriptive statistics, methods of analysis and synthesis, as well as the descriptive method. The paper also uses a comparative method, with the aim of comparing the experience of the Republic of Croatia related to the sustainable development of agriculture.

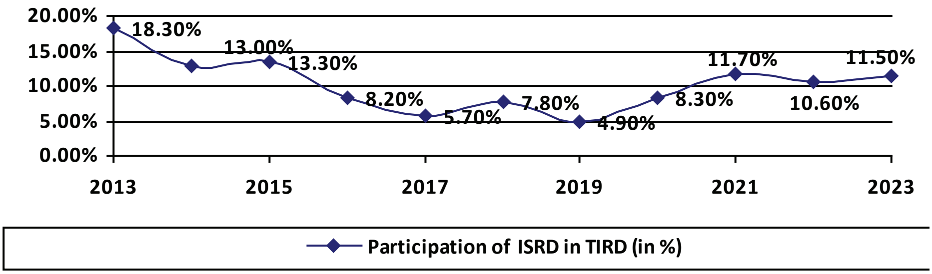
The data sources used are domestic and foreign academic literature, laws, regulations and ordinances regulating the research area. The data sources used are from the website of the Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia and from the website of the Ministry of Agriculture, Forestry and Fisheries of the Republic of Croatia.

3. Research Results and Discussion

Incentives for sustainable rural development (ISRD), i.e. incentives for the preservation and improvement of the environment and natural resources (the name of this measure of agrarian policy bis 2017) are paid in Serbia in accordance with the Law on Incentives in Agriculture and Rural Development (Law, a), rules and regulations adopted for each calendar year.

Incentives for sustainable rural development (ISRD) are part of rural development incentives (RDI). The share of incentives for sustainable rural development (ISRD) in total rural development incentives (TRDI) is shown in Figure 1. Participation of ISRD in the TIRD had a downward trend in the period 2013–2023. More precisely, the share of ISRD in TIRD was 37% lower in 2023 compared to the initial 2013. The average share of ISRD in TIRD was 9.4% in the period 2013–2023. This is almost 50% less participation compared to the participation of ISRD in TIRD in 2013, as the starting year of the analyzed period (Figure 1). This trend is worrying, given the importance of sustainable development of agricultural production for rural communities, rural economies, and more broadly at the national level.

Figure 1: Participation of ISRD in TIRD (2013–2023)



Data source: RDIARD 2013–2023. Author's processing

In the structure of ISRD in the analyzed period (2013–2023) there are:

(a) incentives for organic production – IOP;

(b) incentives for conservation of plant and animal genetic resources – ICPAGR;

(c) incentives to support agroecological measures, good agricultural practice and other environmental protection and preservation policies;

(d) incentives for sustainable use of forest resources.

Table 1: Structure of ISRD 2013–2023

Incentives / Year	IOP (in %)	ICPAGR (in %)	Incentives for agroecological measures, good agricultural practice and other environmental protection and preservation policies (in %)	Incentives for sustainable use of forest resources (in %)	ISRD (in %)
2013	90.9	9.09	-	-	100.00
2014	75.7	24.3	-	-	100.00
2015	82.2	17.8	.	.	100.00
2016	61.3	38.7	.	.	100.00
2017	55.21	39.88	4.91	.	100.00
2018	43.30	56.70	.	.	100.00
2019	46.55	53.45	.	.	100.00
2020	69.44	30.56	.	.	100.00
2021	99.99	0.01	.	.	100.00
2022	71.70	28.29	.	0.01	100.00
2023	70.00	30.00	.	.	100.00
Average:	69.66	29.89	0.45	.	100.00

Data source: RDIARD 2013-2023. Author's processing

IOP had a dominant average share (69.66%) in the structure of ISRD in the analyzed period (2013–2023). In second place in terms of participation are ICPAGR, with an average participation of 29.89% (Table 1). Incentives for supporting agro-ecological measures, good agricultural practice and other environmental protection and preservation policies, as well as incentives for the sustainable use of forest resources, had a symbolic average share in the total ISRD in the analyzed period, and they will not be the subject of a more detailed analysis in this paper.

ISRD, also, include ICPAGR. ICPAGR include: (a) incentives for conservation of plant genetic resources – ICPGR; (b) incentives for conservation of animal genetic resources – ICAGR; (c) incentives for conservation of animal genetic resources in the gene bank – ICAGRGB. In the structure of ICPAGR, in the analyzed period (2017–2023), incentives for the conservation of animal genetic resources (ICAGR) had the largest average share (82.24%). Incentives for the conservation of plant genetic resources (ICPGR) had an average participation of 11.28%, and the average participation of incentives for the conservation of genetic resources in the gene bank (ICGRGB) was 6.48% in the total ICPAGR in the period 2017–2023 (Table 2).

Table 2: Structure of ICPAGR 2017–2023

Incentives / Year	ICPGR (in %)	ICAGR (in %)	ICGRGB (in %)	Total ICPAGR (in %)
2017	7.69	89.23	3.08	100.00
2018	1.39	97.22	1.39	100.00
2019	1.61	96.78	1.61	100.00
2020	1.30	97.40	1.30	100.00
2021	33.33	33.34	33.33	100.00
2022	33.33	66.67	-	100.00
2023	0.28	95.05	4.67	100.00
Average:	11.28	82.24	6.48	100.00

Data source: RDIARD 2017–2023. Author's processing

It is evident that in the structure of incentives for sustainable rural development, incentives for plant production have a significantly smaller share compared to livestock production. The large imbalance in the structure of these incentives (ICPAGR) should be corrected in the coming period (Table 2).

ICPGR include incentives to support programs related to sustainable rural development, and which are implemented to preserve and improve the environment. According to current regulations, the maximum amount of ICPGR per one user (agricultural entity) is 2,000,000 RSD per year (Rulebook, c), and the maximum total amount of ICAGR per one user can receive for one calendar year is 3,000,000 RSD (Rulebook, d).

On the other hand, ICGRGB include support that is realized in accordance with a special regulation defining "the list of genetic reserves of domestic animals and the method of preserving the genetic reserves of domestic animals, as well as the list of indigenous breeds of domestic animals and endangered indigenous breeds". The highest total amount of incentives that one user can achieve in one calendar year amounts to 15,000,000 RSD (Rulebook, e).

Bearing in mind that, according to the data presented in Table 1, incentives for organic production (IOP) had the largest average participation in total incentives for sustainable rural development (TISRD) in the period 2013–2023, IOP will be the subject of a more detailed analysis in this paper. Table 3 shows the share of incentives for sustainable rural development (ISRD) and incentives for organic production (IOP) in the agricultural budget (AB) in the period 2013–2023.

Table 3: Participation TISRD and IOP in AB 2013–2023

Incentives / Year	AB (in RSD)	TISRD (in mil. RSD)	IOP (in RSD)	Participation of TISRD in AB (in %)	Participation of IOP in AB (in %)
2013	44,699.5	220.0	200.0	0.49	0.45
2014	45,427.2	123.8	93.7	0.27	0.21
2015	45,308.2	112.0	92.0	0.25	0.20

2016	40,465.7	150.00	91.0	0.37	0.22
2017	43,787.6	163.0	90.0	0.37	0.21
2018	44,109.2	254.0	110.0	0.58	0.25
2019	54,614.7	232.0	108.0	0.42	0.20
2020	56,067.9	504.0	350.0	0.90	0.62
2021	60,271.3	200.0	200,0	0.33	0.33
2022	78,571.5	530.0	380.0	0.67	0.48
2023	79,700.0	1,070.9	750.0	1.34	0.94
Average participation:				0.54	0.37

Data source: RDIARD 2013–2023. Author's processing

Based on the analysis of the presented data in Table 3, it can be concluded that both participations (IOP and TISRD) had a cyclical movement in the period 2013–2023. In the last analyzed year (2023), there was an increase in the share of TISRD and IOP in AB compared to the first year of the analyzed period (2013). Specifically, the share of TISRD in AB increased by 273% in 2023 compared to 2013. The share of total IOP in AB increased by 209% in 2023 compared to 2013. However, the average participation of IOP in AB was 0.37%, and the average participation of TISRD in AB was 0.54%, in the analyzed period (Table 3).

In the coming period, it would be appropriate to allocate more funds from the agricultural budget for incentives for sustainable rural development and incentives for organic production, as well as to direct some of them to incentives for increasing demand, i.e. for subsidizing the selling prices of organic products.

Table 4: Structure of IOP 2017–2023

Incentives / Year	IOPP (in %)	IOLP (in %)	IOP (in %)
2017	33.33	66.67	100.00
2018	8.18	91.82	100.00
2019	7.41	92.59	100.00
2020	42.86	57.14	100.00
2021	20.00	80.00	100.00
2022	21.05	78.95	100.00
2023	46.67	53.33	100.00
Average participation:	25.99	74.01	100.00

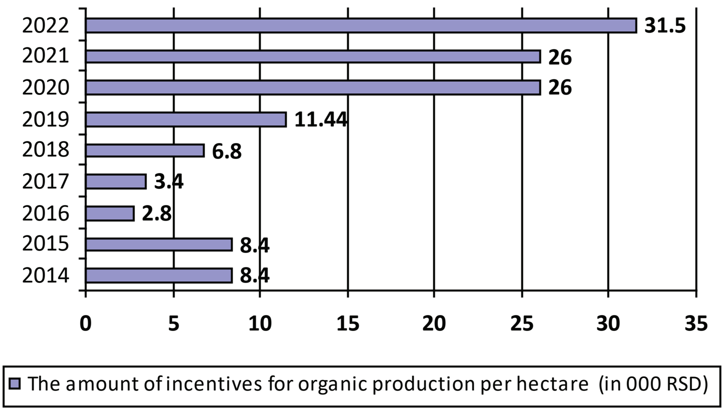
Data source: RDIARD 2017–2023. Author's processing

Analyzing the structure of IOP, it can be concluded that incentives for organic livestock production (IOLP) had a dominant share in their structure in the entire analyzed period. More precisely, the average share of IOLP was 74.01%, and the average share of incentives for organic plant production (IOPP) was 25.99% in the total IOP in the analyzed period, 2017–2023 (Table 4). The stated results of the research are expected considering that, according to the current regulations, the amounts of incentives in organic livestock production are significantly higher than in organic plant production. Specifically, the maximum amount of incentives for organic livestock production per user (agricultural entity) in one calendar year is 55 million RSD (Rulebook, b, 2023), and for organic plant production, the maximum amount of incentives per user (agricultural entity) in one calendar year is only 1.26 million RSD (Rulebook, a, 2023).

Despite the evidently smaller amounts of incentives in organic plant production, they are significantly higher than incentives in conventional plant production. By analyzing both categories of incentives (paid per hectare of arable land), it can be concluded that IOP were higher than incentives for conventional production: (a) by 40% in 2014, 2015 and 2016; (b) by 70% in 2017 and 2018; (c) by 120% in 2019; (d) by 400% in 2020; (e) by 550% in 2021; (f) by 250% in 2022.

IOP have been paid continuously since 2005 from the AB of the Republic of Serbia. Analyzing the data shown on Figure 2, it can be noticed that the absolute amount of incentives per hectare increased by 375% in 2022 compared to 2013. Also, IOP are paid from the budget of the Autonomous Province of Vojvodina, as well as from the budget of individual local governments. For example, the City of Novi Sad is the first local government to introduce IOPP, and they have been paid continuously since 2011. All of the above represents a good basis for the development of organic production in the Republic of Serbia.

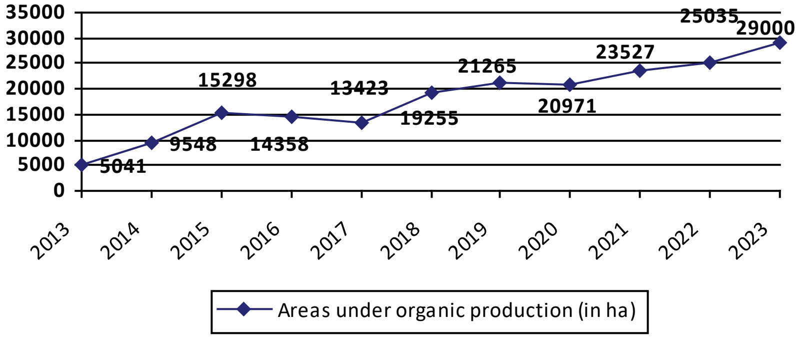
Figure 2: The amount of IOP per hectare 2014–2022 (in 000 RSD)



Data source: RDIARD 2014–2022. Author’s processing

Are the above incentives a good basis for the development of organic agriculture in the Republic of Serbia? Have higher amounts of incentives in organic livestock production initiated a greater development of this production compared to organic plant production? The answers to these questions will be the subject of research and analysis in the remainder of the paper. The development of organic plant and livestock production in the Republic of Serbia in the period 2013–2022 is presented on Figure 3 and Table 5.

Figure 3: Organic plant production in Serbia (in ha) 2013–2023



Data source: RSMAFWM-OP. Author's processing

Arable areas in the organic agricultural production system in Serbia increased by 496.6% in 2022 compared to 2013 (Figure 3). However, taking into account that 3,257,100 ha is the total area of used agricultural land (Census of agriculture, 2023), it can be concluded that only 0.9% of the total arable land was in the organic agricultural production system in 2023. It is a very small participation. For example, in the Republic of Croatia, areas under ecological farming account for 8.1% of the total used agricultural land (Radović, Gantner, Subić, 2025).

According to Eurostat data (Eurostat, 2025), in Europe in 2023, the areas under organic production had the largest share in the total arable areas in the following countries: Estonia (22.8%), Portugal (22.5%), Italy (18.8%), Sweden (18.4%), Switzerland (18.2%) and the Czech Republic (16.2%). When analyzing the neighboring countries, the areas under organic production had the smallest share in the total cultivated areas in Albania (0.1%), North Macedonia (0.3%) and Montenegro (1.6%). This participation was slightly higher in Bulgaria (3%), Romania (5.5%), and Hungary (6.4%). In Croatia, as already mentioned, it was (8.1%), and in Slovenia it was the highest (11.4%). When comparing the mentioned data with the modest areas under organic production in Serbia, we can state that there are certain problems in the development of organic production in Serbia.

This conclusion is also indicated by the fact that the cultivable areas in the organic production system were 27,600 ha in 2024, that is, they were reduced by 5% compared to 2023. Possible reasons for insufficient areas in the system of organic agricultural production in Serbia are the lack of labor in rural areas, which is necessary for this type of production. Also, the prices of organic products are often too high at resellers (in markets), and many producers do not have the conditions for direct sales of their products. Therefore, the demand exists, but the supply is fragmented and dislocated, and in order to develop organic production in Serbia, it is necessary to invest in sales channels, as well as better organization of producers.

Table 5: Organic livestock production in Serbia (in the number of animals) 2013–2023

Year	Sheep	Pigs	Cattle	Goats	Poultry	Horses	Bee colonies
2013	4,031	175	2,176	946	1,390	210	1,940
2014	3,153	76	2,726	1,154	1,140	173	894
2015	4,848	232	2,746	1,686	1,380	218	2,504
2016	4,378	283	2,895	1,406	3,158	165	2,878
2017	4,665	87	3,094	2,048	4,415	177	2,307
2018	5,138	284	3,594	1,486	6,735	114	3,061
2019	6,099	315	3,556	536	17,751	88	9,969
2020	5,711	326	4,627	286	14,936	16	12,618
2021	11,152	280	6,708	349	32,896	45	11,964
2022	13,212	217	9,423	522	40,066	20	103,236
2023	15,322	190	8,772	535	36,726	27	12,305

Data source: RSMAFWM-OP. Author's processing

In 2023 in Serbia, the number of almost all domestic animals in the organic production system increased compared to 2013, except for the number of goats and horses. When analyzing the movement of the number of individual animals by year, a cyclical movement is observed. In 2023, compared to 2022, the number of pigs in the organic production system was reduced by 12.4%, and the number of beehives was reduced by as much as 88.1% (Table 5). When the number of animals in the organic production system in 2023 is compared with the total number of individual species of animals in the same year according data in Census of agriculture – 2023, it can be concluded that in 2023 there were only 0.9% sheep, 0.01% pigs, 1.2% cattle, 0.4% goats, 0.2% poultry and 1% beehives in the organic production system.

The author concludes that, also, and organic livestock production is underdeveloped in Serbia, despite high incentives for this type of production. The reasons lie in problems in production, but also in placement. Specifically, producers are dissatisfied with the selling prices of their products, which prevent them from making adequate profits and therefore, often, they give up this production.

Table 6: Incentives for the development of ecological (organic) agriculture in the Republic of Croatia in 2023

Incentives for the development of ecological (organic) agriculture	Realized incentive amounts in 2023 (in €)	Number of users (producers) who have exercised their right to incentives
Incentives for the transition to ecological agricultural practices and methods	100,551.30	110
Incentives for maintaining ecological agricultural practices and methods	3,485,858.48	1,549
Total:	3,586,409.78	1,659

Data source: ARSA, 2023, p. 72. Author's processing

Table 7: Green payments (eco schemes) in the Republic of Croatia

Type of incentives within the framework “Eco-scheme “	Incentive amount in 2023 (in €)	Participation in total incentives for "Eco Schemes" in 2023 (in %)
Incentives for intensifying the diversity of agricultural areas	28,467,585.86	77.0
Incentives for intensive maintenance of ecologically significant areas	600,091.24	1.70
Incentives for maintaining a minimum share of legumes of 20% within agricultural areas	7,275,535.81	19.7%
Incentives for the conservation of grasslands of great natural value	560,639.10	1.6%
Total:	36,903,852.01	100.00

Data source: ARSA, 2023, p. 67. Author's processing

To explore possible directions for the development of organic plant production in Serbia, incentives for this type of production in the Republic of Croatia are also examined. Incentives for the development of organic (ecological) agriculture are also paid out in Croatia, as well as in Serbia, within the framework of incentives for rural development measures. Incentives for the development of ecological (organic) agriculture in the Republic of Croatia in 2023 are shown in Table 6. Analyzing the data presented in Table 6, it can be concluded that in Croatia in 2023, producers in the organic production system were entitled to annual incentives in the amount of 914.10 euros – incentives for the transition to ecological agricultural practices and methods or 2,250.40 euros – incentives for maintaining ecological agricultural practices and methods.

As a member of the European Union, the Republic of Croatia applies other types of incentives for sustainable rural development. These are greening payments, which were introduced in 2013 as a measure of the Common Agricultural Policy, and they began to be applied, that is, paid to farmers in 2015. These incentives are part of direct payments, they are paid per hectare of arable land, with the aim of adopting ecologically acceptable agricultural practices. The structure and amounts of green payments, which were paid to farmers in the Republic of Croatia in 2023, are shown in Table 7. It is important to note that these schemes are voluntary for farmers. Farmers who apply them undertake an annual obligation to comply with them and on that basis receive the mentioned incentives.

Conclusion

Based on the results of the research carried out in this paper, it can be concluded that:

(a) incentives for organic agriculture dominated in the structure of incentives for sustainable rural development in the Republic of Serbia in the analyzed period (the average share of incentives for organic agriculture in incentives for sustainable rural development in the period 2013–2023 was 69.66%);

(b) in the structure of incentives for organic agriculture, incentives for organic livestock production had a dominant share in the Republic of Serbia in the analyzed period (the average share of incentives for organic livestock production in incentives for organic agriculture, in the period 2013–2023, was 74.01%);

(c) arable land in the organic farming system recorded growth in the analyzed period (2013–2023), but in 2023 only 0.9% of the total arable agricultural land in the Republic of Serbia was in the organic farming system;

(d) the number of almost all domestic animals in the organic production system increased in the period 2013–2023, but in 2023 there were only 0.9% sheep, 0.01% pigs, 1.2% cattle, 0.4% goats, 0.2% poultry and 1% beehives in the organic livestock production system out of the total number of the mentioned species of animals in the Republic of Serbia.

The above data are proof of the accuracy of the initial hypothesis of this research, that financial incentives in the previous period did not have an adequate impact on the development of organic agriculture in the Republic of Serbia.

What are the possible reasons? There are certainly many of them.

Financing is an important condition for the development of any production, but it is also necessary to have a good organization of it, as well as a good sales strategy. Many producers are not able to do it independently, and they are also not ready to join forces, so they often give up on organic production for the above reasons. The relatively high prices of products from the organic production system require developed sales channels, which would connect the dislocated supply with the paying demand. The paper also proposes the introduction of new incentives to increase demand for organic agricultural products, which could also be implemented as subsidies for reduced sales prices for certain categories of residents. Of course, it is necessary to educate producers, not only in the area of production, but also in the area of sales and promotion.

Therefore, in order to promote the development of organic agriculture in the Republic of Serbia, it is necessary to adopt a strategic document that would unify the identified development challenges and propose potential solutions. The development strategy and financial incentives, existing and new, proposed in this paper, would collectively encourage the development of organic agriculture, but and sustainable agricultural production in the Republic of Serbia.

The scientific contribution of the paper is in assessing the effectiveness of incentives for the development of organic agricultural production in the Republic of Serbia in the period 2013–2023, as well as in comparing the current types of incentives for sustainable rural development in the Republic of Serbia and the Republic of Croatia. The Republic of Croatia is taken as a comparative example, taking into account that in both countries, agriculture has a similar economic importance. Organic (ecological) agriculture is developing in approximately the same period in both Serbia and Croatia. The comparative analysis presented in this paper is significant given that the Republic of Croatia is a member of the European Union, while the Republic of Serbia is currently in the process of European integration. Precisely with the aim of harmonizing the agrarian policy in the Republic of Serbia with the Common Agricultural Policy of the European Union, it would be useful to provide farmers in Serbia with the possibility of using “eco-schemes”, i.e. green payments. In particular, it would be useful to introduce, within the framework of incentives for sustainable rural development, measures supporting the intensive maintenance of ecologically significant areas, the conservation of grasslands of high natural value, and the maintenance of a minimum share of legumes of 20% within agricultural areas.

It is important to note that in the paper are only analyzed the planned amounts of incentives for organic production, given that analytical data on the realized individual types of incentives for sustainable rural development in the Republic of Serbia are not available. Future research should analyze planned and realized incentives for sustainable rural development, both in total and by type incentives.

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CONTROL OF THE DIGITALIZATION STRATEGY OF HEIs USING THE KEY SUCCESS FACTORS METHOD

Abstract

The digitalization of higher education institutions is one of the most important modern activities undertaken by these institutions. It enables the improvement of teaching and non-teaching activities, as well as increasing the competitiveness of the institution in national and international environments. During the digitalization process, modern technologies and innovations are used to modernize the traditional education system. A limitation of the digitalization process is that the achieved effects are not easily visible to measure, which complicates the process of control. For this reason, strategic control methods are applied, which enable reliable control of the success of the digitalization strategy in higher education institutions during and after implementation. In this process of defining control indicators, the key success factors method is particularly useful. The aim of this paper is to present the methodological procedure for the application of the key success factors method. The goal is also to present a concrete example that illustrates the process of defining strategic goals for the digitalization of higher education institutions, defining key success factors, and then selecting and formulating key performance indicators according to key success factors.

Key words: *strategy, digitalization, higher education institutions, control, key success factors*

JEL classification: *I23*

КОНТРОЛА СТРАТЕГИЈЕ ДИГИТАЛИЗАЦИЈЕ ИНСТИТУЦИЈА ВИСОКОГ ОБРАЗОВАЊА ПРИМЕНОМ МЕТОДА КЉУЧНИХ ФАКТОРА УСПЕХА

Апстракт

Дигитализација институција високог образовања је једна од најзначајнијих савремених активности ових институција. Она омогућава унапређење наставних и ненаставних активности, као и повећање конкурентности институција у националном и међународном окружењу. Током процеса дигитализације користе се савремене технологије и иновације које модернизују традиционални систем образовања. Недостатак процеса дигитализације је што остварени ефекти нису видљиви и лаки за мерење, чиме је отежан процес контроле. Из тог разлога

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се примењују методе стратегијске контроле које омогућавају поуздану контролу успешности стратегије дигитализације у институцијама високог образовања, у току њене имплементације и након њене имплементације. У том процесу, дефинисање индикатора за контролу, посебно је корисна метода кључних фактора успеха. Циљ овог рада је да прикаже методолошки поступак у примени метода кључних фактора успеха. Такође, циљ је да прикаже и конкретан пример који илуструје процес дефинисања стратегијских циљева дигитализације институција високог образовања, дефинисања кључних фактора успеха, а онда и избора и формулисања кључних индикатора перформанси по кључним факторима успеха.

Кључне речи: *стратегија, дигитализација, институције високог образовања, контрола, кључни фактори успеха*

Introduction

The digitalization of higher education institutions is a significant factor in improving the quality of education, increasing accessibility, and adapting to modern requirements. Digital learning is not only focused on technology, but primarily on the learning process (Ivenicki, 2023, p. 127). The education system plays a very meaningful role in the competitive advantage of a country (Krstić & Rađenović, 2020, p. 262). The potential of higher education to stimulate economic development and improve the quality of life in society is significant (Krstić & Krstić, 2018). The global e-learning market was worth around US$200 billion in 2019, with a projected growth of US$848.12 billion by 2030 (Gkrimpizi et al., 2023, p. 1). The COVID-19 pandemic also had a major impact on this growth. Kaplan (2022) points out that technology for online teaching has been around for a long time, but the COVID-19 pandemic has changed the academic community's stance and encouraged opponents of digitalization to become its advocates. Rodrigues (2017) believes that digital transformation is not just technical adoption, but a change in the business model of higher education institutions to increase their performance. These changes are based on the use of various resources and advanced technologies, such as artificial intelligence (AI), big data, cloud technology, augmented and virtual reality, mobile applications, and blockchain. The success of digital transformation of higher education institutions depends on factors such as organizational culture, employee competencies, resource availability, resistance to change, legal regulations, and data protection. Higher education institutions (HEIs) are in the process of evolving towards a new model – the so-called "digital university" (Fernández et al., 2023, p. 12351). The concept of the "digital university", in addition to adopting new technologies, also deals with the transformation of higher education institutions and is aimed at providing quality and competitive education.

This work consists of a theoretical and empirical part. The theoretical segment analyzes the digitalization of HEIs and the process of digital transformation. Then, the control of the digitalization strategy of HEIs is discussed, and the key success factor method and its importance in the control of the digitalization strategy are analyzed. The practical part of the paper contains an example of controlling the digitalization strategy of the Faculty of Civil Engineering, Architecture, and Geodesy in Split (FCEAG) using the key success factors method.

1. Digitalization of HEIs – Concept and Challenges

Higher education institutions are key to creating a competent workforce, scientific research results, innovation, knowledge transfer, as well as fostering entrepreneurship and economic growth (Krstić et al., 2016, p. 102; Krstić & Rađenović, 2020, p. 263). The modern environment requires these institutions to digitize and transform. The development of digital education takes place within the framework of the broader digital economy (OECD, 2023, p. 27). It is crucial to modernize traditional education methods, which will enable the improvement of digital skills of future professionals (Klochkova et al., 2020, p. 72; Radivojević et al., 2019, p. 105). Digital transformation is "a series of deep and coordinated culture, workforce, and technology shifts that enable new educational and operating models and transform an institution's operations, strategic direction, and value proposition" (World Bank, 2022, p. 34). The digitalization of HEIs must not be reduced to simply transferring courses to an online format, but should also involve profound pedagogical and organizational innovations (Kaplan, 2022, p. 3). HEIs most often implement digitalization in three areas (World Bank, 2022, p. 3):

1. Teaching and learning – introduction of e-learning platforms, hybrid teaching models, application of artificial intelligence;
2. Administration – digitalization of academic and non-academic activities;
3. Research – use of digital tools in research and data analysis.

The digital transformation of HEIs is not only technological, but also encompasses a pedagogical and social process (Rodrigues, 2017, p. 2). To better understand the digital transformation of higher education institutions, it is important to introduce the concept of digital readiness. Digital readiness refers to "the capacity of a higher education institution to support its own digitalization process" (OECD, 2021, p. 16). Digital readiness assesses the readiness of a higher education institution to adopt and integrate digital technologies into its activities, strategies, and culture (Chounta et al., 2024, p. 2).

HEIs are in the phase of widespread use of communication software and learning management systems (Schuetze et al., 2024, p. 7). The digital transformation of HEIs creates new challenges that require attention and adaptation by institutions. Transformation includes digital technology and employees who need to be educated (Kučna Softić et al., 2021, p. 19). Digital transformation is focused on changing business (Kolarski, 2022, p. 52). It also builds new skills and models through digital technologies (Oliveira & De Souza, 2022, p. 283). The successful implementation of digital technologies depends largely on the attitudes of teaching staff. It is the teaching staff that is the key factor on which whether digital technology will be accepted and implemented or not depends (Meštrić et al., 2023, p. 68). The level of motivation of teaching staff has the greatest impact on the result. It is common for teachers and students to be digitally competent in using digital tools and methods. In this way, they slow down the process of digital transformation. To overcome these problems, it is necessary to provide teachers and students with continuous training and support. The digital transformation process should take place gradually and with careful selection of digital tools. Although the initial costs of establishing digital tools are high, the long-term results are significant and valuable (Qureshi et al., 2021, p. 41). Each higher education institution should identify the necessary tools and thus create its own structure of digital tools. It is also necessary to take into account the characteristics and goals of HEIs in all areas (Carmo et al., 2025, p. 2). The use of digital tools in HEIs has multiple significance, enabling greater efficiency, higher quality of the teaching process, and transparency (World Bank, 2022, pp. 51–61).

Digital transformation in HEIs is a relatively new field (Aparisi-Torrijo et al., 2024, p. 3). It permeates all processes, places, formats, and objectives of teaching, learning, and research in HEIs (University of Shkodra "Luigj Gurakuqi", 2023, p. 11). For this reason, digital transformation faces barriers that make its implementation difficult. Gkrimpizi et al. (2023, p. 16–20) classify barriers as follows: environmental barriers, strategic barriers, organizational barriers, technological barriers, human resource barriers, and organizational culture barriers. These barriers are connected. The lack of financial resources affects the technological infrastructure, which affects both teaching and non-teaching staff. Although barriers may slow down the process of digital transformation, it nevertheless permeates all processes of learning, teaching, research, and the overall work of HEIs. The crucial motivation is to have an accurate and clear picture of how HEIs are transforming, what digital transformation initiatives they are implementing, and whether they are doing so through an integrated plan that is aligned with the digital strategy (University of Shkodra "Luigj Gurakuqi", 2023, p. 11).

2. Control of the Digitalization Strategy of HEIs

Digital transformation affects all activities of HEIs (Kaputa et al., 2022, p. 64). Measuring and controlling the digitalization process in HEIs are complex activity, which is hampered by numerous limitations and shortcomings. If HEIs do not recognize the importance of actively controlling digital transformation, this can be a source of difficulties (Esteve-Mon et al., 2023, p. 560). The evaluation of higher education is a quite complex process that requires reliable and adequate standards, criteria, and performance measures (Krstić & Rađenović, 2020, p. 264). Insufficient systematicity in data collection results from different institutional priorities, uneven levels of digital maturity, and limited financial and human resources (OECD, 2021, p. 78).

The process of controlling a digitalization strategy as a long-term plan (for example, four years) can be viewed as:

1. Control during the implementation period (after each year of its implementation) and
2. Control after the implementation (after each year of implementation), and it is to define a management checklist based on the principles of a modern performance measurement system (Krstić, 2012, p. 175).

By applying a system (set, aggregate) of performance measures, HEIs can systematically monitor the progress of digitalization strategy implementation. They can also identify deviations during its implementation and take timely corrective actions. In this way, after the entire implementation period, all long-term goals that were planned through the process of its formulation are achieved, and during the period of its implementation. In order to achieve the long-term goals defined by the digitalization strategy, it is necessary to set budgets based on it, as one-year plans. It is necessary to "translate" the long-term goals in the strategic plan into a set of objectives that will be realized annually within the time horizon of the strategy's implementation.

2.1. Control of the Digitalization Strategy of HEIs During Implementation

The control of digitalization strategy during implementation has the character of control of operational efficiency and effectiveness in the implementation and direction of activities such as projects, actions, programs, and initiatives (Krstić, 2012, p. 175). This type of control covers a period of six months or a year. Control during the implementation of the digitalization strategy is based on budget control. Since this control does not provide sufficient information, it is necessary to include a set of financial and non-financial control instruments during the implementation of the digitalization strategy of higher education institutions. Table 1 presents the control instrument during the implementation of the digitalization strategy.

Table 1: Control instrument during the implementation of the digitalization strategy

Time period covered by the digitalization strategy	Plan/budget	Budget control and planning of financial goals				Selection/definition of additional measures/goals (financial and non-financial) by activities/actions for operationalizing the strategy			Target level	Achieved and deviation from the target	Corrective action and the responsible person
		Actual value	Deviation ±	Corrective action	Responsible person(s)	Planned activity A for the execution of annual budgets and strategy	Planned activity B for the execution of annual budgets and strategy	Planned activity C for the execution of annual budgets and strategy			
1st year	Annual objecitve 1.1 Annual objecitve 1.2 Annual objecitve 1.3 Annual objecitve 1.4					- - -	- - -	- - -			
2nd year	Annual objective 2.1 Annual objective 2.2 Annual objecitve 2.3					- - -	- - -	- - -			
3rd year	Annual objective 3.1 Annual objecitve 3.2					- - -	- - -	- - -			
4th year	Annual objective 4.1 Annual objective 4.2 Annual objecitve 4.3 Annual objective 4.4 Annual objective 4.5					- - -	- - -	- - -			

Source: Adapted according to Krstić, B. (2012), p. 175

Table 1 shows a structured framework for controlling and monitoring the implementation of the digitalization strategy of higher education institutions. The table represents a framework for monitoring progress, where the rows represent the years of implementation of the digitalization strategy. The columns present the most important control components: plan/budget, budget control, and selection of financial and non-financial performance measures for the digitalization process/activity. Also shown are the target/desired performance levels for individual processes/activities through which the digitalization strategy is implemented, i.e., achieves short-term (annual) goals. Their implementation by year actually implements a (four-year) digitalization strategy in a higher education institution.

The target level column shows the planned results for each activity, while the actual value and deviation show the actual state, as well as the deviation from the planned state. Based on the differences, corrective measures and the person responsible for their implementation are identified. The approach to controlling the digitalization strategy during implementation allows for monitoring progress, identifying deviations, and taking timely corrective action. Combining budget control with financial and non-financial instruments provides comprehensive insight into the process of implementing the digitalization strategy. In this way, an effective control instrument is established within higher education institutions.

In addition to the above, it is emphasized that the digitalization strategy can be implemented by defining programs that should be implemented for the period of its implementation (e.g., four years). Programs consist of two or more projects that must be implemented to finalize the program. In this way, a project approach is introduced into the process of formulating and implementing a digitalization strategy, i.e., managing the performance of projects related to various digitalization processes of a higher education institution. From each conceived project, the definition of appropriate actions can emerge.

2.2. Control of the Digitalization Strategy of HEIs After Implementation

Control of the digitalization strategy after implementation is carried out using a management control chart, in which goals are defined by projects, initiatives, or actions, and based on these goals, performance measures are selected to monitor the success of their implementation (Krstić, 2012, p. 175–176). The application of the management control chart allows HEIs to evaluate the effects of digital transformation. This allows for the assessment of the degree of achievement of strategic goals through established performance measures. Table 2 presents the control instrument after the implementation of the digitalization strategy of higher education institutions.

Table 2: Instrument for monitoring effects after implementing a digitalization strategy

Elements	Program 1	Program 2	Program 3
	Project 1/ Project 2	Project 3 / Project 4 / Project 5	Project 6/ Project 7
	Activities or actions in project implementation (A1.1, A 1.2, A 1.3, A 2.1, A 2.2, A 2.3, A 2.4...)	Activities or actions in project implementation (A3.1, A3.2, A3.3, A4.1, A4.2, A4.3, A4.4, A5.1, A5.2...)	Activities or actions in project implementation (A6.1, A6.2, A6.3, , A7.1, A7.2, A7.3, A7.4...)

Description (definition) of goals for the time period covered by the strategy (for example, 4 years or, possibly, longer and their disaggregation by years of program/project implementation)	...	...	...
The performance metrics used to track them	...	...	...
Target (desired) cumulative performance level for a specific period	...	...	...
Achieved performance value	...	...	...
Achievement of the defined goal	Yes/No	Yes/No	Yes/No
Identification of factors/causes of failure to meet the target by the responsible persons	...	...	...
Need to redefine the target performance level	Yes (by how much)/ No	Yes (by how much)/ No	Yes (by how much)/ No
EVALUATION OF THE SUCCESS OF THE DIGITALIZATION STRATEGY	Successful/ Unsuccessful	Successful/ Unsuccessful	Successful/ Unsuccessful

Source: Adapted according to Krstić, B. (2012), p. 176

Table 2 shows the instruments for controlling the digitalization strategy of HEIs after its implementation. The first column provides a description of the control elements, while the other columns provide the activities of higher education institutions. The first line describes the goals for a specific time period. After that, the following lines determine the performance measures for monitoring the implementation of the defined goals, as well as the target performance levels planned for a certain period. By comparing planned and achieved performance, the degree of success of the strategy implementation is assessed by programs/ projects and activities.

Identifying factors or causes of failure to meet goals enables the timely detection of problems and the definition of corrective measures. If necessary, the target performance level is redefined. At the end of the table, the success of the digitalization strategy for each activity is assessed, and it is determined whether the strategy achieved the planned goals or not. This tool allows HEIs to comprehensively evaluate their strategy, identify gaps, and improve future digital transformation processes.

3. The Key Success Factors Method in Strategy Control

In the management literature, there are a large number of studies that develop different views on strategic control, such as (Krstić, 2012, p. 105): control of strategic assumptions/premises; control of strategy implementation; strategic monitoring (strategic oversight); steering by strategic issues and strategy updating, and the key success factors method. One of the methods particularly applied in practice is the key success factors method. Key success factors (KSFs) are specific areas of business that management should focus on in order to better differentiate the organization's activities from the competition (Krstić, 2012, p. 111). KSFs are characteristics, conditions, or variables that can have a significant impact on the success of a company competing in a particular industry (König et al., 2023, p. 4479). There are three main understandings of key success factors: as a characteristic of business, as a planning tool, and as a description of the market (Grunert & Ellegaard, 1992, p. 2). KSFs in the industry are competitive determinants that influence an organization's success in the market. They include resource characteristics, capabilities, competencies, product/service characteristics, technology characteristics, and other elements. Companies should develop a strategy that encompasses the KSFs necessary for effective implementation (Magd et al., 2022, p. 21). The list of KSFs for a specific company organization depends on the level of competition in the industry, the market position of the company, the characteristics of the industry, etc. However, company management should also identify KSFs in production, distribution, marketing, and other areas. Using key success factors in strategy implementation can be helpful for companies (Leyh et al., 2021, p. 433). The term KSFs is used in two contexts. First, during (re)formulating the strategy, and second, during controlling the implementation of the strategy (Krstić, 2012, p. 111).

The first use of the KSFs concept is when formulating, or reformulating, a digitalization strategy, as a support for the strategic planning process. KSFs arise from the organization's mission/vision and strategic market assessment. In the case of applying KSFs to formulate a strategy, the starting point is market information and a defined mission/vision. Here, KSFs are defined as determinants by which a company can differentiate itself from competitors and thus create stable and effective relationships with customers/consumers. It is a market-oriented approach to key success factors. According to this approach, they include: quality, time, cost savings, innovation, services, etc. It is emphasized that KSFs are derived from the market and cannot be directly managed. Therefore, in the second stage, they are connected to key business processes. Starting from market-oriented KSFs, the following relation can be derived (Krstić, 2012, p. 112):

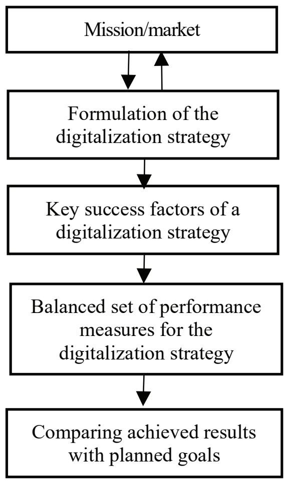
Mission/market/strategy ⇒ KSFs ⇒ Key business processes ⇒ Key control variables (performance measures).

When a significant deviation between the created and expected value is identified, the organization's management will analyze what caused the deviation. If the negative deviation is significant (and thus unacceptable), management must review and analyze key (but especially critical and problematic) business processes. However, if the processes are implemented without any particular problems, it is necessary to revise (reformulate) the digitalization strategy. The revision is being carried out because there have probably been some changes in the premises/assumptions of strategic planning, as well as in the KSF. The revised digitalization strategy is then the starting point (basis) for redesigning the system of financial and non-financial performance measures.

KSFs in another context – strategy implementation controls, is important because they are derived from the digitalization strategy, in fact, they are largely determined by a specific strategy (Figure 1). The identified KSFs then form the basis for designing a performance control (measurement) system. The KSFs method serves the purpose of defining metrics (indicators) for monitoring success in implementing a digitalization strategy. The connection between the measurement (control) system and the concept of KSFs in the process of implementing a digitalization strategy can be illustrated as follows (Krstić, 2012, p. 112):

Mission/market/strategy ⇒ KSFs ⇒ Balanced system of key performance indicators ⇒ Performance measurement and comparison with defined objectives.

Figure 1: Key success factors (KSFs) as a method of strategic control



Source: Authors

The two different perspectives of the KSFs, highlighted above, are neither opposed to each other nor are they mutually exclusive. They, in fact, constitute unity (Krstić, 2012, p. 113). This is because the strategic management process is cyclical.

4. Control of the Digitalization Strategy of the FCEAG in Split by Applying the KSFS Method

The Faculty of Civil Engineering, Architecture and Geodesy (FCEAG) in Split has adopted a digital transformation strategy for the period from 2024 to 2028, which clearly defines the institution's vision as a modern and digitally mature faculty that uses modern technologies to enhance teaching, research, and management (FCEAG, Split, 2024, p. 2–4). The strategy is aligned with national and European documents, and in particular with the Action Plan for Digital Education for the period 2021–2027 and the digitalization strategy of the University of Split. The main objectives of the digital transformation strategy are presented in Table 3.

Table 3: Goals of the digital transformation strategy of the FCEAG in Split

Strategic (long-term) objective	***Description of the strategic objective***
No. 1: Digitalisation of teaching and learning	Integration of digital tools into teaching, development of hybrid learning, and improvement of digital competencies of teachers and students
No. 2: Advancement of scientific and artistic excellence	Application of advanced technologies for simulations, data analysis and research innovations
No. 3: Increasing efficiency through continuous improvement of ICT infrastructure and digitalization of business processes	Improving administrative processes, ICT equipment and communication for more efficient management and sustainable development
No. 4: Improving cooperation with the community and business partners	Creating platforms for cooperation, joint projects and events with the economy

Source: FCEAG, Split (2024), p. 9–18

FCEAG's vision for digital transformation is reflected in a holistic approach that includes modernisation of education, research, administration, and management, while connecting with industry and promoting sustainable practices (FCEAG, 2024, p. 4). The effects of the implemented digital transformation strategy are expected to include improved quality and inclusiveness of education, strengthened research and artistic capacities, increased innovation, enhanced international cooperation, and the development of digital competencies among teaching staff and students, as well as broader social and economic development through the application of modern digital technologies in teaching, research, and management.

The objectives of the digital transformation strategy of the FCEAG, presented in Table 3, indicate a comprehensive and multidimensional approach to digitalization. This approach includes improving: teaching, research, infrastructure, and community collaborations. The integration of digital tools in teaching requires continuous training of teaching staff and the development of digital competencies of students. The application of advanced technologies in research involves systematic planning and the use of digital tools and data. Increasing efficiency through the digitalization of business processes and administration emphasizes the need for the introduction of a unified information system and a stable network infrastructure.

In analysing the current state, some limitations can be identified. Although the modernization process has begun in recent years, primarily through the introduction of e-learning platforms and partial renovation of equipment through various projects, there is a need for a systemic approach that would ensure uniform equipment. While some departments and laboratories are technologically well-equipped, other departments still use outdated equipment. The strategy envisages the continuous procurement of computer and network equipment, the introduction of cloud technology for data processing and storage, as well as the integration of various digital services into a single faculty information system.

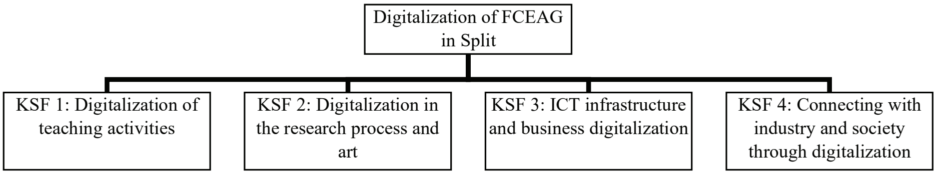
The digital transformation strategy prioritises the digitalization of the teaching process, emphasizing its role in improving the quality of education and pedagogical methods. In addition to improving hybrid and online teaching, the systematic creation of multimedia teaching materials, the introduction of interactive platforms, and the encouragement of new approaches that should enable personalized learning and greater student involvement in the process are planned. The COVID-19 pandemic has shown the need for such solutions, but also the limited digital competencies of some teaching staff. For this reason, the strategy envisages extensive training programs, including workshops, online courses, and cooperation with other universities and organizations in the country and abroad (FCEAG, 2024, p. 2–3). In the user support section, FCEAG introduces the concept of a digital learning center, which serves as technical and pedagogical support for teaching staff and students. This includes the development of e-mentoring, counseling, and technical assistance, thereby contributing to reducing the digital imbalance among users. Stakeholder engagement is another important component of the strategy. In addition to cooperation with the University of Split, the digital transformation strategy foresees the involvement of the private sector, as well as participation in international projects and networks.

Financing of digital transformation is based on a combination of state funds, university budgets, and European funds. A key factor in sustainability is efficient resource management. Monitoring and evaluation are central to FCEAG's digital transformation strategy. Clear progress indicators have been set, as well as specific deadlines for the implementation of activities over four years. Each phase of implementation should be followed by reports and feedback. This allows the strategy to be adjusted according to results and new needs. This approach identifies successful initiatives, but also enables a timely response to potential deviations, thereby increasing the efficiency of digital transformation.

The key success factors are actually key areas defined by the digitalization strategy of the FCEAG in Split. According to the key success factor method, as one of the most important for strategic control (Krstić, 2012, pp. 111–112), it is necessary to determine key success factors as specific areas of business. Management should focus on these factors to better differentiate its activities from the competition. Key success factors are used when formulating a strategy or when monitoring the implementation of a strategy. When formulating a strategy, key success factors are used to support the strategic planning process. Key success factors arise from the mission/vision of the higher education institution and strategic market assessment. When controlling the implementation of a strategy, key success factors are derived from the strategy and form the basis for creating a performance control system.

The process of strategic control, i.e., control of the digitalization strategy of the FCEAG in Split using the key success factors method, can be represented through four key success factors (Figure 2).

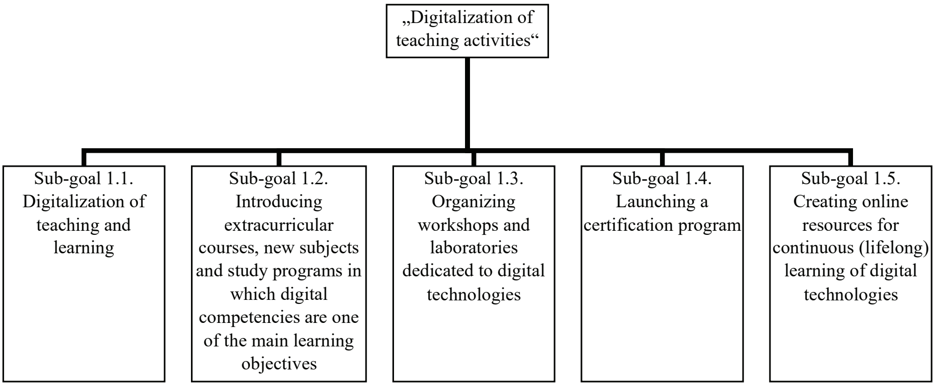
Figure 2: Key success factors of the digitalization strategy of the FCEAG in Split



Source: Author according to FCEAG, Split, 2024, p. 8

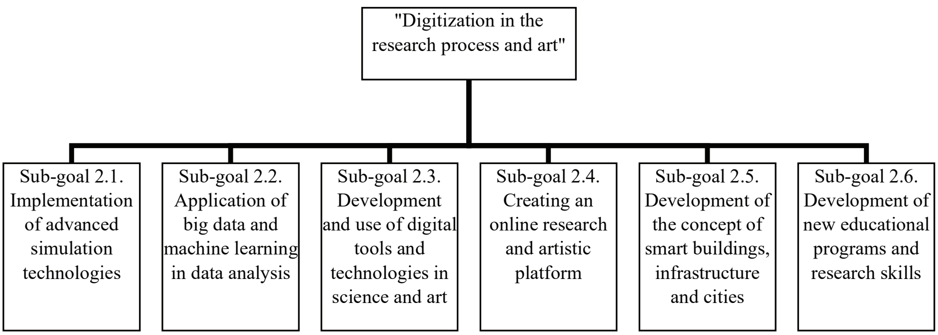
For each key success factor, FGAG in Split defined specific activities to be implemented, thereby translating long-term (strategic) goals into sub-goals, i.e., short-term operational objectives grouped by key success factors (Figures 3–6).

Figure 3: Key success factor No.1 "Digitalization of teaching activities" and defined sub-goals of Strategic Goal No. 1



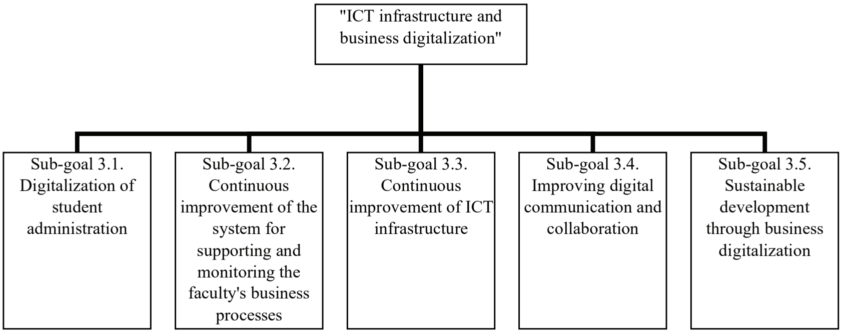
Source: Author according to FCEAG, Split (2024), p. 8

Figure 4: Key success factor No. 2 - "Digitalization in the research process and the arts" and defined sub-goals of Strategic Goal No. 2



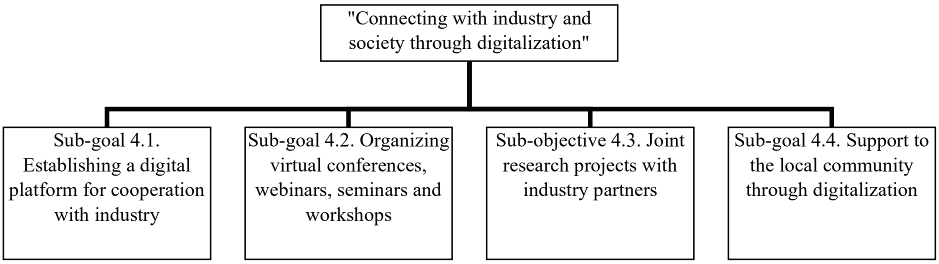
Source: Author according to FCEAG, Split (2024), p. 8

Figure 5: Key success factor No. 3 - "ICT infrastructure and business digitalization" and defined sub-goals of Strategic Goal No. 3



Source: Author according to FCEAG, Split (2024), p. 8

Figure 6: Key success factor No. 4 - "Connecting with industry and society through digitalization" and defined sub-goals of Strategic Goal No. 4



Source: Author according to FCEAG, Split (2024), p. 8

Sub-goals, i.e., short-term (operational) goals, are linked to the activities that need to be implemented. The effective implementation of these sub-goals will ensure the realization of the formulated strategic (long-term) goals. For each operational objective (sub-objective), the relevant activities have been defined. For each activity, a qualitative or quantitative measure of activity performance is selected that is necessary for controlling that activity, but also for controlling the key success factor. Ultimately, these measures allow for control of the decentralization strategy either during its implementation or after its implementation.

For the control of key success factor No. 1, activity performance measures have been defined (Table 4).

Table 4: Key success factor No. 1 - sub-goals, activities, and control measures

Sub-goals		
S 1.1 Digitalisation of teaching and learning	**Activities for the implementation of S1.1**	**Activity performance control measures A1.1**
	A1.1.1. Continued introduction of online learning platforms and implementation of LMSs such as Merlin or Blackboard for curriculum management, student progress tracking, and distribution of teaching materials.	M1. Increasing the number of online learning platforms introduced. M.2 Increase in the percentage of subjects using learning platforms.
	A1.1.2. Implementing hybrid learning by combining physical presence and online teaching to enable flexibility and accessibility of education.	M3. Implemented hybrid learning in at least five subjects in accordance with regulations.
	A1.1.3. Using AR/VR technology in the teaching process and for simulating real projects. The goal is to gain student experience in a virtual environment.	M4. AR/VR was introduced in at least one subject per study program over a period of 3 years.
	A1.1.4. Introducing modern learning technologies into teaching.	M5. Modern digital equipment and aids have been introduced within the teaching processes in at least five subjects per study program.
	A1.1.5. Introducing the principles of digital pedagogy into the teaching process with the aim of developing an innovative learning process supported by digital technologies.	M6. Principles of digital pedagogy are introduced in at least three subjects per study program.
	A1.1.6. Organizing workshops to strengthen teachers' competencies for digital teaching, including redesigning teaching methods according to the principles of digital pedagogy.	M7. At least one workshop is organized per year, with 100% teacher coverage.
S 1.2. Introducing extracurricular courses, new subjects and modules, and study programs with digital competencies as key learning outcomes	**Activities for the implementation of S1.2**	**Activity performance control measures A1.2**
	A1.2.1. Creation of a catalog of necessary digital competencies for qualifications acquired at universities.	M8. Catalogs created for all undergraduate and graduate study programs by the end of 2026.
	A1.2.2. Amendments and additions to study programs with the necessary digital competencies.	M9. All study programs offered at the faculty have been amended and supplemented with the necessary digital competencies.
	A1.2.3. Analyzing the digital competencies of students and teachers (including general digital competencies and those specific to the field of study) to provide an analytical basis for the selection of extracurricular courses.	M10. A survey conducted via online self-evaluation questionnaires for all students and teachers and a report was created once a year.
	A1.2.4. Introducing extracurricular courses that cover basic and advanced aspects of digitalization needed in construction for teachers and students.	M11. Organized at least one course per year for basic training in the use of tools such as: AutoCAD, Python or MATLAB. M12. Organized at least one course per year for advanced training in the use of tools such as: AutoCAD, Python or MATLAB.
	A1.2.5. Developing a new study program with an ICT qualification.	M13. Developed a university master's degree in geoinformatics based on the newly developed 7th-level qualification from the LABIRINT project.
	A1.2.6. Organizing courses on creating, analyzing and managing BIM models focused on BIM technology. BIM enables the integration of building information throughout its entire life cycle, from design to maintenance.	M14. At least one interdisciplinary course for advanced training in the use of BIM technologies has been organized within the past two years.
	A1.2.7. Organizing courses focused on GIS technology that enables the integration of geospatial data in the planning and management of the built and natural environment.	M15. At least one interdisciplinary course for advanced training in the use of GIS technologies has been organized within the past two years.

S 1.3. Organizing workshops and laboratories dedicated to digital technologies	**Activities for the implementation of S1.3**	**Activity performance control measures A1.3**
	A1.3.1. Organizing practical workshops on machine learning and data processing, on the use of machine learning and analytical tools for predicting the behavior of construction materials, optimizing construction processes and analyzing big data.	M16. At least one workshop organized within the two years.
	A1.3.2. Implementation of laboratories where students can work with 3D printers and robotic systems. Learning how these technologies are used in construction and architecture to create models, prototypes, or entire structures.	M17. Ensured the availability of 3D printing and robotics laboratories.
	A1.3.3. Implementation of laboratories where students can work with GIS technology. Learning how this technology is used in planning and managing the built and natural environment.	M18. Ensured the availability of GIS-SPO and Geodetic and Geoinformatics Laboratories.
S 1.4. Launching a certification program	**Activities for the implementation of S1.4**	**Activity performance control measures A1.4**
	A1.4.1. Creating and launching modules for the certification of digital tools and technologies in cooperation with software companies and software distributors such as: Autodesk, Bentley, Trimble, etc. These modules allow students to gain official certifications for using key digital tools that are in demand in the industry.	M19. Created and launched modules for certification of digital tools and technologies – at least two certification modules.
	A1.4.2. Creating and launching a certification module in sustainable construction. Education and certification of students in sustainable construction and energy efficiency using digital tools for resource analysis and optimization.	M20. At least one module for educating and certifying students in sustainable construction and energy efficiency using digital tools for resource analysis and optimization created and launched.
	A1.4.3. Establishing courses or colleges that cover the concept of smart cities and the application of IoT technologies in development projects. Students learn how to implement sensors, collect data and manage infrastructure through digital networks, use GIS technology for planning and managing urban spaces, as well as for analyzing topographic data in the context of construction projects.	M21. At least one course (collegium) covering the concept of smart cities established.
	A1.4.4. Developing digital skills through interdisciplinary projects with industry partners. Engaging students in interdisciplinary projects with industrial partners where they apply their digital skills to real-world challenges in the construction industry. Projects cover all phases, from digital design to process automation and optimization.	M22. Application and implementation of the process with industry partners of at least one interdisciplinary project dealing with digital design or automation and optimization.
	A1.4.5. Encouraging cooperation between the faculty and the IT sector on the development of software solutions for the construction industry, such as project management applications, simulation tools and data analysis tools.	M23. At least one collaboration with the IT sector on the development of software solutions for the construction industry achieved.
	A1.4.6. Establishing courses and workshops that train students on the use of VR and AR technology for simulating construction processes, reviewing 3D models, and training construction site workers. These technologies enable an interactive experience that improves understanding and precision in planning and executing work.	M24. At least one course or workshop established to train students on the use of VR and AR technology for simulating construction processes.
	A1.4.7. Developing interactive simulations that allow students to train skills in a virtual environment, including operating construction machinery, planning construction sites, and performing complex construction operations.	M25. At least one interactive simulation or training developed.
S 1.5. Establishing online resources for continuous (lifelong) learning of digital technologies	**Activities for the implementation of S1.5**	**Activity performance control measures A1.5**
	A1.5.1. Launching e-learning platforms – creating online courses and resources available to students and professionals who want to improve their digital skills. This includes video lectures, interactive modules, and knowledge tests.	M26. Launched an e-learning platform for continuing (lifelong) education.
	A1.5.2. Developing a continuing education program that allows professionals to upgrade their digital skills through short courses, workshops, and certification programs.	M27. At least three continuing education programs have developed.

Source: Adapted from FCEAG, Split (2024), p. 9–11

Table 4 shows that the achievement of key success factor No. 1 "Digitalization of teaching activities" is planned through the implementation of 25 activities, the success of which will be monitored, directed, and controlled using 27 key performance indicators. The planned activities are defined based on 5 sub-goals (short-term goals), the successful implementation of which in the four years of strategy implementation should ensure the realization of the defined long-term strategic goal No. 1.

For the control of key success factor No. 2 appropriate activity performance measures have been defined (Table 5).

Table 5: Key success factor No. 2 - sub-goals, activities and, control measures

Sub-goals		
S 2.1. Implementation of Advanced Simulation Technologies	**Activities for the implementation of S2.1**	**Activity performance control measures A2.1**
	A2.1.1. Using digital twins to create virtual copies of buildings and cities. This enables researchers to monitor and analyze the performance of buildings in real time and simulate various scenarios, such as: operational processes, planning decisions for urban development, or emergencies such as fires, earthquakes, floods, and other natural disasters.	M1. At least five research projects reported through which this technology will be implemented. M2. At least one research project implemented in which digital twin technology will be implemented.
	A2.1.2. Using simulation software to test different combinations of materials and designs before implementation in real projects can help develop new, more efficient and sustainable building solutions.	M3. At least five scientific research or professional projects implemented using advanced simulation software.
S 2.2. Application of big data analytics and machine learning in data analysis	**Activities for the implementation of S2.2**	**Activity performance control measures A2.2**
	A2.2.1. Application of big data analytics to collect and analyze field data through measuring devices, sensors, drones, etc. to optimize processes, predict risks, and reduce construction costs.	M4. At least one project implemented in which various field data will be collected and analyzed using various measuring devices, sensors, drones, etc., to optimize processes, predict risks, and reduce construction costs.
	A2.2.2. Using machine learning based on collected data to predict the behavior of building materials and structures over time. The goal is better planning of maintenance and extending the lifespan of buildings.	M5. At least one project using machine learning based on collected data implemented.
S 2.3. Development and use of new digital tools and technologies in science and art	**Activities for the implementation of S2.3**	**Activity performance control measures A2.3**
	A2.3.1. Research into the application of 3D printing in construction for the construction of complex structures or prototypes can reduce costs and speed up the construction process.	M6. At least one project implemented that explores the application of 3D printing in construction.
	A2.3.2. Research into the use of robots on construction sites or in prefabricated element factories to automate repetitive or dangerous tasks.	M7. At least one project implemented that explores the use of robots on construction sites or in factories.
	A2.3.3. Researching the use of digital technology in artistic processes in the field of architecture, advanced visualizations and interactive tools.	M8. At least one project implemented that explores the use of digital technology in artistic processes.
S 2.4. Creating an online research and artistic platform	**Activities for the implementation of S2.4**	**Activity performance control measures A2.4**
	A2.4.1. Establishing an online research platform where researchers and artists from different universities and industrial partners can collaborate on joint projects.	M9. Established research and artistic online platform.

S 2.5. Development of the concept of smart buildings, smart infrastructure and smart cities	**Activities for the implementation of S2.5**	**Activity performance control measures A2.5**
	A2.5.1. Research into the integration of smart construction, architectural and urban solutions in the broader context of smart cities.	M10. At least one project implemented that explores the integration of smart building solutions in the context of smart cities.
	A2.5.2. Developing the concept of smart buildings and infrastructure through the installation of sensors in buildings for real-time condition monitoring.	M11. At least one pilot project implemented that includes the concept of smart buildings or infrastructure.
S 2.6. Development of new educational programs and research skills	**Activities for the implementation of S2.6**	**Activity performance control measures A2.6**
	A2.6.1. Developing new educational programs and research skills by introducing courses that train students in the use of advanced digital tools such as BIM, GIS, Python, Java, MATLAB, data analytics, artificial intelligence, machine learning, digital twins, cybersecurity, the Internet of Things, virtual and augmented reality, cloud computing, automation, robotics, and blockchain technology.	M12. At least three courses or educational programs held to improve digital research skills.
	A2.6.2. Promoting cooperation between different disciplines such as computer science, electrical engineering, maritime engineering, civil engineering, architecture, urban planning, geodesy and geoinformatics to develop innovative solutions.	M13. At least one roundtable held to encourage collaboration between different disciplines.
	A2.6.3. Developing digital platforms for environmental impact assessment that enable the simulation of long-term effects of construction projects.	M14. At least one project that explores sustainable development through digitalization has been implemented.
	A2.6.4. Implementing digital tools to optimize the use of resources such as water, energy, and building materials to reduce the environmental footprint.	M15. At least one digital tool for optimizing resource use implemented.

Source: Adapted from FCEAG, Split (2024), p. 12-14

Table 5 shows that the achievement of key success factor No. 2 “Digitization in the research process and art” is planned through the implementation of 14 activities. The success of the activity will be monitored, directed, and controlled using 15 key performance indicators. The planned activities are defined on the basis of 6 sub-goals (short-term goals), the successful implementation of which in the four years of strategy implementation should ensure the implementation of the defined long-term strategic goal No. 2.

For the control of key success factor No. 3, appropriate activity performance measures have been defined (Table 6).

Table 6: Key success factor No. 3 - sub-goals, activities, and control measures

Sub-goals		
S 3.1. Digitalization of student administration	**Activities for the implementation of S3.1**	**Activity performance control measures A3.1**
	A3.1.1. Actively monitoring the development of new ISVU services and their introduction into business processes at the faculty.	M1. New ISVU services introduced into business processes.
	A3.1.2. The expansion of the Faculty's Electronic Document Management System (DMS) to include student service documentation.	M2. Extended coverage.

S 3.2. Continuous improvement of the Faculty Business Process Support and Monitoring System (SP4)	**Activities for the implementation of S3.2**	**Activity performance control measures A3.2**
	A3.2.1. Analysis of employees' digital competencies (including general digital competencies and those specific to the field of work) for the purpose of selecting and organizing training.	M3. Surveys were conducted via online questionnaires for all employees and a report produced once a year.
	A3.2.2. Organization of digital competence workshops for administrative staff.	M4. At least one workshop held each year, with 100% coverage by the end of 2028.
	A3.2.3. Implementation of a system for supporting and monitoring the faculty's business processes in all processes in order to integrate all administrative functions. This includes applications and implementation of scientific and professional projects, management of equipment, finances, human resources, procurement and maintenance of facilities.	M5. Implemented a system for supporting and monitoring faculty business processes in 90% of processes.
	A3.2.4. Expansion of the electronic document management system (DMS) for the secure storage, organization and search of all administrative documents in digital format.	M6. Expanded electronic document management system (DMS).
	A3.2.5. Establishing a system for monitoring the application and implementation of scientific and research projects within a unified information system.	M7. A system for digital monitoring of the application process and implementation of scientific and research projects established.
S 3.3. Continuous improvement of the ICT infrastructure	**Activities for the implementation of S3.3**	**Activity performance control measures A3.3**
	A3.3.1. Creation of a plan for the renewal and procurement of servers and network infrastructure.	M8. An annual plan developed.
	A3.3.2. Development of a plan for the renovation and procurement of ICT office equipment.	M9. An annual plan developed.
	A3.3.3. Renovation and procurement of servers, network infrastructure and office ICT equipment.	M10. Procurement implemented on an annual basis.
S 3.4. Enhancing digital communication and collaboration	**Activities for the implementation of S3.4**	**Activity performance control measures A3.4**
	A3.4.1. Creating an internal online platform for student and employee support with an archive of frequently asked questions and answers, as well as the ability to ask new questions and report problems.	M11. An online platform created to support students and employees.
	A3.4.2. Developing an internal portal for employees and students that provides access to important information, notifications, and documents.	M12. Developed an internal portal for employees and students that provides access to important information, notifications and documents.
	A3.4.3. Launching an initiative at the University of Split level for the development of mobile applications that would allow students to access all important information and services from any location.	M13. An initiative launched to develop a mobile application at the University of Split.
S 3.5. Sustainable development through business digitalization	**Activities for the implementation of S3.5**	**Activity performance control measures A3.5**
	A3.5.1. Reducing paper use in all processes that currently require paper, by switching to e-documents, e-reports and digital presentations.	M14. Reduced paper use in administration by at least 50%.
	A3.5.2. Introducing and using technology to monitor and optimize energy consumption in faculty buildings, such as systems for automatic regulation of lighting, heating, and cooling according to needs.	M15. Technology introduced for monitoring and optimizing energy consumption in faculty buildings.

Source: Adapted from FCEAG, Split (2024), p. 15–16

Table 6 shows that the achievement of Key Success Factor No. 3, "ICT Infrastructure and Business Digitalization," is planned through the implementation of 15 activities. The success of the activity will be monitored, directed and controlled using 15 key performance indicators. The planned activities are defined on the basis of 5 sub-goals (short-term goals), the successful implementation of which in the four years of strategy implementation should ensure the realization of the defined long-term strategic goal No. 3.

For the control of key success factor No. 4, appropriate activity performance measures have been defined (Table 7).

Table 7: Key success factor No. 4 - sub-goals, activities, and control measures

Sub-goals		
S 4.1. Establishing a digital platform for collaboration with the industry	**Activities for the implementation of S4.1**	**Activity performance control measures A4.1**
	A4.1.1. Developing a digital platform for student collaboration with industry partners through work on real projects. Through the platform, students would register their interests and skills, and companies would list available projects and internship opportunities. The platform would facilitate establishing contacts and implementing cooperation.	M1. Developed a digital platform for collaboration with industry partners.
	A4.1.2. Developing a virtual career center: establishing a digital employment center through which companies would publish open calls for employment. Students would search for available jobs, submit their resumes, and participate in virtual interviews.	M2. A virtual career center established.
S 4.2. Organization of virtual conferences, webinars, seminars and workshops	**Activities for the implementation of S4.2**	**Activity performance control measures A4.2**
	A4.2.1. Organizing virtual conferences, webinars, seminars and workshops in partnership with industry leaders and experts in construction, architecture and geodesy. This would enable students, researchers, and professionals to exchange knowledge, ideas, and innovations regardless of geographic location.	M3. At least one activity held per year.
	A4.2.2. Organizing digital skills competitions in which students can participate in solving real-world construction problems. Organize competitions in cooperation with companies, which could offer prizes or even employment to the best participants.	M4. At least one activity held per year.
S 4.3. Joint research projects with industry partners	**Activities for the implementation of S4.3**	**Activity performance control measures A4.3**
	A4.3.1. Joint research projects with industry partners. The projects would enable joint work on the development of new technologies, materials or methods, with financial support from industry and funds.	M5. Applied to at least five calls for proposals for joint research projects with industry partners. Conducted at least two joint research projects with industry partners.
	A4.3.2. Establishing an innovation center in collaboration with leading industry companies, where students and researchers could engage in prototype development, testing new technologies, and the commercialization of innovations.	M6. Innovation center established.
S 4.4. Supporting the local community through digitalization	**Activities for the implementation of S4.4**	**Activity performance control measures A4.4**
	A4.4.1. Establishing an online platform through which citizens, businesses, and local authorities could receive expert advice and consultations from professors and faculty students on projects, sustainable practices, and infrastructure renovation.	M7. Online platform established.
	A4.4.2. Developing free online courses and educational materials on topics such as energy efficiency, sustainable construction, and construction site safety. These publicly available resources would help educate the general public on key construction topics.	M8. At least ten courses or educational materials developed.
	A4.4.3. Using digital design and urban planning tools such as GIS and BIM in cooperation with local and regional government units.	M9. At least one cooperation agreement with local and regional self-government units formalized.

Source: Adapted from FCEAG, Split (2024), p. 17–18

Table 7 shows that the achievement of Key Success Factor No. 4, "Connecting with Industry and Society through Digitalization," is planned through the implementation of nine activities. The success of the activity will be monitored, directed and controlled using 9 key performance indicators. The planned activities are defined based on 4 sub-goals (short-term goals), the successful implementation of which in the four years of strategy implementation should ensure the realization of the defined long-term strategic goal No. 4.

A set of 66 performance control indicators has been defined to control the digitalization strategy (during and after implementation). The digital transformation strategy of FCEAG in Split can be said to be comprehensive and offers a clear path towards digital transformation. Although challenges in the area of financial sustainability and uneven implementation remain, consistent implementation of the strategy, motivation of teaching staff, continued support from the state, the EU, the University, as well as active use of international funds and partnerships, are key areas that can ensure successful digital transformation.

Conclusion

Control is seen as a key instrument for achieving quality, efficiency, and sustainability of digital transformation. Controlling the digitalization strategy allows institutions to monitor the implementation of set goals and detect deviations in the implementation process. It contributes to transparency, improved governance, and timely adoption of corrective measures. Effective control is based on regular reporting, data analysis, and the engagement of all stakeholders in the system. The challenges in measuring and controlling the digitalization strategy of HEIs can be great. Measuring the effects of digitalization is often made difficult by the inability to convert qualitative results (such as motivation and teaching quality) into measurable indicators. Fragmented data and the lack of uniform standards are also problems. Control of the digitalization strategy of HEIs is seen as control during and after the implementation of the digitalization strategy. During implementation, control includes monitoring the activity plan, testing the solution, and educating users, and the control instrument is explained during implementation. Monitoring the digitalization strategy of HEIs after implementation involves assessing the long-term effects on teaching, efficiency, and higher education institutions. This control involves comparing achieved and planned performance, as well as potentially redefining the strategy. The post-implementation control instrument is explained, which evaluates the strategy based on successfully implemented activities that were achieved during the strategy implementation period. The application of key success factors as a strategic control method allows for linking planned goals to appropriate performance measures. This makes it easier to monitor the success of strategy implementation. Identifying key success factors makes it easier to monitor the most significant areas that have a key impact on the achievement of the strategy. The example of the Faculty of Civil Engineering, Architecture, and Geodesy in Split demonstrates the practical application of key success factors in controlling a digitalization strategy. By defining key success factors, FCEAG focused attention on key areas and defined sub-goals for them. The FCEAG also defined activities to achieve these sub-goals, as well as key performance indicators for the defined activities. This approach allows for control of strategy implementation and adequate response if its implementation is not implemented according to plans.

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