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An Overview of the Third Mission Activities of a Higher Education Institution in Szekesfehervar

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Abstract: The subject of the study provides an overview of the third mission activities of a higher education institute (HEI) operating in Szekesfehervar. The study presents the results of the latest literature about the third mission of HEIs. Our most important task was creating an insight into the development of the examined topic through a review of the literature produced between 2021 and 2025 and to identify recognisable trends. In our short study we touched on the challenges facing the higher education. We proposed suggestions for the HEIs on the opportunities for developing their third mission activities. With this development, they can contribute not only to overcoming their own challenges, but also to the sustainable development of the city providing them with a home.

Keywords: third mission, higher education institute, regional services, sustainable cities

1 Introduction

With the According to the Research, Development and Innovation Strategy of Hungary (2021-2030), accepted in 2021, the higher education institutions (HEIs) need to pay special attention to develop their third mission activities in which the strategy aiming to realise the SDGs were highlighted along with any other areas

(social responsibility, popularization of science, knowledge sharing, closer ties with the economy) [1]. With its Sustainable Development Goals framework, the UN wish to shift the development trajectory of the world to a sustainable direction for the future prosperity of the people, peace and protection of our planet [2].

The EU has integrated the SDGs and determined a roadmap for implementation until 2030. The cities of the member states of EU have defined their strategic objectives and planned specific interventions in their sustainable urban development strategies, for which the EU has also provided an methodological handbook (Busti, 2020) [3]. In its document titled „Universities without Walls – Vision 2030”, the European Universities Alliances (EUA) envisions a future in which open, inclusive, flexible universities promote sustainability through collaborations, social engagement and innovation (EUA, 2021) [4]. The European Commission (EC) accepted the document titled The European Strategy for Universities in 2022 to support the adaptation of HEIs to digital and green transitions, strengthening the European identity as well as developing the transnational collaboration. The EC intends to support the universities as the key actors of change, and to prepare them to contribute to resilience and recovery of Europe [5]. Vorley and the co-authors examine the third mission of higher education as the responsibility through case studies how they move away from their traditional roles to engage with different stakeholders (entrepreneurs, charities, communities etc.) to design new solutions [6]. By developing their third mission activities, the HEIs can not only contribute to tackling their own challenges, but also to the sustainable development of the cities providing homes to them. The authors interpret the third mission of HEIs as a continuously evolving and overarching beyond the boundaries of science, complex phenomenon, which encompasses social and economic missions, contributing to the development of communities and the region [7]. Due to their geographical location, the higher education institutions (HEIs) have special characteristics, capacities and networks which influence the kind of third mission activities they can undertake and carry out in their immediate environment also utilizing their popularity. Stoeber and co-authors conducted research among the European universities (N=309) in 2025, which shed light on the fact that 84% of participants already have sustainability and environment friendly strategy and 11% of them are currently working on it. Furthermore 74% of the institutions indicated that these areas are high strategic importance in their mission [8].

With this study we aim to get to know the third mission activities of HEIs operating in Szekesfehervar (HU) and to formulate suggestions along these trends.

2 Method

The goal was to prepare a descriptive, summary study providing an overview of the third mission activities of a higher education institution operating in Szekesfehervar. We used the Scopus database to review literature between 2021 and

2025 applying the following keywords (higher education, third mission, sustainability, regional competitiveness) as a result, we identified 21 studies that could contribute to objectives of this study. Through the literature review, we gained insight into third mission activities and outlined the trends in this field. In the following section, we provided a very short introduction to the higher education institution under study and then gathered information about its third mission activities based on news and reports found on its website. Following this overview, we examined the faculty's third mission activities in comparison with the third-mission objectives formulated by the university. After this assessment, we identified opportunities for future development for the institution of higher education.

3 Literature Review

3.1 On the Third Mission Activities of HEIs Related to Entrepreneurial University Model

In relation to the third mission activities of HEIs, it is necessary to mention the promotion of the culture which can be executed as an „entrepreneurial university”. Compagnucci and co-author highlighted in a systematic literature review on the topic of the third mission that establishing an entrepreneurial culture has a crucial role in transforming higher education institution into an entrepreneurial university which should spread among academic staff. They found that the entrepreneurial initiatives within the university should be communicated through organisational units, because lacking this and the fact that most employees haven't got any business experience, they will not understand the essence of the entrepreneurial life and may even consider it dangerous for implementation of the traditional missions. The study also touched on the summary of the role of the knowledge transfer offices, which support the spread of entrepreneurial education and culture within the community of the university [7]. In their study, Lopes and his co-authors pointed out that, in accordance with its third mission, the university contributes to the development of students' entrepreneurial mindset and ambitions. They highlighted the connection between creativity and business success, which can manifest in the harnessing of ideas and opportunities and the optimal use of resources, which can contribute to the creation of efficient and innovative processes. Based on their results, the researchers found that related to intention of students to become entrepreneurs is influenced by several factors, such as behavioural variables (entrepreneurial attitude and perceived behaviour) and young people's perceptions of entrepreneurship (business success, business skills) [9]. The conceptual framework presented by Cunningham and co-authors can help higher education institutions transition to the third mission by adjusting their internal organizational structure to the needs of the entrepreneurial process. The authors consider the shaping of both structural and cultural elements to be a significant tool for

supporting the different phases of the entrepreneurial journey: the initial (ideas/motivation), the formation (team/plan), the launch (start-up), and the growth stages [10]. Another important aspect highlighted by Civera and co-authors is the importance of the diverse makeup of university spin-off teams; by including members with different professional backgrounds, ways of thinking, and even those with industry or business experience, such teams can contribute most effectively to growth, beyond simply achieving success. This type of knowledge integration can improve problem-solving, creativity, and strategic decision-making [11].

3.2 A Paradigm Shift Related to the Third Mission: A Shift Toward the SDGs?

The authors considered the third mission to be a paradigm shift, in which universities contribute to solving social problems, supporting economic development, and fostering cultural and intellectual growth [12]. We consider the third mission to be a driving force for regional development; however, there are contradictions related to the methodology for measuring results. Haj Taieb pointed this out after reviewing studies that analysed the methodologies for measuring the third mission of European universities, based on which he identified some contradictions. The first of these is that the results of the third mission have a wide range, which means there is currently no standardized measurement method. The second is linked to a quality assessment criterion that does not take into account differences between institutions' geographical conditions and their management [13]. The authors draw attention to a new perspective on measuring results in Germany; in connection with the EXIT program of the government, they have identified a shift that is clearly visible in the third mission. The authors highlight that there has been a shift away from success measured purely by economic performance toward spin-offs and startups that serve sustainability goals, through which social and ecological values can be created (Lehmann et al., 2024) [14]. Attention is turning to impact entrepreneurship, as modern challenges require modern solutions - a contribution to which can be made by the concept of the "impact university".

Fia and colleagues conducted a systematic literature review on the 2030 roadmap of higher education institutions. They found that institutions link the Sustainable Development Goals (SDGs) to four main activities: research, education, operational management (e.g., campus environmental management, reducing energy consumption), and the third mission - community engagement. They highlighted that there is a visible shift from previously fragmented sustainability efforts toward holistic, comprehensive strategies [15]. In addition, during the third mission, universities will build partnerships with local communities to apply their knowledge to solving real-world challenges related to sustainability. In rethinking the role of universities, the authors concluded that these institutions can proactively foster regional sustainability transitions through location-based innovation activities. Committed universities are required that can address local, complex environmental and social challenges by driving systemic change, leveraging living lab structures, and fostering collaborations as we move toward sustainability [16]. Van Mensel and

co-authors pointed out that while universities are expected to have a social impact, there are no clear guidelines or practical mechanisms for achieving this. Therefore, universities may interpret and implement the social aspect of the third mission in different ways. The authors emphasise that, due to today's social and environmental problems, engagement with society will gain importance in third mission activities, rather than economic aspects. They conducted a systematic literature review to support higher education institutions in this transition with a guiding framework [17].

3.3 Are Universities Adopting the SDGs due to External Pressure or Out of Their Voluntary Commitment?

In the area of third mission activities, there is a clear shift toward the SDGs and social responsibility. However, this leads to the question: is this shift driven mainly by external pressure, or does it come from voluntary commitment? The authors consider higher education institutions to be key players in sustainable development, facing pressure from both within and without to continue moving in this direction. The authors emphasise that, in relation to their third mission, these institutions should focus on sustainable development in the context of society. Furthermore, they urged universities to reflect on the unique opportunities of their own organisations (capacity + context) and to consider what obstacles they might face in achieving the SDGs, as well as what might help them in carrying out their mission [18]. The authors examined the role of European universities in achieving the SDGs based on a sample from 22 countries. Following their research, the authors made a positive statement in their study on the results, as the number of institutions not addressing the Sustainable Development Goals is small, and more than 30% of respondents indicated that they address the Sustainable Development Goals to a large or very large extent. The authors also pointed out that institutions address certain SDGs (e.g., SDGs 1, 2, 14, 15, and 16) less frequently [19]. Within the institution, staff, students, and faculty should be encouraged to commit to the third mission and the SDGs as promoters of change. In analysing the potential for universities to become drivers of the sustainability transition, the authors concluded that universities must shift away from their traditional role of knowledge transfer toward developing viable solutions with the involvement of stakeholders. The authors emphasised that, as part of the strategy to carry out this mission, efforts could focus on integrating sustainability into the curriculum, applying the living lab principle to campus operations, and encouraging transdisciplinary research [20]. In addition to all this, it is important not to forget the international rankings of higher education institutions (THE, GreenMetric), which help to raise the visibility and enhance the positioning of these institutions on the global stage; this topic is included among the evaluation criteria for such rankings. The authors presented and compared the content of the sustainability plans of two Italian universities, which helps clarify the practices they aim to implement to achieve environmental sustainability. The study used a case study approach and analysed the possibility of its introduction at a Russian university [21].

3.4 On the Cities of the Future

We hope that the data-driven cities of the future will be intelligent and sustainable enough to cope with the accelerated urbanisation process, to find solutions not only to rising energy demands and population growth but also to environmental pressures and the impacts of climate change. In their research, the authors identified the environmental, economic, social, and technological challenges and opportunities related to sustainable smart cities that can facilitate planning processes and decision-making [22]. As early as 2017, Ringenson and his colleagues drew attention to the fact that smart, sustainable cities can face numerous limitations, which they recommended mitigating. They emphasised that the development of digital infrastructure could be a suitable means of addressing cities' sustainability challenges, but that this must be implemented in tandem with the creation of an analog backup. After all, the new system could directly lead to future vulnerabilities, which could weaken our cities contrary to our intentions [23]. The EU's Green Deal, adopted in 2019, set out at the strategic level the goal of making our continent cleaner, healthier, and climate-neutral by 2050 [24]. The authors examined the role of cities (where 75% of Europe's population lives) and universities in the implementation of the EU's Green Deal. The authors emphasised that, through their role as network builders, universities can establish partnerships both locally and globally, thereby expanding their existing knowledge, experience, and best practices. By sharing these, they can contribute to the sustainable development of their environment, city, and region, and to the creation of a fairer and more peaceful world [25]. In their study, the authors point out that higher education institutions can provide impulses for sustainable development in a certain region through unique research projects carried out in collaboration with regional partners. By participating in development projects focused on specific neighbourhoods, they can demonstrate their commitment; the authors emphasize that they can often contribute to regional sustainability through small impulses of change as a secondary product of their research [26].

4 A Higher Education Institution in Szekesfehervar (HU)

Since its founding in 2014, Alba Regia Faculty, Obuda University has continued the tradition of its predecessor institutions (1962: Higher Surveying Technical School (FFT) – known for “Geo” and its surveying program; 1970: the Kandó Kálmán College's branch campus with its electrical engineering program) – has aimed to serve the region's development through its educational and research activities. Over the years, however, a third element has emerged alongside the two mentioned above, which the institution carries out as its “third mission.” In this way, it contributes to the development of the region by applying its knowledge as a kind of social mission.

4.1 On the Third Mission Activities of Alba Regia Faculty, Obuda University [27]

The Alba Regia Faculty regularly organises **public science promotion and educational programmes** that are also open to the citizens of the city. The *Géza Garai Open University lecture series*, launched in 2013, makes scientific topics understandable and accessible to people who are not familiar with the academic world. Another type of science popularisation programme is *Researchers' Night*, where the university opens its doors wide so that interested visitors can learn about and see research results in a fun way, try out state-of-the-art laboratory equipment and robots, and become familiar with various scientific fields. *Girls' Day* stands out among the programs because, as a career-oriented event, it aims to support the growing number of women by presenting the career paths of women working in engineering and the natural sciences.

Sharing the latest research findings at professional events and conferences encourages scientific debate, fosters mutual trust, and promotes dialogue. The 30th event of the *GISopen conference* was held in 2026; its significance goes beyond that of traditional academic conferences, as it also includes certain cultural elements related to the preservation of the Selmec student traditions, which have been added to UNESCO's National List of Cultural Heritage. The program serves as a professional forum for surveyors and geoinformatics specialists. The 21st AIS (*21st International Symposium on Applied Informatics and Related Areas*) conference will be held in 2026; the presence of international participants will create a vibrant cultural atmosphere on the university campus throughout the event. In addition to the conferences, the organisers are also holding *workshops* (e.g., Robotics) and networking events (1. Security Technology, 2. Connectivity, Digitalisation, and Industrial Solutions), which are expected to stimulate lively professional dialogue in the city. As part of their commitment to social responsibility, they organised a *series of lectures* (e.g., cybersecurity lectures for students in primary and secondary schools) to raise awareness of an issue that affects all segments of society and to help increase cybersecurity awareness.

The university reaches out to the youth of Szekesfehervar in various ways as part of its commitment to social responsibility, as the faculty is dedicated to organise competitions on a variety of topics. The 5th "*Junior Engineers Camp – HARMAN Hackathon*", an idea and prototype development competition to be held in the fall of 2026, is a joint initiative of the Municipality of Szekesfehervar, Harman Becker Ltd. and the Alba Regia Faculty of Obuda University, will contribute to improving the cultural level of innovation among two target groups (secondary school students and university students), developing participants' soft and hard skills, and promoting the startup spirit.

By organising the 9th *Antal Bejczy Memorial Technical Innovation Tournament* for Secondary Schools, the organisers aim to raise awareness of robotics among participating students and their families, as well as to identify talented secondary school students who are interested in building and programming robots. Secondary school students interested in the field apply to participate in the *Geoinformatics*

Competition, now in its 12th year and held in association with GIS Day. Each year, through their school projects, they bring fresh perspectives that draw attention to new areas of geoinformatics applications. A competition related to the Sustainable Development Goals (SDGs), titled the “*SDG Competition*”, will be held for the first time in 2026 for primary and secondary school students, with the aim of both promoting interest in the topic and fostering knowledge sharing. According to the plans, in the competition finals, students will develop innovative ideas aligned with the SDGs that can contribute to the sustainable development of their own communities. As we enter the era of artificial intelligence, any university competition that promotes innovation among young people and improves their digital literacy can contribute to the development of the regional economy. Among the student events is the preservation of the *Selmec student traditions* (which date back to the late 18th century), which have been included in UNESCO’s National List of Cultural Heritage. In the city, this tradition highlights the presence of the university’s student community, which contributes to the enrichment of the town’s cultural life.

The faculty plays a key role in ensuring a continuous supply of new skilled workers for the city. In 2015, by laying the basis for the *dual training system*, and in the following years through the establishment of the Dual Training Office, a university department, and through a commitment to open dialogue and the success of dual students, the university faculty has fostered a relationship of trust in which corporate partners treat this training model as an integral part of their HR policies and rely on it to ensure a supply of skilled professionals. By launching awareness-raising, knowledge-sharing, and mentoring programs focused on dual education, the faculty has provided a labour market service to their corporate partners in recent years, a service that has manifested itself in the achievements of the mutually trained students and in the form of positive feedback from employers. In 2026, the 10th Dual Education Information Day and Job Fair was held, where local companies could meet directly with secondary school students applying to the faculty; this event supports the corporate recruitment process for dual education programs. The popularity of dual training remains high in the city, which, as the country’s third-largest economic powerhouse, has a significant industrial sector that relies heavily on engineers, business professionals graduating from the faculty.

In the context of developing the social and economic environment, it is important to mention the extensive network of relationships and the strong ties to industry that characterise the higher education institution. Industry-higher education collaborations take many forms, and the faculty is fundamentally characterised by an open, flexible, and pragmatic attitude. Their research results and collaborations create the opportunity to ensure high-quality and competitive engineering education, contribute to the spread of digital literacy, and support the digital transition for the city. It has become a key player in the process of developing the urban and regional innovation ecosystem. In the smart specialisation strategy, the *Science and Innovation Park* is currently being established at the Alba Regia Faculty, Obuda University in Szekesfehervar, in line with the priority given to

mechatronics in Fejér County. The Science Park supports research, development, and innovation based on deepening industry-university ties through its infrastructure; with its service portfolio, it can contribute to enhancing the competitiveness of economic organisations in the region. The goal for the faculty is to *further develop and strengthen industrial and corporate collaborations*. It currently plays an active role in partnerships with large corporations, which has resulted in the establishment of the *Industrial Departments* (Kyndryl, Harman, Videoton).

The faculty provides training for the *next generation of professionals in several fields within the city and its surrounding region*: computer engineering (at the regional level), mechanical engineering, electrical engineering, and mechatronics engineering (at the regional level), as well as technical management, business administration and management (at the local level). These Bachelor and Master programmes support the region's technological and industrial development through knowledge transfer.

The faculty offers programs with national impact, such as sports economics, land surveying engineer, and geoinformatics. These can contribute to meet national economic needs. The curricula include a wide range of sustainability-related topics, from energy management to precision farming.

4.2 On The Obuda University's Third Mission Objectives and the Activities of the Alba Regia Faculty [28]

A summary of the Obuda University's third-mission goals can be found on the University's website. These are as follows: "1) Strengthening the institution's impact on local economic development. 2) Increasing the institution's activity in addressing social challenges and promoting social innovation. 3) Expanding services that popularize science, disseminate knowledge, and shape public attitudes, and increasing free access to higher education knowledge bases. 4) Creating up-to-date informational content and ensuring widespread access to it. 5) Strengthening the service functions of higher education for both students and the local community. 6) Improving the quality and expanding the scope of Hungarian education beyond the border" [28].

The activities of the Alba Regia Faculty in Szekesfehervar contribute to the fulfilment of the Obuda University's third mission objectives, as outlined in points 1) and 3), and partially contribute to those outlined in point 2). After reviewing the activities of the faculty, it becomes clear that, in addition to the achievements made, the level of social responsibility can be further enhanced by establishing collaborations with actors in the civil society sector. By involving a new community of stakeholders, it would be possible to gain a better understanding of the social problems that the institution of higher education institution could help solve. In this way, the faculty could further strengthen its role as a service provider in the region, which would not only be aimed at local and regional economic development but would also support innovation processes designed to address local and regional social issues.

Discussions and Conclusions

The Alba Regia Faculty, Obuda University is currently considered one of the Szekesfehervar's leading centres for higher education and innovation, and through its third-mission activities, it contributes to strengthening the local economy by facilitating knowledge transfer, developing collaborations, and providing innovative services through the Science and Innovation Park, while ensuring a supply of skilled professionals for the region. The third mission activities of the faculty are considered classical and demonstrate the institution's commitment to the city that is its home and to society at large. Currently, however, the faculty does not have a mission statement (this exists at the university level) on third mission activities, even though this could help clarify the issue for the university community, raise awareness among the entire community, and further strengthen their commitment.

Based on the literature, the shift toward sustainable development goals observed in the third mission activities should be further strengthened within the faculty, both in education and in research. We recommend further developing the interdisciplinary character of research through mixed research groups, given that the campus also offers programs related to the sports industry, which, when combined with technical education, can open the way for innovations in sports technology.

In connection with the further development of the local innovation ecosystem, we recommend examining what business development skills are needed among students and lecturers. Are hard skills more necessary, or is there a need to develop soft skills in order to change students' willingness to launch startups or lecturers' willingness to establish spin-offs in the city? It would also be beneficial to establish a research group dedicated to addressing local social issues, which could contribute more directly to the sustainable development of the city. The faculty must develop and expand its network of partners in order to identify new stakeholders (civil society organisations) and, in collaboration with them, support innovative processes aimed at solving local and regional social problems.

A limitation of our study is that we undertook to review the third mission activities of a single higher education institution in a single locality. However, in the case of the third mission, the specific characteristics and embeddedness of the higher education institution determine what missions can be carried out by that organisation.

A potential future research direction would be to assess the willingness and activity of the university community regarding third mission activities within the institution, in order to identify directions for developing further missions. It would also be worthwhile to examine the city's other higher education institution on this topic to gain a more comprehensive picture of third mission activities and their impacts in the city.

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Fair Evaluation of Classical Machine Learning Methods for Vibration-Based SHM

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Abstract: Glass Fiber Reinforced Plastic (GFRP) is widely used in industrial applications, from wind turbine blades to lightweight drones and aircraft structures. Its non-linear, anisotropic behavior makes damage detection harder than for metallic materials, while damage types such as delamination, matrix cracking, and fiber breakage substantially affect structural durability. Structural Health Monitoring (SHM) aims to replace scheduled manual inspections with automated, data-driven damage detection.

This work presents a vibration-based dataset of 32 GFRP plates (8 undamaged and 24 damaged across four damage levels) in two aging states, together with a fair benchmarking framework for classical machine learning. Six models are evaluated across five feature sets using repeated nested cross-validation (4 outer folds $\times$ 30 repeats), Optuna-based hyperparameter optimization, and Friedman-Nemenyi statistical comparison. A trivial baseline that always predicts the majority class is included to expose the optimistic bias of accuracy and F1 under class imbalance.

The benchmark shows that rigorous nested evaluation reduces the reported balanced accuracy from 88% to 69.5% on identical data, that feature choice has a stronger effect than model selection, and that accuracy and F1 are misleading under this class imbalance. The trivial baseline reaches 75% accuracy and 86% F1, while only balanced accuracy reveals actual learning.

1 Introduction

Composite materials are widely used in engineering structures such as aircraft components and wind turbine blades. However, due to their complex internal structure and the variety of possible damage states, they still require frequent manual inspections [1]. Structural Health Monitoring (SHM) aims to address this limitation by using sensors and algorithms to automatically detect damage within such structures [2]. In this paper, we focus on vibration-based measurements of Glass Fiber Reinforced Plastic (GFRP) plates as a model system.

A common challenge in experimental SHM studies is that only small and imbalanced datasets are available [3, 4]. This complicates the implementation of a robust evaluation methodology for distinguishing damaged from undamaged states and requires careful methodological design. Using an inadequate evaluation methodology or an unsuitable metric can lead to misleading conclusions or optimistic bias in the reported results [5].

This paper does not propose a novel algorithm for SHM discrimination of damaged and undamaged states. Instead, it documents the design decisions made when constructing a robust evaluation framework for a small dataset of vibration-based measurements of GFRP plates. The remainder of the paper is structured as follows: we first describe the data acquisition process and the vibration measurements performed on the plates, then present the methodology of the machine learning pipeline, and finally evaluate and discuss the results. This ordering reflects that several methodological choices in the evaluation framework are direct consequences of the dataset's size and class structure.

2 Data Acquisition

2.1 Sample production

The specimens utilized in this study were Glass Fiber Reinforced Plastic (GFRP) plates, representing materials found in wind turbine blades and fuselages of

lightweight drones. To ease the manufacturing process and state-of-the-art analysis, a simplified flat-plate geometry was adopted.

Initial samples were produced using a manual hand lay-up process on a glass base (process see Figure 1). While functional for initial testing, this method proved labor-intensive and resulted in inherent manufacturing defects, including entrapped air (voids), surface delamination, and thickness inconsistencies. Only 32 specimens produced achieved the quality necessary for the following FRF measurements.

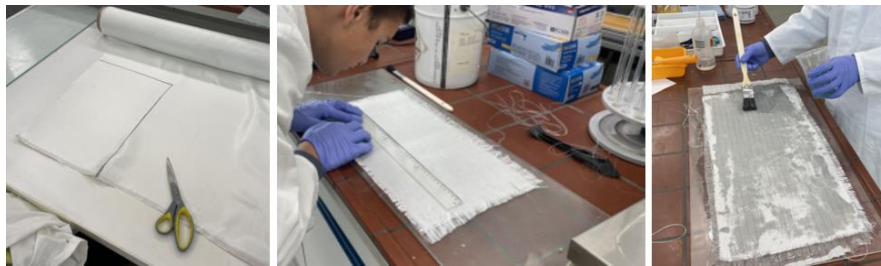


Figure 1
Manual lamination process. Left: cutting the glass fiber fabric.
Middle: Alignment of the fabric layers on a glass base plate.
Right: Application of resin by brushing

To mitigate the defects and labor intensity of manual lamination, a Vacuum Infusion Process (VIP), where the liquid resin is pulled evenly through the fiber layers using vacuum (Figure 2), was adopted for the second production phase. This method utilizes a vacuum-driven pressure differential to ensure a consistent, pore-free resin impregnation, enabling the high-volume production of over 100 specimens. However, due to the extensive volume of data generated, these newer samples have not yet been fully analyzed. Consequently, the Machine Learning analysis presented in the following section pertains exclusively to the initial 32 specimens produced via manual lamination.



Figure 2
Vacuum infusion process

2.2 Variation of the Sample Plates: Weathering and Damage

To create the diverse material states required for this study, specimens were subjected to two distinct degradation methods, applied either independently or in combination:

- Environmental Weathering (Figure 3): Accelerated aging in a climate chamber (high temperature, humidity, and UV) to simulate long-term atmospheric exposure.
- Mechanical Impact (Figure 4): Controlled damage via a drop-weight machine (dropping of steel balls with predefined energy) to induce failures such as delamination, fiber breakage, and matrix cracking.



Figure 3
Aging of the sample plates in the climate chamber

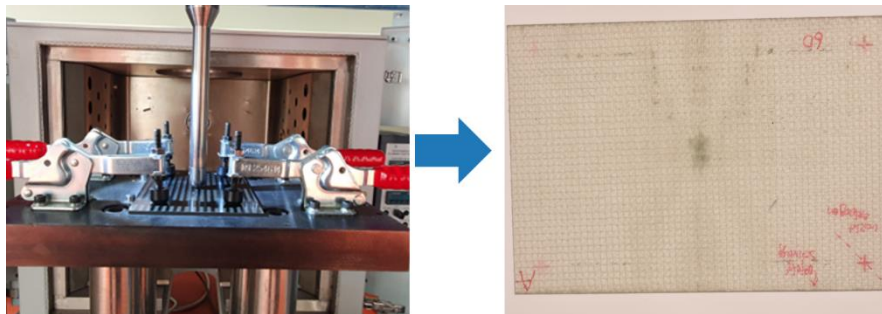


Figure 4
Damaging of the sample plates by a drop-weight test machine

The resulting experimental matrix consists of 8 variations from the 32 samples (4 samples per variation, Figure 5).

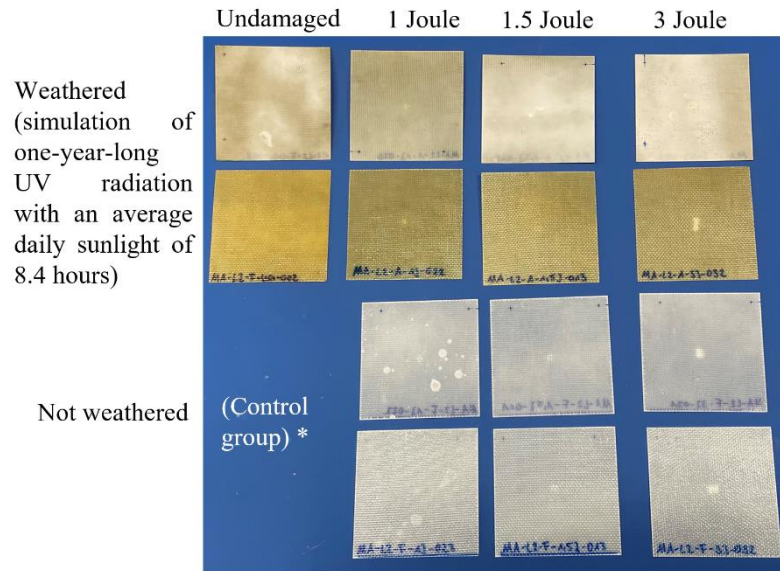


Figure 5
Specimen variations. Undamaged, not weathered control samples consumed during destructive material characterization

2.3 Vibration Measurement

The specimens were measured using a Scanning Laser Doppler Vibrometer (SLDV) and an automated modal hammer. The experimental setup employed a "fixed-excitation, roving-response" configuration. While an automated hammer provided consistent impulse excitation at a single corner point, the laser scanned over various points (measurement grid) across the specimen. Both the impulse force and velocity responses were processed via Fourier Transform to generate Frequency Response Functions (FRFs) for every measurement point (Figure 6 left).

The peaks within these FRFs identify the material's resonance frequencies. By correlating data across all scan points, the mode shapes (physical deformation patterns) were reconstructed (Figure 6 right). These range from simple bending at lower frequencies to complex twisting patterns at higher frequencies. Together, these resonance frequencies and mode shapes form a unique "vibration fingerprint," serving as the primary feature set for the subsequent Machine Learning algorithms.

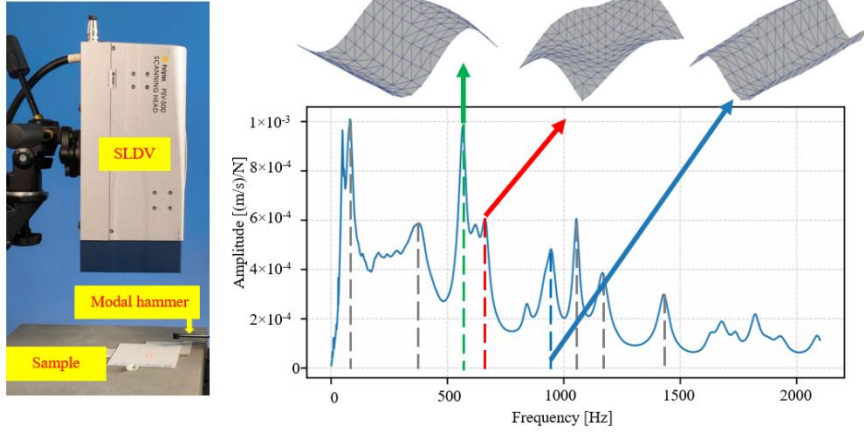


Figure 6
Measurement setup (left) and the output of the measurements (right)

3 Benchmarking Methodology

For the machine learning benchmark, the experimental conditions were collapsed into a binary classification task. Plates without mechanical impact damage were labeled as undamaged, whereas all impact-damaged plates were labeled as damaged, independent of the weathering state. This resulted in an imbalanced dataset of 8 undamaged and 24 damaged specimens. To compare and evaluate predictive performance, a range of classical machine learning models was applied to several feature sets extracted from the measured Frequency Response Functions (FRFs). One limitation is that, while many measurements are available per plate, the small number of plates overall constrains the dimensionality of the feature sets. It should also be noted that only frequencies up to 2000 Hz were used, due to constraints arising from the planned use of simulated plates. Although this discards some measurement information, we observed only a marginal decrease in the reported evaluation.

3.1 Feature sets

Five different feature sets were extracted, each from its own domain to capture complementary information. The first feature set was inspired by the standard manual inspection of the plates, in which modal properties are analyzed. For feature set A, we extracted the first six modes and computed their frequency, amplitude,

damping, and Cross-MAC values (mean, standard deviation, and maximum) [6]. We used the SMAC algorithm [7], which considers all 121 measurement positions of the plate. Feature set B describes the spectral domain of the measurements through properties such as spectral centroid, spread, energy, bandwidth, roll-off, and flatness [8]. The third set describes statistical properties of subbands of the spectrum: the primary-channel measurements were subdivided into four bands (0–500 Hz, 500–1000 Hz, 1000–1500 Hz, and 1500–2000 Hz), and from each band we extracted the mean, standard deviation, skewness, and kurtosis; the same statistics, together with the Shannon entropy of the magnitude spectrum, were also computed over the full 0–2000 Hz range. A combined feature set was additionally evaluated to assess potential synergy effects between feature sets A, B, and C. The final set was based on a property typically applied in the time domain in other studies [9]: Wavelet Packet Energy. In our case, the same principle was applied to a frequency-domain wavelet packet decomposition (Daubechies-5, level 5), yielding 32 normalized subband energies complemented by their Shannon entropy, the log total energy, and the maximum subband share.

Set	Description	Dim
A	Modal	21
B	Spectral	6
C	Statistical	21
G	Combined: A + B + C	48
WPE	Wavelet packet energy (db5, level 5) (Frequency-Domain)	35

Figure 7
Overview of the five evaluated feature sets and their dimensionality.

3.2 Model selection

On the model side, a range of classical machine learning methods was evaluated. The methods include robust implementations such as Support Vector Machines with different kernels, Random Forest, and eXtreme Gradient Boosting ensembles, as well as simpler models such as Logistic Regression and k-Nearest Neighbors [10, 11]. We additionally included a Multilayer Perceptron (a small neural network) restricted to a limited number of neurons and at most one or two hidden layers. This restriction was motivated by the small number of observations in the dataset and is also the reason why no deep learning methods were considered.

The aim of the evaluation was to determine whether model choice has a substantial impact on the results, or whether simple models perform comparably given the selected features.

Model	Type
Support Vector Machine	Kernel-based (RBF, linear, poly)
Random Forest	Bagging ensemble
eXtreme Gradient Boosting	Boosting ensemble
k-Nearest-Neighbors	Distance-based
Logistic Regression	Linear baseline
Multilayer Perceptron	Neural network (1–2 layers)

Figure 8
Classical machine learning models evaluated in the benchmark.

3.3 Nested cross-validation

From the start, hyperparameter optimization was planned to adjust model parameters based on observed performance. However, this can introduce an optimistic bias if the same observations are used both to tune the parameters and to score performance. If hyperparameters are tuned on the same data on which the model is evaluated, the optimizer effectively selects the configuration that best fits the noise of that specific split, and the reported score reflects this overfit rather than true performance. It is therefore imperative that optimization is kept separate from evaluation [5].

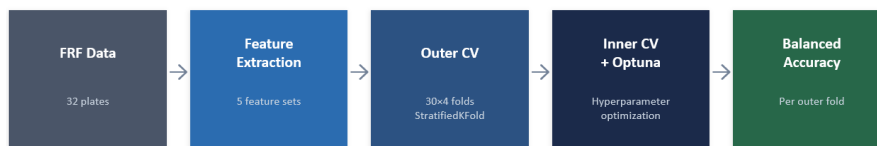


Figure 9
Nested cross-validation pipeline with outer evaluation and inner Optuna-based hyperparameter tuning.

For this reason, we used two cross-validation loops: a 4-fold outer loop and a 6-fold inner loop, both implemented as StratifiedKFold to preserve the class distribution after splitting. The outer loop was used solely for evaluating each model–feature-set combination and was repeated over 30 different random seeds, yielding 120 evaluation results per combination. The repetition was intended to mitigate the

influence of favorable splits. The training portion of each outer split was then passed to the inner loop.

Hyperparameter optimization took place in the inner loop, separately from the outer loop. Optimization was performed using Optuna with its built-in Tree-structured Parzen Estimator [12, 13]. The data passed to the inner loop was again split via cross-validation, with the training set used to fit the model and the inner test set used to tune its hyperparameters. After tuning, the selected hyperparameters were returned to the outer loop, where the model was trained on the outer training portion and evaluated on the outer test set. For the fair evaluation, only the outer test set results are reported. The gap between inner and outer test scores nevertheless serves as an indicator of overfitting.

Within each model–feature-set evaluation, some pipeline steps were fixed while others were tuned by Optuna. The pipeline was structured as follows: Imputation → StandardScaler → Feature Selection (none / ANOVA / PCA) → optional SMOTE [14] → Classifier. Imputation and scaling were fixed, whereas Optuna decided whether feature selection or oversampling improves performance, and additionally tuned the parameters and the algorithm of the feature selection step itself, only within the inner loop.

3.4 Evaluation metrics

The primary evaluation metric was balanced accuracy. Accuracy, F1-score, and MCC were tracked only for additional examination. Balanced accuracy was chosen because of the imbalanced class distribution: it weights performance according to class membership rather than overall sample frequency [15]. In addition, we report a trivial baseline that always predicts the majority class, which in our case is damaged. This trivial baseline reaches 75% accuracy and 86% F1, but only 50% balanced accuracy.

3.5 Statistical comparison

Rather than relying solely on the mean balanced accuracy, we additionally applied rank-based statistical tests for comparison. We performed two Friedman tests, one across the selected models and one across the feature sets. For the model comparison, scores were averaged across all feature sets, and vice versa for the feature-set comparison. If statistical significance was found, a Nemenyi post-hoc test was performed [16]. The Friedman test should, however, not be treated as a definitive answer, since the results are not independent across repeats. It is therefore used only as an indicator of the relative importance of model and feature-set choice, while the Nemenyi post-hoc indicates whether a clear winner exists within each category. The reported critical differences should therefore be interpreted as indicative rather than as strict inferential bounds.

4 Results

4.1 Main benchmark

The evaluation reveals three distinct findings. First, the best overall model–feature combination, measured by mean balanced accuracy across the 120 outer folds, is k-Nearest Neighbors with feature set G, closely followed by the same model with the statistical feature set C. Second, on the model side there is no substantial difference between the six classifiers, while on the feature side, sets C and G (which includes C as a subset) perform consistently better than the remaining ones. Third, feature set WPE performs noticeably worse than the other feature sets.

The best combination reaches 69.5% balanced accuracy, indicating that the models do learn information about the plate condition, although performance remains far from perfect. Clustered bootstrap ($n = 5000$, clustered by plate) yields 95% confidence intervals of $[0.58, 0.80]$ for the best combination (kNN + G) and $[0.58, 0.78]$ for the second-best (kNN + C). The intervals overlap substantially and reach close to chance level at the lower bound, indicating that the reported point estimates carry considerable variance under the small dataset size.

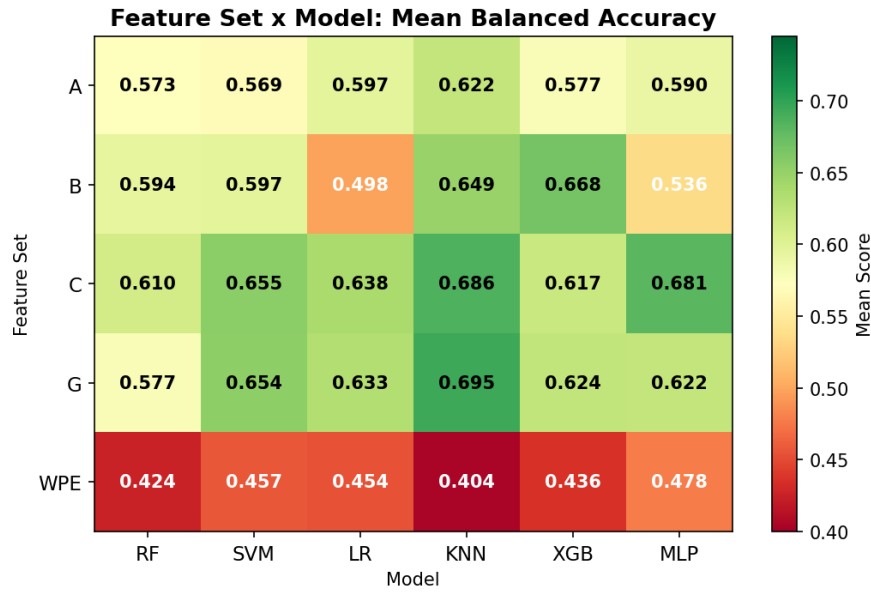


Figure 10
Mean balanced accuracy across all model–feature-set combinations over 120 outer folds.

4.2 Comparison of evaluation metrics

The comparison between our results and the trivial baseline illustrates why the choice of metric is critical. Any trained model that fails to outperform this baseline on balanced accuracy has not learned anything beyond the class prior. When the same result is reported in terms of accuracy, the best combination reaches 68%, compared to 75% for the baseline. A similar discrepancy appears for the F1-score, with the baseline reaching 86% and the trained classifier only 76%. Based on these two metrics alone, one might conclude that the trained classifier performs worse than the baseline, yet the baseline, by construction, never detects any undamaged plate. Under the imbalanced class distribution, the trained model is therefore the more informative predictor: it does learn the damage-related information in the plates, even though accuracy and F1-score fail to reflect this. Balanced accuracy makes the difference visible, with the baseline reaching 50% and the trained classifier 69.5%.

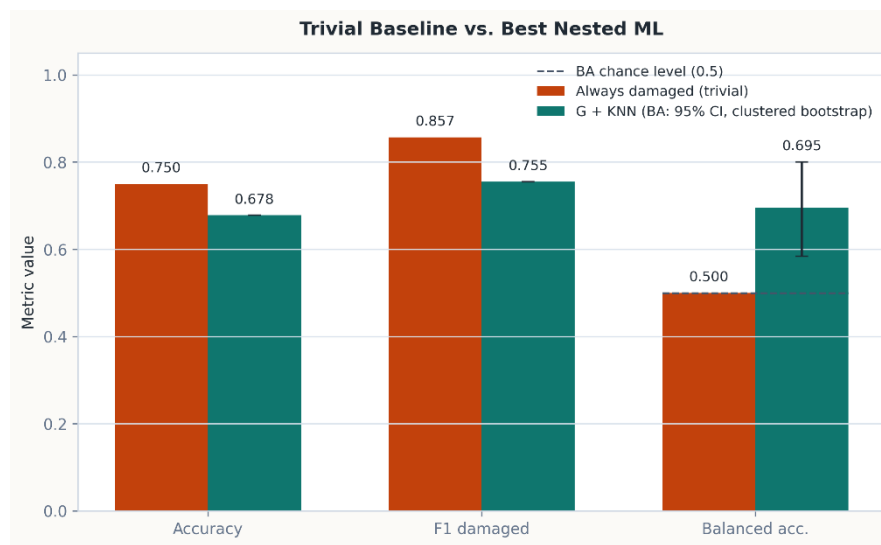


Figure 11

Trivial baseline compared to the best nested model (kNN + feature set G).

A second source of optimistic bias arises from the evaluation protocol itself. If we report the score that hyperparameter optimization itself produced, i.e. the inner-loop best score, as one would naively do without nesting for an outer evaluation loop, we obtain approximately 88% balanced accuracy on the same data. With the outer test set result at 69.5%, this corresponds to a gap of 18 percentage points. Without nesting for an outer evaluation loop, the reported performance is therefore overly optimistic and likely not achievable on unseen data.

4.3 Statistical significance

The statistical tests confirm the patterns observed in the heatmap. The Friedman test indicates clearer rank differences on the feature side, with $\chi^2 = 177.8$, than on the model side, with $\chi^2 = 33.7$. The pairwise post-hoc comparison shows that, from a model perspective, no single classifier is clearly superior to the others: kNN ranks consistently above Logistic Regression and Random Forest, exceeding the critical difference of 0.688. On the feature side, sets C and G consistently outrank sets A, B, and WPE, exceeding the critical difference of 0.557.

Overall Model Comparison		
Friedman $\chi^2 = 33.7$, $p = 2.7 \times 10^{-6}$		
Rank	Model	Mean Rank
1	KNN	2.85
2-3	SVM	3.38
2-3	XGB	3.38
4	MLP	3.42
5	LR	3.87
6	RF	4.10

CD = 0.688 | Significant: KNN > {LR, RF}, SVM/XGB > RF. Most pairs NOT significant.

Overall Feature Set Comparison		
Friedman $\chi^2 = 177.8$, $p = 2.2 \times 10^{-37}$		
Rank	Feature Set	Mean Rank
1	C (Statistical)	2.20
2	G (Combined)	2.31
3	B (Spectral)	2.94
4	A (Modal)	2.96
5	WPE (Wavelet)	4.59

CD = 0.557 | C = G (not significant).
C/G significantly better than A, B, WPE.
WPE significantly worst across all models.

Figure 12

Friedman ranks and Nemenyi post-hoc results for models (left) and feature sets (right).

5 Discussion

The aim of this study is not to present a novel approach to structural health monitoring, but to demonstrate the methodology behind a fair model and feature comparison and how the choices it involves, such as the choice of metrics, have wide-ranging effects on the results. Omitting nested cross-validation for an outer evaluation loop in combination with hyperparameter optimization yielded an inflated balanced accuracy of 88%, while applying the nested protocol produced lower but fairer results [5]. It should be noted that omitting this step does not necessarily imply that the result is wrong; rather, a sound evaluation framework is required to enable a fair comparison between feature sets and models and to provide a more reliable estimate of how the same combination would perform on unseen data. This is particularly relevant for structural health monitoring, where the response to damage can vary widely and meaningful gaps between models may exist.

The metrics in particular reveal differences and should be interpreted accordingly. Although our trained model achieved less than the trivial baseline in terms of accuracy and F1-score, balanced accuracy demonstrated that the model did in fact

learn damage-related information from the plates. This can be traced back to the imbalance in our class distribution, which influences both key design decisions in implementing the framework and the interpretability of the reported results [17]. A study could plausibly report an F1-score of 88%, but without a description of the underlying methodology and an accompanying baseline or metric explanation, the interpretation would be drastically different. The statistical tests also indicate that, in our dataset, feature choice matters more than model choice. One possible explanation is that there are simply too few observations, and that the models would require more (or more advanced) engineered features to better capture the spatial distribution of the measurements.

The most limiting factor of this study is the small dataset size, which does not permit higher-dimensional feature sets. With only 32 plates measured and a class imbalance of 1:3, and with the framework having to set aside samples for independent testing, the number of undamaged plates available for hyperparameter optimization is reduced even further. In addition, the manufactured plates likely contained errors introduced during the manual production process, which may have influenced the observed results. A further limitation is that environmental data such as humidity and temperature were not tracked during the measurements, even though these are known to affect frequency response functions [18]. These properties could also act as confounders within the dataset, which we were unable to either confirm or rule out. Given these limitations, the results obtained should be regarded as within-dataset findings, while the methodology behind the evaluation remains relevant, particularly for small, imbalanced datasets. While the present results are dataset-bound, the evaluation framework itself transfers directly to larger datasets.

Conclusion

In summary, we firstly created a dataset of glass fiber reinforced plastic plates that were damaged, weathered, and characterized through their vibration response to impulse excitation. Secondly, we used this dataset to compare different machine learning models for structural health monitoring and implemented a rigorous evaluation framework for comparing different model and feature set combinations. The results show that the methodology behind the evaluation has a substantial impact on the conclusions that can be drawn. In our case, a direct evaluation of the trained models would have inflated the reported result by approximately 18 percentage points. The choice of metric is also particularly important when working with small, imbalanced datasets, where the trivial baseline outperformed our best combination in both accuracy and F1-score, while being clearly outperformed in terms of balanced accuracy.

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The investigation of the interrelationship between digitalization and gross domestic product in Azerbaijan

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Abstract: Digitalization is widely recognized as a key driver of economic growth and sustainable development. This study examines the relationship between digitalization and economic growth in Azerbaijan from the perspective of the economic dimension of digitalization. Instead of using infrastructure-based indicators, digitalization is measured by ICT value added and ICT product imports, as these variables directly reflect the economic contribution of the ICT sector and the diffusion of digital technologies in Azerbaijan. Gross Domestic Product (GDP) is employed as the indicator of economic growth. Given the possibility of reverse causality, alternative model specifications are estimated in which GDP and ICT-related variables are treated alternately as dependent and explanatory variables. The empirical analysis applies OLS, ARDL Bounds Testing (ARDLBT), FMOLS, DOLS, CCR, and the Vector Error Correction (VEC) model to estimate both the short-run and long-run relationships. The results indicate that ICT value added and ICT product imports individually exert a positive and generally statistically significant effect on economic growth. However, when both ICT indicators are included simultaneously, the effect of ICT product imports becomes statistically insignificant and, in some specifications, negative. The findings suggest that the contribution of digitalization to economic growth in Azerbaijan remains constrained by the structural characteristics of the economy, particularly the dominant role of the hydrocarbon sector.

Keywords: Digitalization; Information and Communication Technologies (ICT); ICT Value Added; ICT Product Imports; Economic Growth; Gross Domestic Product (GDP); ARDL Bounds Testing.

JEL Classification: C22, E01, O11, O47, O39

1 Introduction

The “digital revolution” unfolding in the modern world has significantly reduced economic, social, and geographical constraints, transforming digitalization into a decisive factor in accelerating innovation-driven economic growth, facilitating the transition to a sustainable and inclusive development model, and improving overall governance systems. The experience of developed countries clearly demonstrates that the widespread implementation of innovative digital strategies across all sectors of society and the economy has enabled them to achieve dynamic economic growth.

According to the Digitalisierungsindex, 2024 report, the development of digital infrastructure has a positive impact on aggregate demand in the short term and contributes to the acceleration of economic growth. Technological progress, in turn, reduces production costs, lowers prices, and stimulates demand expansion, thereby fostering an increase in real Gross Domestic Product (GDP). The extensive use of digital technologies affects the growth dynamics of the national economy through several key transmission channels. These include technological progress stimulated by digitalization, the transition toward the sharing economy, structural changes in employment patterns, the effective utilization of time savings generated by

technological advancements, increased investment demand, and the broader contribution of technological progress to economic growth [26].

The digital economy serves as a powerful instrument for reducing various types of costs—time, financial, and material—thereby accelerating processes across all stages of economic reproduction. This leads to cost reductions, increases in labor productivity, and improvements in the overall efficiency of economic systems. Furthermore, information resources create opportunities for the implementation of innovative methods and tools, attract businesses to emerging sectors of the economy, lower barriers to market entry, and positively influence the country's socio-economic development.

The *Global Connectivity Index 2025* report prepared by Huawei (2025) indicates that every US dollar invested in ICT infrastructure generates approximately USD 3–5 in additional GDP growth over the long term. It should also be emphasized that ICT development not only accelerates economic growth but also enhances labor productivity and contributes to job creation. According to expert estimates, by 2030, approximately 30% of jobs in developed and rapidly developing countries will be automated, while 77% of the workforce will require new skill sets [27].

The comprehensive digital transformation of all sectors, spheres, and levels of the national economy enables the identification and objective assessment of long-term economic growth potential, as well as the determination of optimal solutions to strategic development goals. In this process, economic efficiency and social inclusiveness are considered fundamental criteria.

In Azerbaijan, the practical transition to a digital economy effectively began in 2003 with the adoption of the “National Strategy on Information and Communication Technologies for the Development of the Republic of Azerbaijan.” Subsequently, the 2016 “Strategic Roadmap for the Development of Telecommunications and Information Technologies in the Republic of Azerbaijan” emphasized that ICT has the potential to transform various aspects of business and trade operations. By leveraging ICT for regulatory optimization, service support, and efficiency enhancement, the government could generate additional economic benefits. In accordance with this document, a corresponding “digital transition plan” was developed [2].

In recent years, the digital transformation of the economy and society has become one of the key priorities of the Republic of Azerbaijan. The widespread digitalization of public services has created a strong foundation for effective digital transformation. The “Digital Transformation Strategy of the Republic of Azerbaijan for 2021–2030” outlines three main objectives: transparency and awareness, governance and coordination, and the support of digital applications. For each objective, priority directions for phased implementation have been clearly defined.

Considering the growing importance of artificial intelligence (AI) for sustainable and efficient national economic development and environmental balance, the

“Artificial Intelligence Strategy for 2025–2028” was approved in 2025. The primary objective of this strategy is to accelerate the development of the AI sector, create favorable conditions for the widespread application of AI technologies across all areas of public and economic life, and strengthen digital economic development as a key pillar of national progress. The strategy identifies priority areas such as large-scale AI implementation, the establishment of data centers, and the future expansion of digitalization sectors [3].

The Government of the Republic of Azerbaijan adopted a state-level decree establishing the Digital Development Council of the Republic of Azerbaijan to identify priority areas in digitalization, e-government, artificial intelligence, and innovation; strengthen national technological capacity; reinforce digital sovereignty; accelerate the transition to an innovation-driven economic model; and ensure the unified and coordinated implementation of state policy in these domains [4]

At the same time, digitalization leads to the disappearance of many traditional roles in the labor market, resulting in workforce displacement. Although businesses may reduce costs through AI adoption—thereby achieving economic efficiency—this process can increase unemployment and social tension, as workers face the necessity of retraining or acquiring new professions. Furthermore, the adaptation of the labor market to rapidly changing economic conditions, particularly in the context of digital transformation, often lags behind the pace of technological advancement, thereby intensifying social challenges.

Justification for the Selection of Digitalization Indicators

Digitalization is widely recognized as a multidimensional concept encompassing digital infrastructure, digital connectivity, digital skills, the adoption and use of digital technologies, digital public services, and the economic outcomes generated by digital transformation. Accordingly, previous studies have employed a broad range of proxy variables, including Internet users, fixed broadband subscriptions, mobile cellular subscriptions, the Digital Adoption Index (DAI), the Digital Economy and Society Index (DESI), the ICT Development Index (IDI), and the E-Government Development Index (EGDI).

The objective of the present study, however, is not to measure the overall level of digitalization, but rather to evaluate the direct macroeconomic contribution of the digital sector to economic growth in Azerbaijan. For this reason, the analysis focuses on two variables that directly reflect the economic dimension of digitalization.

The first indicator, value added generated in the ICT sector, measures the productive capacity of the digital economy by capturing the value created through information and communication technology activities. Unlike infrastructure-based indicators such as Internet penetration or broadband subscriptions, ICT value added reflects

the actual economic output generated by digital technologies and therefore provides a direct measure of the sector's contribution to Gross Domestic Product.

The second indicator, imports of ICT products, was selected because Azerbaijan remains largely dependent on imported digital equipment, hardware, communication technologies, and other ICT-related products. As domestic production of ICT goods is relatively limited, imports constitute the primary channel through which digital technologies are introduced into the national economy. Consequently, ICT imports represent an important indicator of digital capital accumulation and technological diffusion, particularly in developing and resource-dependent economies.

Moreover, the choice of these variables is consistent with the structural characteristics of the Azerbaijani economy. Unlike many developed economies, where digital infrastructure has already reached a mature stage and indicators such as Internet penetration exhibit relatively limited variation over time, Azerbaijan continues to rely substantially on imported digital technologies while simultaneously expanding domestic ICT production and value creation. Therefore, ICT value added and ICT imports provide more informative measures for assessing the economic effects of digitalization than purely infrastructure-based indicators.

It should also be acknowledged that these variables do not capture every dimension of digitalization. Instead, they represent the economic and production-oriented dimensions of digital transformation. Consequently, the findings of this study should be interpreted within this specific conceptual framework rather than as a comprehensive assessment of digitalization in its broadest sense. Future research may extend the analysis by incorporating additional indicators of digital infrastructure, digital adoption, digital skills, and e-government development to construct a more comprehensive multidimensional measure of digitalization.

2 Literature review

The interrelationship between digitalization and economic growth has become one of the most relevant issues in contemporary economic research.

In the modern era, digitalization is not merely characterized by the emergence of new technologies; rather, it constitutes a structural transformation that significantly influences economic performance and long-term growth dynamics. Raeskyesa and Lukas (2019) examined the relationship between digitalization and economic growth in eight middle-income ASEAN countries over the period 1999–2014 using panel regression analysis. Their findings indicate that information and communication technologies (ICT), alongside physical and human capital, exert a statistically significant positive effect on economic growth. The authors recommend

that countries invest in human capital development to maximize the benefits derived from ICT utilization [53].

Solomon and Van Klyton (2020) investigated the impact of digital technologies on economic growth in 39 African countries between 2012 and 2016. Their study differs from others by separately analyzing ICT usage by individuals, firms, and governments. Employing a system Generalized Method of Moments (GMM) estimation based on the Networked Readiness Index, the authors concluded that individual ICT usage has a positive and significant impact on economic growth [54].

Some theorists argue that the development and diffusion of digital and other technologies may generate only modest productivity gains, and that the net employment effect of digitalization could be negative. However, the extent to which innovation-driven growth in new products and services compensates for potential labor displacement remains uncertain [6].

Aleksandrova A et al. (2022) assessed the impact of digitalization on economic growth in Russia using indicators such as the Digital Adoption Index, the Index of Digital Life, GDP per capita, the Resilience Index, and the Global Competitiveness Index. Their empirical findings suggest that insufficient digital readiness of the population and macroeconomic constraints limit the ability of digital technologies to significantly accelerate economic growth [5].

Hina Asma et. al. (2024) analyzed the relationship between digitalization and economic growth across 87 developing countries over the period 2000–2024 using a panel Autoregressive Distributed Lag (ARDL) model. The results demonstrate that the Digital Index (DI), Gross Fixed Capital Formation (GFCF), Labor Force Participation Rate (LFPR), and Broad Money (M2) positively affect economic growth. The study recommends increasing investment in digital infrastructure and technology adoption to stimulate economic expansion [7].

Several studies confirm the positive contribution of digital development to economic growth. Török, L (2024) examined the impact of digital evolution on economic growth in European Union (EU) member states between 2015 and 2022 using indicators from the Digital Economy and Society Index (I-DESI). Pearson and Spearman correlation analyses confirmed a positive relationship between digital development and GDP per capita. Countries with higher levels of digitalization tend to demonstrate higher income levels and stronger growth dynamics, particularly among more advanced EU economies [58].

Magoutas, A. et. al, (2024) analyzed the dynamic relationship between ICT development and economic growth across all 27 EU member states using data from DESI 2022, EUROSTAT, and OECD reports. Through structural equation modeling, they identified a positive correlation between ICT development and GDP. The study emphasizes the accelerating role of artificial intelligence adoption in the business sector as a key driver of technological progress and economic growth [41].

Zhang et al. (2024) examined the impact of digital industrialization on economic growth in China during 2011–2019 using double fixed-effects and spatial Durbin models. Their results indicate a positive relationship, suggesting that digital industrialization enhances the efficiency of economic growth [59].

Jangid H.et. al, (2024) investigated the effects of digitalization on economic growth in G20 countries over the period 2010–2020 using a panel ARDL approach. Their findings reveal a positive long-run relationship but a negative short-run correlation between digitalization and economic growth [30].

The contribution of digitalization to Gross Domestic Product was examined within the framework of the European Union’s Digital Agenda and the Hungarian National Info communication Strategy, based on a sample of 1,045 small and medium-sized enterprises operating in Hungary during the period 2010–2018. The level of digitalization was measured using the Digital Economy and Society Index (DESI), while the contribution to GDP was assessed through indicators such as the number of employees, wage expenditures, and turnover.

By employing a least squares structural equation modeling approach, the study found that the current financial position of an enterprise is a key determinant of its contribution to GDP. However, digitalization-particularly the implementation of software systems-also plays a significant role in enhancing firm performance. Therefore, the continuation of digitalization efforts is considered essential for achieving sustainable economic growth [57].

The impact of digital technologies on economic growth and social development has also been examined in the context of developing countries. Key dimensions of digitalization, including e-commerce, digital payments, and the application of technology in social services, have been analyzed. Alongside the positive effects of this process, issues such as the digital divide, inclusive development, information security, and data privacy must also be taken into consideration during the implementation of digital technologies. Overall, the adoption of digital technologies is expected to stimulate economic and social development in developing countries, thereby contributing to sustained future growth [17].

Ghita Regasse and Zineb Karfa (2025) investigated the impact of digitalization on Gross Domestic Product in seven European countries-Germany, France, Italy, Sweden, Austria, the Czech Republic, and Hungary-over the period 2017-2022. Using the Panel Data Method, their findings indicate that the Digital Economy and Society Index (DESI) and R&D expenditures exert a positive effect on economic indicators [23].

Digital technologies influence economic growth by affecting multiple sectors of the national economy. Therefore, regardless of their level of development, European Union member states consider digitalization a driving force of economic prosperity. The application of digital tools to economic growth in the EU-27 countries was examined for the period 2017–2021. Employing Principal Component Analysis

(PCA) and the Ordinary Least Squares (OLS) model, the study found that prior to the pandemic, the level of digitalization was below average, reflecting limited technological progress. Countries with higher levels of digitalization exhibited stronger economic development. The results suggest that achieving long-term economic growth requires restructuring national digitalization strategies and accelerating the implementation of digital technologies [39].

A comparative analysis of the impact of digitalization on economic growth in the European Union and BRICS-T countries was conducted by Kasap A. (2025). Using Panel Data Analysis, the study examined EU countries for the period 2001–2022 and BRICS-T countries for 2003–2021. The findings indicate that in EU countries, internet usage, broadband access, and gross capital formation positively affect economic growth. In BRICS-T countries, the main drivers of economic growth were identified as mobile cellular subscriptions, internet usage, and gross capital formation. The study emphasizes the importance of digital infrastructure for economic development and recommends optimizing digitalization processes in both developed and developing economies [36].

From a globalization perspective, digitalization can be regarded as a key driver of technological advancement. This development exerts a strong impact on economic efficiency and Gross Domestic Product. In economies that are heavily dependent on oil revenues and classified as developing, such analyses require deeper investigation. Neffati, M. (2025) examined the impact of digitalization on economic growth in Saudi Arabia over the period 1990–2022 [43]. By applying Ordinary Least Squares (OLS), Fully Modified Ordinary Least Squares (FMOLS), Dynamic Ordinary Least Squares (DOLS), and Canonical Cointegration Regression (CCR) models, the study concluded that digitalization makes a significant contribution to economic growth in both the short and long run.

The influence of digital technologies on economic growth has been widely analyzed across countries worldwide. Similar analyses are also being conducted for the economy of the Republic of Azerbaijan. Notably, in 2025, the President of the Republic emphasized the relevance of assessing the impact of digitalization on economic growth and issued a decree concerning the implementation of the relevant Strategy. The Strategy focuses on accelerating digital transformation across economic sectors to achieve economic growth and ensuring the implementation of comprehensive measures in this direction [3].

3 Statistical database, methods and methodology

To examine the relationship between the digital economy and economic growth, Gross Domestic Product (GDP), value added generated in the ICT sector, and ICT product imports were selected as the main variables. Initially, GDP was considered

the dependent variable, while value added in the ICT sector and ICT product imports were treated as independent variables.

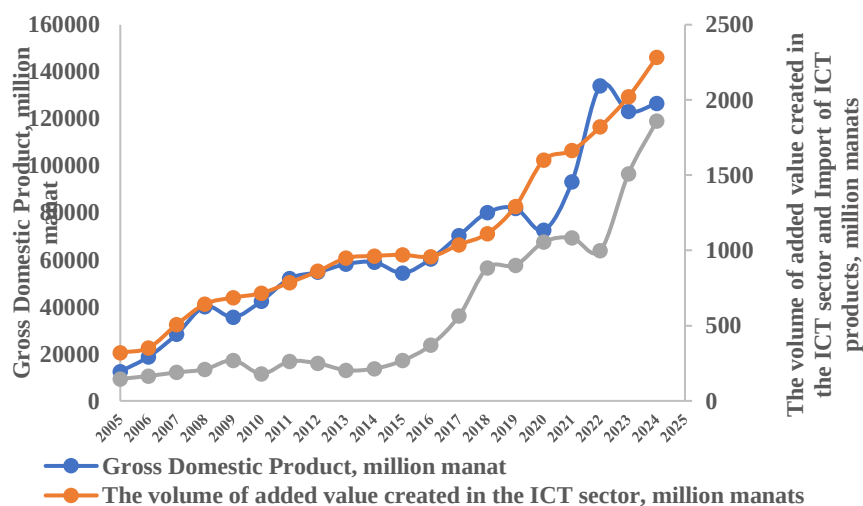
However, considering that a significant share of GDP in Azerbaijan is related to the oil and gas sector, and that the development of other sectors is largely dependent on revenues generated from the oil and gas industry as well as on overall GDP performance, it was decided to investigate the reverse relationship as well. Although the initial estimations were conducted using absolute values, the variables were subsequently transformed into logarithmic form in order to reduce variability and mitigate potential distortions in the economic interpretation of the model coefficients. The estimations were then recalculated using the log-transformed variables.

The data for the variables used in the study were obtained from the official website of the State Statistical Committee of the Republic of Azerbaijan (<https://www.stat.gov.az/>).

	Gross Domestic Product		Value Added in the ICT Sector		ICT Product Imports	
	million AZN	ln	million AZN	ln	million AZN	Ln
	GDP	LGDP	VVICT	LVVICT	IICT	LIICT
2005	12522,5	9,44	320,5	5,77	145,8	4,98
2006	18746,2	9,84	352,6	5,87	165,5	5,11
2007	28360,5	10,25	507,3	6,23	189,5	5,24
2008	40137,2	10,60	643,8	6,47	209,9	5,35
2009	35601,5	10,48	686,8	6,53	270,0	5,60
2010	42465	10,66	715,8	6,57	180,2	5,19
2011	52082	10,86	786,7	6,67	262,6	5,57
2012	54743,7	10,91	861,8	6,76	249,2	5,52
2013	58182	10,97	949,0	6,86	203,8	5,32
2014	59014,1	10,99	963,3	6,87	214,4	5,37
2015	54380	10,90	970,7	6,88	268,6	5,59
2016	60425,2	11,01	958,7	6,87	371,1	5,92
2017	70337,8	11,16	1038,1	6,95	565,1	6,34
2018	80092	11,29	1112,0	7,01	883,8	6,78

2019	81896,2	11,31	1293,3	7,16	901,6	6,80
2020	72578,1	11,19	1600,9	7,38	1055,9	6,96
2021	93203,2	11,44	1663,8	7,42	1083,2	6,99
2022	133972,7	11,81	1822,2	7,51	998,7	6,91
2023	123128,4	11,72	2021,8	7,61	1510,2	7,32
2024	126524,2	11,75	2282,9	7,73	1859,5	7,53

Table 1.
Dynamics of the Model Variables
source: <https://www.stat.gov.az/>



Graph 1.
Dynamics of GDP, VVICT), and IICT
source: <https://www.stat.gov.az/>

The empirical analysis was conducted using OLS, ARDLBT, FMOLS, DOLS, CCR, and VEC.

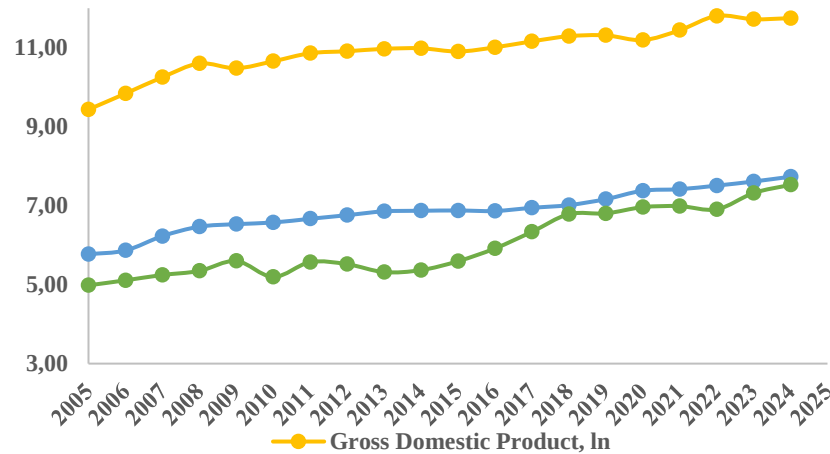
Although OLS is a classical regression technique, its potential to generate spurious results in the presence of non-stationary time series was taken into consideration. Therefore, ARDLBT—an approach that has gained substantial attention in recent empirical research—was employed as the primary estimation method. ARDLBT enables the identification of both short-run and long-run relationships regardless of whether the variables are integrated of order I (0) or I (1).

To verify the robustness, adequacy, and reliability of the long-run estimates obtained from ARDLBT, additional cointegration estimators—FMOLS, DOLS, and CCR—were applied. These methods address issues related to endogeneity and

serial correlation, thereby ensuring consistent and efficient parameter estimation. Finally, VEC was utilized to examine the short-run adjustment mechanisms and the long-run equilibrium relationships among the variables.

The following hypotheses were formulated:

- H1₀ – The volume of value added generated in the ICT sector positively affects the volume of Gross Domestic Product (GDP).
- H2₀ – The volume of ICT product imports positively affects the volume of GDP.
- H3₀ – The volume of value added generated in the ICT sector and the volume of ICT product imports jointly exert a positive effect on the volume of GDP.
- H4₀ – The volume of GDP positively affects the volume of value added generated in the ICT sector.
- H5₀ – The volume of GDP positively affects the volume of ICT product imports.



Graph 2.
Trends in LGDP, LVVICT, and LIICT
Source: <https://www.stat.gov.az/>

Method and Methodology

This study employs the Autoregressive Distributed Lag (ARDL) modelling approach for econometric analysis, as it is particularly suitable for examining both short-run and long-run relationships among variables in relatively small-sample time-series data. One of the principal advantages of the ARDL framework is its

ability to simultaneously estimate both the short-term dynamics and the long-term equilibrium relationships among the variables.

Unlike conventional cointegration techniques, the ARDL approach does not require all variables to be integrated of the same order as a precondition for estimation. Instead, it allows the inclusion of variables that are integrated of order zero, $I(0)$, and order one, $I(1)$, provided that none of the variables is integrated of order two, $I(2)$. Consequently, the ARDL bounds testing procedure enables the investigation of cointegration relationships among variables with mixed orders of integration, a characteristic frequently observed in macroeconomic time-series data (Pesaran et al., 1999).

Compared with the Johansen and Juselius (1990) cointegration methodology, the ARDL approach has been shown to provide more reliable and efficient estimates in studies involving relatively short time-series samples. Another important advantage is that it estimates both short-run and long-run coefficients within a unified modelling framework. Furthermore, unlike the Engle–Granger two-step procedure (Engle & Granger, 1987), the ARDL methodology permits direct hypothesis testing of the estimated long-run coefficients, thereby providing greater flexibility in empirical analysis.

Overall, the ARDL framework offers several methodological advantages over traditional cointegration techniques. In particular, it accommodates variables integrated at $I(0)$ and $I(1)$, either separately or simultaneously, while producing unbiased parameter estimates and valid t-statistics even in the presence of potential endogeneity among regressors. Moreover, selecting the optimal lag structure helps eliminate residual serial correlation and substantially reduces endogeneity concerns.

The short-run dynamics are incorporated into the long-run equilibrium relationship through the Error Correction Model (ECM). The ECM represents a linear transformation of the ARDL model that preserves long-run information while capturing short-run adjustments toward equilibrium. The Error Correction Term (ECT) measures the extent to which deviations from the long-run equilibrium are corrected over time, thereby indicating the speed of adjustment back to equilibrium. For this reason, the ECT coefficient is commonly interpreted as the speed of adjustment parameter. A negative and statistically significant ECT coefficient indicates that the system converges toward its long-run equilibrium following short-run disturbances, providing evidence of a stable long-run cointegration relationship among the variables (Pesaran et al., 2001).

It should be noted, however, that the ARDL bounds testing approach proposed by Pesaran and Shin (1999) and further developed by Pesaran et al. (2001) becomes invalid if any of the variables included in the model is integrated of order two, $I(2)$.

In this study, the Error Correction Model (ECM) is employed to analyse both the short-run dynamics and the long-run equilibrium relationship. Within the ECM framework, the error correction term captures the disequilibrium generated by

short-run shocks and measures the adjustment process through which the system returns to its long-run equilibrium. Accordingly, the long-run dynamics of the endogenous variables are constrained by the short-run adjustment mechanism represented by the ECM. For this reason, the ECM is commonly regarded as the cointegration representation of the conventional ARDL model. The ARDL specification is transformed into a dynamic ECM by incorporating lagged values of the dependent variable, thereby allowing the model to capture both dynamic adjustments and equilibrium correction simultaneously.

According to the adopted research methodology, the ARDL modelling procedure consists of three sequential stages.

Stage I. Testing for cointegration using the Unrestricted Error Correction Model (UECM) framework.

$$\Delta y_{it} = \phi_i (y_{i,t-1} - \beta_i' x_{it}) + \sum_{j=1}^{p-1} \lambda_{ij}^* \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \delta_{ij}^* \Delta x_{i,t-j} + \mu_r + \varepsilon_{it}$$

Where:

Y	– dependent variable;
X	– independent (explanatory) variable;
Δ	– first-difference operator;
ϕ_i	– error correction coefficient of the model;
β_i	– ($k \times 1$) vector of coefficients associated with the explanatory variables;
$y_{i,t-1} - \beta_i' x_{it}$ = EC_{it}	– error correction term (ECT), representing the deviation from the long-run equilibrium;

$$\phi_i = - \left(1 - \sum_{j=1}^p \lambda_{ij} \right), \beta_i = \sum_{j=0}^q \delta_{ij};$$

$$\lambda_{ij}^* = - \sum_{m=j+1}^p \lambda_{im}, j = 1, 2, \dots, p-1;$$

$$\lambda_{ij}^* = - \sum_{m=j+1}^q \delta_{im}, j = 1, 2, \dots, q-1$$

Alternatively, the ARDL–ECM specification can be expressed in the more commonly used simplified form:

$$\Delta Y_t = a_0 + \sum_{j=1}^p \theta_j \Delta Y_{t-j} + \sum_{j=0}^q \gamma_j \Delta x_{t-j} + \lambda_1 Y_{t-1} + \lambda_2 X_{t-1} + \eta_t$$

where:

- λ_1, λ_2 – denote the long-run coefficients (long-run elasticities);
- θ, γ – represent the short-run coefficients (short-run elasticities);
- Δ – denotes the first-difference operator;
- η – is a stochastic error term with zero expected value;
- p, q – denote the optimal lag lengths of the dependent and explanatory variables, respectively.

The optimal lag length for the ARDL model is determined by first identifying the appropriate lag order of the underlying Vector Autoregression (VAR) model using standard information criteria. In this study, the Akaike Information Criterion (AIC) and the Schwarz Information Criterion (SC) are employed for lag selection. The results of these criteria indicate that the optimal lag length is one, suggesting that a VAR(1) specification provides the most appropriate representation of the dynamic interactions among the variables. This lag structure achieves an appropriate balance between model goodness-of-fit and parsimony while ensuring a consistent and efficient estimation of both the short-run dynamics and the long-run equilibrium relationship.

If a cointegration relationship among the variables is confirmed, the analysis proceeds to the second stage.

Stage II. Estimation of the Long-Run Relationship

$$Y_t = \sum_{j=1}^p \nu_j Y_{t-j} + \sum_{j=0}^q \xi_j x_{t-j} + \varpi_t$$

Stage III. Estimation of the Short-Run Dynamics Using the Error Correction Model (ECM)

$$\Delta Y_t = c + \sum_{j=1}^p \zeta_j \Delta Y_{t-j} + \sum_{j=0}^q \varrho_j \Delta x_{t-j} + \zeta ECT_{t-1} + \epsilon_t$$

To initiate the estimation procedure, the ARDL Bounds Test is employed to examine the existence of a long-run cointegration relationship by formulating the null and alternative hypotheses. Subsequently, the significance of the lagged regressors is evaluated using both the t-statistic proposed by Banerjee et al. (1998) and the F-statistic introduced by Pesaran et al. (2001). Since many empirical studies

rely on relatively small sample sizes, Narayan (2005) developed adjusted critical values for the F-statistic that are more appropriate for small-sample analyses.

The hypotheses for the cointegration test are specified as follows:

H_0 : No cointegration exists

H_1 : Cointegration exists.

The joint significance of the lagged level variables is assessed using the F-test based on the following hypotheses:

$H_0: v_i = \xi_i = 0$

$H_1: v_i \neq 0, \xi_i \neq 0$

The decision to reject or fail to reject the null hypothesis is based on comparing the calculated F-statistic with the critical bounds values. If the computed F-statistic exceeds the upper critical bound, corresponding to variables integrated of order one, $I(1)$, the null hypothesis is rejected, indicating the existence of a long-run cointegration relationship among the variables. Conversely, if the F-statistic falls below the lower critical bound, corresponding to $I(0)$, the null hypothesis cannot be rejected, implying that no long-run equilibrium relationship exists. When the calculated F-statistic lies between the lower and upper critical bounds, the test result is considered inconclusive, and no definitive inference regarding cointegration can be drawn.

As an additional robustness check, the significance of the long-run relationship is further verified using the t-Bounds test, which is based on the following hypotheses:

$H_0: v_i = \xi_i = 0$

$H_1: v_i < 0$

Diagnostic Tests for the ARDL Model

The validity of the ARDL model requires that the error term (ϵ_t) be serially independent and normally distributed. Accordingly, the Breusch–Godfrey Lagrange Multiplier (LM) Test (Breusch, 1978; Godfrey, 1978) is employed to examine the presence of serial correlation in the residuals, while the Jarque–Bera Test (Jarque & Bera, 1987) is used to assess the normality of the error term.

Furthermore, the Breusch–Pagan–Godfrey Test (Breusch & Pagan, 1979) and the Autoregressive Conditional Heteroskedasticity (ARCH) Test developed by Engle (1982) are applied to detect the presence of heteroskedasticity in the estimated model. These diagnostic procedures ensure that the assumptions underlying the

ARDL framework are satisfied and that the estimated coefficients are statistically reliable.

Stability Analysis of the Model

The dynamic stability of the estimated model is evaluated through recursive residual-based stability tests. In particular, the Cumulative Sum of Recursive Residuals (CUSUM) test and the Cumulative Sum of Squares of Recursive Residuals (CUSUMSQ) test developed by Brown et al. (1975) are employed to assess the stability of the estimated coefficients over the sample period. These tests are widely used in ARDL applications to verify whether the estimated parameters remain stable in the presence of structural changes.

In addition, the Ramsey Regression Specification Error Test (RESET) (Ramsey, 1969; 1974) is performed to evaluate the functional form of the model and to detect potential specification errors arising from omitted variables, incorrect functional forms, or other misspecifications.

A model is considered stable if the CUSUM and CUSUMSQ statistics remain within the 5% critical bounds throughout the sample period. Such results indicate parameter stability and support the robustness of the estimated long-run and short-run relationships.

Alternative Cointegration Estimation Methods: FMOLS, DOLS, and CCR

To enhance the robustness of the empirical findings, the study also employs several alternative cointegration estimation techniques. These include the Fully Modified Ordinary Least Squares (FMOLS) method proposed by Phillips and Hansen (1990), the Dynamic Ordinary Least Squares (DOLS) estimator developed by Stock and Watson (1993), and the Canonical Cointegrating Regression (CCR) approach introduced by Park (1992).

The application of FMOLS, DOLS, and CCR provides an additional robustness check for the long-run estimates obtained from the ARDL Bounds Testing approach. Comparing the results across different cointegration techniques increases confidence in the empirical findings and reduces the likelihood that the conclusions are driven by the limitations of a single estimation method. Therefore, the consistency of results across ARDL, FMOLS, DOLS, and CCR estimators provides stronger evidence regarding the existence and magnitude of long-run equilibrium relationships among the variables.

Unit Root Tests

Prior to estimating the ARDL model, the stationarity properties of the variables are examined using several conventional unit root tests. Employing multiple tests

allows for a more comprehensive assessment of the integration properties of the variables and improves the reliability of the empirical results.

Accordingly, three widely used unit root tests are applied:

- Augmented Dickey–Fuller (ADF) Test (Dickey & Fuller, 1981);
- Phillips–Perron (PP) Test (Phillips & Perron, 1988);
- Kwiatkowski–Phillips–Schmidt–Shin (KPSS) Test (Kwiatkowski et al., 1992).

Each of these tests is based on different statistical assumptions and testing procedures. Consequently, the results may either confirm or contradict one another. Moreover, each test possesses specific strengths and limitations. While some tests may be sensitive to structural breaks, serial correlation, or model misspecification, others may be more robust to such issues. Therefore, applying multiple unit root tests provides a more reliable basis for determining the order of integration of the variables and strengthens the validity of subsequent cointegration analysis.

Augmented Dickey–Fuller (ADF) Test

The ADF test can be expressed as follows:

$$\Delta y_t = \beta_0 + \psi t + \beta_1 y_{t-1} + \sum_{i=1}^k \alpha_i \Delta y_{t-i} + \varepsilon_t$$

where:

- Δy_t – denotes the first difference of the variable;
- t – represents the deterministic time trend;
- β_0 – is the intercept term;
- β_1 – measures the presence of a unit root;
- α_i – denotes the coefficients of the lagged first differences;
- ε_t – is a white-noise error term.

The null hypothesis of the ADF test states that the series contains a unit root, whereas the alternative hypothesis indicates stationarity.

Bayer–Hanck Combined Cointegration Test

To provide additional evidence regarding the existence of a long-run equilibrium relationship, the study employs the Bayer–Hanck Combined Cointegration Test developed by Bayer and Hanck (2012). This approach combines the results of several individual cointegration tests into a single Fisher-type framework, thereby increasing the overall power and reliability of cointegration inference.

The Bayer–Hanck procedure integrates the following cointegration tests:

- Engle–Granger (1987);
- Johansen (1988);
- Boswijk Error-Correction-Based Test (1994);
- Banerjee et al. (1998) Error-Correction Test.

The combined test statistic is calculated using Fisher’s (1932) methodology based on the p-values obtained from the individual cointegration tests:

$$\tilde{\chi}_I^2 = -2 \sum_{i \in I} \ln(p_i)$$

where (p_i) denotes the probability value (p –value) associated with each individual cointegration test.

For the combined Engle–Granger and Johansen tests:

$$EG - JOH = -2[\ln(p_{EG}) + \ln(p_{JOH})]$$

For the combined Engle–Granger, Johansen, Boswijk, and Banerjee–Dolado–Mestre tests:

$$EG - JOH - BO - BDM = -2[\ln(p_{EG}) + \ln(p_{JOH}) + \ln(p_{BO}) + \ln(p_{BDM})]$$

where (p) represents the corresponding probability values of the individual tests.

The hypotheses of the Bayer–Hanck cointegration test are specified as follows:

H_0 : no cointegration exists among the variables.

H_1 : a cointegration relationship exists among the variables.

If the calculated Fisher statistic exceeds the critical value reported by Bayer and Hanck (2012), the null hypothesis is rejected, indicating the presence of a long-run cointegration relationship among the variables.

Test Results and Model Estimation Results

Variable	ADF Test				PP Test				KPSS Test		
	Test Value	C	t	N	Test Value	C	t	N	Test Value	C	t
<i>lgdp</i>	-3.43**	x			-3.43**	x			0.12*	x	x
<i>lvvict</i>	-2.07	x			-2.07	x			0.10	x	x
<i>liict</i>	-1.52	x	x		-1.51	x	x		0.15**	x	x
<i>Δlgdp</i>	-2.95***	x	x	x	-3.16***	x	x	x	0.20**	x	x
<i>Δlvvict</i>	-3.13**	x	x		-2.01***	x	x	x	0.13*	x	x
<i>Δliict</i>	-4.68***	x			-4.12***	x	x	x	0.08	x	x

Table. 2.
Unit root test results

Notes:

a: ADF PP and KPSS denote the Augmented Dickey – Fuller Phillips – Perron and Kwiatkowski – Phillips – Schmidt – Shin tests;

b: Maximum lag order is set to three and optimal lag order (k) is selected based on the AIC;

c: (*) Significant at the 10%; (**) Significant at the 5%; (***) Significant at the 1%. The critical values for the tests are taken from MacKinnon (1996). Probability based on Kwiatkowski – Phillips – Schmidt – Shin (1992, Table 1)

Estimation period: 2005 – 2024. None means that neither intercept nor trend is included in the test equation. Note that the final unit root test equation can include one of these three: intercept (C), intercept and trend (t) or none of them (N). x indicates that the corresponding option is selected in the final unit root test equation.

According to the results of the unit root tests, the variables employed in the model exhibit different orders of integration. Specifically, *lgdp* was found to be stationary at levels, $I(0)$, according to the ADF, PP, and KPSS tests, with statistical significance ranging from 90% to 99%. In contrast, *lvvict* was determined to be integrated of order one, $I(1)$, based on the ADF, PP, and KPSS tests, with statistical significance between 95% and 99%. Similarly, *liict* was found to be integrated of order one, $I(1)$, according to the ADF and PP tests at the 99% significance level.

Furthermore, none of the variables was found to be integrated of order two, $I(2)$. This finding satisfies the principal prerequisite for applying the Autoregressive Distributed Lag Bounds Testing (ARDLBT) approach and confirms that the ARDL cointegration methodology is appropriate for examining the existence of a long-run equilibrium relationship among the variables.

	Panel A: <i>lgdp/lvvict</i>	Panel B: <i>lgdp/liict</i>	Panel C: <i>lvvict/lgdp</i>	Panel D: <i>liict/lgdp</i>	Panel E: <i>lgdp/lvvict,liict</i>
Model:	(1, 0)	(1, 0)	(2, 0)	(1, 0)	(1, 0, 0)
<i>lgdp</i>	–	–	+0.51***	–0.15	–
<i>lgdp</i> ₍₋₁₎	+0.16	+0.61	–	–	0.16
<i>lvvict</i>	+0.81***	–	–	–	0.81
<i>lvvict</i> ₍₋₁₎	–	–	+0.78***	–	–
<i>lvvict</i> ₍₋₂₎	–	–	–0.44***	–	–
<i>liict</i>	–	+0.09***	–	–	0.005
<i>liict</i> ₍₋₁₎	–	–	–	+1.03***	–
<i>c</i>	+3.64***	+3.74***	–1.09	+1.55	3.63

Table.3.

The results of estimations ARDL Method

Notes: *, **, *** indicate significance at 10%, 5% and 1%, respectively.

According to the initial ARDL estimation results, a one-unit increase in *lvvict* leads to a 0.81-unit (81%) increase in *lgdp*, while a one-unit increase in *liict* results in a 0.09-unit (9%) increase in *lvvict*. Conversely, a one-unit increase in *lgdp* is associated with a 0.51-unit (51%) increase in *lvvict*, whereas a one-unit increase in *liict* leads to a 0.15-unit (15%) decrease in *lvvict*.

Furthermore, based on the multivariate ARDL regression model, the estimated long-run coefficients indicate that a one-unit increase in *lvvict* increases *lgdp* by 0.81 units (81%), consistent with the findings reported in Panel A. In addition, a one-unit increase in *liict* is associated with a 0.005-unit (0.5%) increase in *lgdp*, holding the other explanatory variables constant.

		Panel A: <i>lgdp</i> <i>/lvvict</i>	Panel B: <i>lgdp/liict</i>	Panel C: <i>lvvict/lgdp</i>	Panel D: <i>liict/lgdp</i>	Panel E: <i>lgdp</i> <i>/lvvict,liict</i>
		Model 1	Model 2	Model 3	Model 4	Model 5
<i>F</i>	<i>F^W</i>	+23.781***	+6.410***	+20.931***	+1.437	+14.870***
– Bounds <i>T</i>						
<i>t</i>	<i>t^S</i>	–6.675***	–3.575**	–6.427***	–1.177	–6.444***
– Bounds <i>T</i>						

A:, B:, C:

Null Hypothesis: No levels relationship									
	Asymptotic: ¹		Finite Sample: ²				Test		
	<i>n</i>		<i>n</i> = 35		<i>n</i> = 30		Statistic		
	= 1000		<i>I</i> (0)	<i>I</i> (1)	<i>I</i> (0)	<i>I</i> (1)	<i>I</i> (0)	<i>I</i> (1)	
At the significance level:	10%	4.0 4	4.7 8	+4.22 5	5.05	4.29	5.08	-2. 57	-2.9 1
	5%	4.9 4	5.7 3	5.29	+6.1 75	+5.3 95	6.35	-2. 86	-3.2 2
	2.5%	5.7 7	6.6 8	N/A	N/A	N/A	N/A	-3. 13	-3.5
	1%	6.8 4	7.8 4	7.87	8.96	8.17	9.285	-3. 43	-3.8 2
	<i>D:</i>								
	10%	5.5 9	6.2 6	5.95	6.68	6.01	6.78	-3. 13	-3.4
	5%	6.5 6	7.3 +	7.21	+8.0 55	+8.26 7.36	5	-3. 41	-3.6 9
	2.5%	7.4 6	8.2 7	N/A	N/A	N/A	N/A	-3. 65	-3.9 6
	1%	8.7 4	9.6 3	10.36 5	11.2 95	10.6 05	11.65	-3. 96	-4.2 6
	<i>E:</i>								
	10%	3.1 7	4.1 4	3.393	4.41	3.43 7	4.47	-2. 57	-2.9 1
	5%	3.7 9	4.8 5	4.183	5.33 3	4.26 7	5.473	-2. 86	-3.2 2
	2.5%	4.4 1	5.5 2	N/A	N/A	N/A	N/A	-3. 13	-3.5
	1%	5.1 5	6.3 6	6.14	7.60 7	6.18 3	7.873	-3. 43	-3.8 2

Table 5.

Cointegration test statistics.

*, **, *** indicate significance at 10%, 5% and 1%, respectively.

According to the results of the ARDL Bounds Testing (ARDLBT) cointegration analysis, statistically significant long-run relationships were identified among the variables in Models 1, 2, 3, and 5 at the 1% significance level. These findings provide strong evidence of the existence of cointegration among the variables included in these models. In contrast, Model 4 did not exhibit a statistically

significant long-run cointegration relationship, indicating the absence of a stable long-run equilibrium among the variables specified in that model.

$$\text{Specification with optimal lags, ARDL (1, 0):} \quad \lgdp_t = \theta' + \sum_{i=1}^1 \eta'_i \lgdp_{t-i} + \sum_{i=0}^0 \vartheta'_i lvvict_{t-i} + u_t$$

Variables	OLS	ARDL	CCR	DOLS	FMOLS	VEC
<u><i>lgdp/lvvict</i></u>						
Panel A1: Estimated Long – Run Coefficients						
<i>lvvict</i>	+1.15***	+0.97***	+1.12***	+1.13***	+1.09***	+0.91***
<i>c</i>	+3.07***	+4.33***	+3.26***	+3.22***	+3.49***	+4.66
<i>R</i> ²	+0.88	+0.87	+0.85	+0.83	+0.85	+0.35
<i>AdjR</i> ²	+0.87	+0.85	+0.83	+0.78	+0.84	+0.31
<i>D – W</i>	+1.39	+1.92				
<i>AIC</i>	–0.93	–1.29				–0.45
<i>SC</i>	–0.83	–1.14				–0.34
Panel B1: Residuals Diagnostics Tests Results						
χ^2_{SC}	3.32 [0.18]	8.65 [0.01]				
χ^2_{HETR}	3.46 [0.06]	0.06 [0.96]				
χ^2_{ARCH}	0.15 [0.69]	1.95 [0.16]				
<i>JB_N</i>	0.58 [0.75]	0.60 [0.74]				
<i>F_{FF} t – st</i>	1.97 [0.06]	0.32 [0.75]				
<i>CUSUM</i>	<i>Stability</i>	<i>Stability</i>				
<i>CUSUMS</i>	<i>Stability</i>	<i>Stability</i>				

$$\text{Specification with optimal lags, ARDL (1, 0):} \quad \lgdp_t = \theta' + \sum_{i=1}^1 \eta'_i \lgdp_{t-i} + \sum_{i=0}^0 \vartheta'_i liict_{t-i} + u_t$$

<u><i>lgdp/liict</i></u>						
Panel A2: Estimated Long – Run Coefficients						
<i>liict</i>	+0.38*	+0.22	+0.39	+0.31	+0.35	+0.32
<i>c</i>	+8.54***	+9.65***	+8.59***	+9.20***	+8.84***	+8.92
<i>R</i> ²	+0.24	+0.72	+0.06	+0.39	+0.09	+0.47

<i>AdjR</i> ²	+0.19	+0.68	+0.01	+0.19	+0.03	+0.44
<i>D – W</i>	+0.43	–0.35				
<i>AIC</i>	+0.90	–0.47				–0.65
<i>SC</i>	+1.00	+1.48				–0.55
Panel B2: Residuals Diagnostics Tests Results						
χ^2_{SC}	8.00 [0.02]	2.45 [0.29]				
χ^2_{HETR}	4.23 [0.04]	1.91 [0.38]				
χ^2_{ARCH}	7.00 [0.01]	0.32 [0.56]				
JB_N	0.99 [0.60]	0.84 [0.65]				
$F_{FF} \ t – st$	1.20 [0.24]	0.01 [0.98]				
<i>CUSUM</i>	<i>Stability</i>	<i>Stability</i>				
<i>CUSUMS</i>	<i>Stability</i>	<i>Stability</i>				
Specification with optimal lags, ARDL (2, 0): $lvvict_t = \theta' + \sum_{i=1}^2 \eta'_i lvvict_{t-i} + \sum_{i=0}^0 \vartheta'_i lgdp_{t-i} + u_t$						
<i>lgdp/liict</i>						
Panel A3: Estimated Long – Run Coefficients						
<i>lgdp</i>	+0.76***	+0.77***	+0.82***	+0.94***	+0.87***	+0.92***
<i>c</i>	–1.54*	–1.63*	–2.08**	–3.51*	–2.70*	–3.34
<i>R</i> ²	+0.88	+0.92	+0.86	+0.87	+0.86	+0.45
<i>AdjR</i> ²	+0.87	+0.90	+0.85	+0.83	+0.85	+0.34
<i>D – W</i>	+1.35	+2.20				
<i>AIC</i>	–1.24	–1.86				–0.89
<i>SC</i>	–1.32	–2.03				–0.70
Panel B3: Residuals Diagnostics Tests Results						
χ^2_{SC}	+4.37 [0.12]	+6.52 [0.03]				
χ^2_{HETR}	+1.18 [0.27]	+2.97 [0.39]				
χ^2_{ARCH}	+0.51 [0.47]	+0.63 [0.42]				
JB_N	+0.30 [0.86]	+0.68 [0.71]				
$F_{FF} \ t – st$	+1.42 [0.17]	+2.15 [0.05]				
<i>CUSUM</i>	+ <i>Stability</i>	+ <i>Stability</i>				

<i>CUSUMS</i>	<i>+Stability</i>	<i>+Stability</i>
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Specification with optimal lags, ARDL (1, 0):

$$liict_t = \theta' + \sum_{i=1}^1 \eta'_i liict_{t-i} + \sum_{i=0}^0 \vartheta'_i lgdp_{t-i} + u_t$$

<i>liict/lgdp</i>						
Panel A4: Estimated Long – Run Coefficients						
<i>lgdp</i>	+0.62	+4.28	+0.73	+0.64	+0.88	+2.76***
<i>c</i>	−0.84	−43.34	−2.11	−1.09	−3.71	−24.06
<i>R</i> ²	+0.24	+0.79	+0.16	+0.18	+0.14	+0.11
<i>AdjR</i> ²	+0.19	+0.77	+0.11	−0.09	+0.08	−0.08
<i>D – W</i>	+0.33	+2.45				
<i>AIC</i>	+1.48	+0.28				+0.23
<i>SC</i>	+1.40	+0.16				0.43
Panel B4: Residuals Diagnostics Tests Results						
χ^2_{SC}	+13.63 [0.00]	+2.04 [0.36]				
χ^2_{HETR}	+5.07 [0.02]	+0.99 [0.61]				
χ^2_{ARCH}	+3.18 [0.07]	+0.01 [0.92]				
<i>JB_N</i>	+1.35 [0.51]	+0.33 [0.85]				
<i>F_{FF} t – st</i>	+0.02 [0.99]	+1.39 [0.26]				
<i>CUSUM</i>	<i>Stability</i>	<i>Stability</i>				
<i>CUSUMS</i>	<i>No – stability</i>	<i>Stability</i>				

$$lgdp_t = \theta' + \sum_{i=1}^1 \eta'_i lgdp_{t-i} + \sum_{i=0}^0 \vartheta'_i liict_{t-i} + \sum_{i=0}^0 \vartheta'_i liict_{t-i} u_t$$

Specification with optimal lags, ARDL (1, 0, 0):

<i>lgdp/lvvict, liict</i>						
Panel A5: Estimated Long – Run Coefficients						
	OLS	ARDL	CCR	DOLS	FMOLS	VEC
<i>lvvict</i>	+1.14***	+0.96***	+1.16***	+1.48***	+1.15***	+1.24***
<i>liict</i>	+0.009	+0.005	−0.06	−0.17*	−0.05	−0.07
<i>c</i>	+3.07***	+4.33***	+3.39***	+1.83*	+3.36***	+2.87

R^2	+0.88	+0.87	+0.83	+0.88	+0.84	+0.34
$AdjR^2$	+0.87	+0.85	+0.81	+0.77	+0.82	+0.14
$D - W$	+1.39	+1.92				
AIC	-0.69	-0.99				
SC	-0.81	-1.15				

Panel B5: Residuals Diagnostics Tests Results

χ_{SC}^2	+3.33 [0.19]	+8.68 [0.01]
χ_{HETR}^2	+6.13 [0.05]	+1.73 [0.63]
χ_{ARCH}^2	+0.19 [0.66]	+1.90 [0.17]
JB_N	+0.72 [0.70]	+0.68 [0.71]
$F_{FF} t - st$	+1.95 [0.07]	+0.32 [0.75]
$CUSUM$	+Stability	+Stability
$CUSUMS$	+Stability	+Stability

Table 6.

The results of estimations Long – Run

Notes: The dependent variable is *reer*; residuals diagnostics tests results are from the selected ARDL specifications; χ_{SC}^2 , χ_{HETR}^2 and χ_{ARCH}^2 denote chi-squared statistics to test the null hypotheses of no serial correlation and no heteroscedasticity in the residuals; JB_N and F_{FF} indicate Jarque – Bera and no functional form misspecification statistics to test the null hypotheses of the normal distribution and no functional misspecification, respectively; probabilities are in brackets, and standard errors are in parentheses; ECT is the Error Correction Term, i.e., the residuals of the long-run equation. *, **, *** indicate significance at 10%, 5% and 1%, respectively. Estimation period: 2005 – 2024.

The estimated long-run coefficients indicate that a one-unit increase in *lvvict* is associated with an increase in *lgdp* ranging from 0.91 to 1.15 units (91%–115%), with the relationship being statistically significant at the 1% significance level across the estimated models. This finding suggests that *lvvict* exerts a strong and positive long-run effect on economic growth.

By contrast, a one-unit increase in *liict* is associated with an increase in *lgdp* ranging from 0.22 to 0.38 units (22%–38%). However, this relationship is generally statistically insignificant across the estimated long-run models, with the exception of the Ordinary Least Squares (OLS) estimation, where the coefficient is statistically significant at the 10% significance level. Therefore, although the estimated coefficient is positive, the empirical evidence provides only limited support for a statistically significant long-run impact of *liict* on *lgdp*.

	Engle – Granger		Phillips – Ouliaris	
	<i>tau – statistic</i>	<i>z – statistic</i>	<i>tau – statistic</i>	<i>z – statistic</i>
Model 1	–4.00**	–32.63***	–4.17*	–14.77
Model 2	–2.99	–7.26	–2.99	–8.30
Model 3	–3.64*	–32.38***	–3.30	–14.00
Model 4	–0.61	–1.76	–0.61	–1.70
Model 5	–3.98*	–32.69***	–4.16*	–14.80

Table 7.

The results of Cointegration Test: Engle – Granger and Phillips – Ouliaris

Notes: *, **, *** indicate significance at 10%, 5% and 1%, respectively.

To verify the robustness and reliability of the ARDL Bounds Testing (ARDLBT) cointegration results, additional cointegration estimation techniques, including Canonical Cointegrating Regression (CCR), Dynamic Ordinary Least Squares (DOLS), and Fully Modified Ordinary Least Squares (FMOLS), were employed. The robustness of the estimated long-run relationships was further assessed using the Engle–Granger and Phillips–Ouliaris residual-based cointegration tests.

The empirical results indicate that Model 1 satisfies the Engle–Granger cointegration test at the 5% significance level based on the tau-statistic and at the 1% significance level based on the z-statistic. Similarly, Models 3 and 5 pass the Engle–Granger test at the 10% significance level according to the tau-statistic and at the 1% significance level according to the z-statistic. Furthermore, Models 1 and 5 satisfy the Phillips–Ouliaris cointegration test at the 10% significance level based on the tau-statistic.

Overall, the consistency of the results obtained from the ARDLBT, CCR, DOLS, FMOLS, Engle–Granger, and Phillips–Ouliaris approaches provides robust evidence supporting the existence of stable long-run cointegration relationships among the variables in the respective models.

Model:	Panel A:	Panel B:	Panel C:	Panel D:	Panel E:
	<i>lgdp/lvict</i>	<i>lgdp/liict</i>	<i>lvict/lgdp</i>	<i>liict/lgdp</i>	<i>lgdp/lvict, liict</i>
	(1, 0)	(1, 0)	(2, 0)	(1, 0)	(1, 0, 0)
<i>CointEq₍₋₁₎</i>	–0.84***	–0.39**	–0.66***	–0.26	–0.83
<i>Δlvict₍₋₁₎</i>	–	–	+0.44***	–	–
<i>@trend</i>	–	–	–	+0.03	–
<i>c</i>	+3.64***	+3.74**	–1.09***	+3.05	+3.63
<i>t – Bounds Test</i> <i>t^S</i>	–7.108***	–3.690**	–6.697***	–1.751	–7.110***

R^2	+0.75	+0.44	+0.83	+0.19	+0.75
$AdjR^2$	+0.73	+0.41	+0.81	+0.09	+0.73
$D - W$	+1.92	+1.48	+2.20	+2.18	+1.92
AIC	-1.29	-0.51	-2.17	-0.03	-1.39
SC	-1.38	-0.58	-2.02	+0.11	-1.29

Table 8.

The results of estimations Short – Run

Notes: *, **, *** indicate significance at 10%, 5% and 1%, respectively.

With respect to the short-run dynamics, the estimation results indicate that the intercept (constant term) does not exert a statistically significant effect on the dependent variable in any of the estimated models.

Among the explanatory variables, only Model 3 exhibits a statistically significant autoregressive effect, whereby the lagged value of $lvvict$ at the first lag significantly influences its current value, indicating the presence of short-run persistence in the series.

The estimated coefficient of the error correction term, $CointEq(-1)$, is negative in all estimated models, consistent with the theoretical expectations of the Error Correction Model (ECM). Moreover, the coefficient is statistically significant in three models—Models 1 and 3 at the 1% significance level, and Model 2 at the 5% significance level. The negative and statistically significant error correction coefficient confirms the existence of a stable long-run equilibrium relationship and indicates that short-run deviations from equilibrium are gradually corrected over time. In other words, the estimated adjustment mechanism ensures that the system converges toward its long-run equilibrium following short-term shocks.

		Model 1	Model 2	Model 3	Model 4	Model 5
Engle – Granger	$t - St$	-4.00**	-2.50	-3.65*	-0.37	-3.98*
Johansen	$t - St$	+16.08*	+11.84	+16.08*	+11.84	+19.13
Banerjee	$t - St$	-4.55***	-3.47*	-3.72**	+0.94	-4.20**
Boswijk	$t - St$	+21.52***	+12.05*	+14.86**	+1.92	+19.51**
EG – J:	$F - St$	+16.70**	+6.43	+14.58*	+3.90	+12.13*
EG – J – Ba – Bo	$F - St$	+45.23***	+20.29*	+32.03*	+4.29	+32.01*
5% critical 1	11.229	1% critical 1	17.304	10% critical 1	8.678	
5% critical 1	21.931	1% critical 1	33.969	10% critical 1	16.964	

5% critical 2	11.229	1% critical 2	17.304	10% critical 2	8.678
5% critical 2	21.931	1% critical 2	33.969	10% critical 2	16.964

Table 9
The results of Bayer-Hank combined cointegration test

Finally, the results of the combined cointegration analysis provide further evidence supporting the existence of long-run equilibrium relationships among the variables. Specifically, the Engle–Granger cointegration test confirms cointegration for Model 1 at the 5% significance level and for Model 5 at the 10% significance level. The Johansen cointegration test indicates statistically significant cointegration for Models 1 and 3 at the 10% significance level. Similarly, both the Boswijk and Banerjee et al. error-correction-based cointegration tests confirm the presence of cointegration for Model 1 at the 1% significance level, for Models 3 and 5 at the 5% significance level, and for Model 2 at the 10% significance level.

Furthermore, the combined Engle–Granger–Johansen (EG–J) statistic is statistically significant for Model 1 at the 5% significance level and for Models 3 and 5 at the 10% significance level. Likewise, the comprehensive Engle–Granger–Johansen–Banerjee–Boswijk (EG–J–Ba–Bo) combined statistic is significant at the 1% significance level for Model 1 and at the 10% significance level for Models 2, 3, and 5.

Overall, the consistency of the individual and combined cointegration test results provides strong empirical evidence supporting the existence of stable long-run equilibrium relationships among the variables included in the estimated models. These findings further reinforce the robustness of the ARDL Bounds Testing results and confirm the reliability of the estimated long-run relationships.

Discussion and conclusion

The existing body of literature and practical evidence consistently indicate that digitalization, the expansion of information and telecommunication activities, increasing investment in the digital sector, and improvements in the sector's economic and financial performance generally contribute positively to overall economic development and, in particular, to economic growth. This positive relationship has been documented in numerous empirical studies, especially for developed economies where digital transformation has become one of the principal drivers of productivity and sustainable economic growth.

However, the empirical findings of the present study do not fully support this conventional view. Instead, the estimated relationships suggest that the contribution of digitalization to economic growth in Azerbaijan remains relatively limited and, in some model specifications, statistically insignificant. These findings imply that

the economic benefits of digital transformation have not yet been fully translated into sustained long-run economic growth.

Our results are broadly consistent with the findings of Irtysheva, I. and co-authors (2021), who examined the impact of digitalization on Ukraine's economic development. Their study evaluated the effects of the financial performance of enterprises operating in the information and telecommunications sector, capital investment, foreign direct investment, and the development of digitally transformed economic sectors on real GDP. The authors concluded that Ukraine continues to lag behind developed economies in the production of information and communication technologies and related equipment and remains highly dependent on imports. Consequently, the contribution of digitalization to economic growth has been constrained by structural weaknesses within the domestic economy.

Similarly, the findings of the present study are consistent with those reported by Aleksandrova, A. et al. (2022), who investigated the relationship between digitalization and economic growth in Russia. Their empirical evidence suggests that the existing level of digital readiness among the population, together with prevailing macroeconomic conditions, has limited the ability of digital technologies to generate substantial improvements in the rate of economic growth.

Furthermore, the short-run results obtained in this study are broadly in line with the conclusions of Jangid, H. et al. (2024), who found evidence of a negative short-run relationship between digitalization and economic growth across the G20 economies. This suggests that the economic benefits of digital transformation may require a longer adjustment period before becoming fully reflected in macroeconomic performance.

The similarity between our findings and those reported for Ukraine and Russia can largely be explained by the dominant role of other growth determinants in these economies. In Russia, economic growth continues to be heavily influenced by the energy sector, particularly oil and gas production. In Ukraine, agriculture, manufacturing, heavy industry, and mining remain among the primary drivers of economic growth. Under such circumstances, the contribution of digitalization to aggregate economic performance becomes relatively less pronounced.

In contrast, the findings differ from those reported by Neffati, M. (2025), who concluded that digitalization contributes significantly to economic growth in both the short run and the long run in Saudi Arabia. This difference may be attributed to the country's extensive investment in information and communication technologies, advanced digital infrastructure, favourable business environment, and successful implementation of digital transformation strategies aimed at attracting both domestic and foreign investment. These structural advantages have enabled Saudi Arabia to convert digital investments into measurable gains in economic performance.

The empirical evidence for Azerbaijan suggests a different pattern. Although expenditure on digitalization, value added generated by the information and communication technology sector, and imports of digital technologies have increased over time, their contribution to economic growth remains relatively modest. One possible explanation is that Azerbaijan's economic growth continues to be predominantly driven by the hydrocarbon sector. Consequently, the macroeconomic impact of digitalization is partially overshadowed by the dominant influence of oil and gas revenues, reducing the observable contribution of digital transformation to *gdp* growth.

Overall, the empirical analysis indicates that the variables exhibit positive and, in most cases, statistically significant relationships when examined individually, both in their original values and in logarithmic form. However, when the joint effects of multiple explanatory variables are estimated within the multivariate models, the impact of *iict* on *gdp* and *LICT* on *LGDP* becomes statistically insignificant and, in several specifications, negative. These findings suggest that the economic benefits of digitalization in Azerbaijan have not yet reached a level sufficient to generate a robust and statistically significant contribution to long-run economic growth.

With regard to the research hypotheses, the empirical results provide support for the majority of the proposed hypotheses. The only hypothesis that is not fully confirmed is *H3*, which postulated a positive and statistically significant impact of information and communication technology investment on economic growth within the multivariate framework. The estimated coefficients indicate that, after controlling for other explanatory variables, the effects of *iict* on *gdp* and *liict* on *lgdp* are weak, statistically insignificant, and, in some model specifications, negative. This outcome suggests that increasing investment in the digital sector alone may not be sufficient to stimulate economic growth unless accompanied by complementary institutional reforms, technological innovation, improvements in human capital, and greater efficiency in the utilization of digital infrastructure.

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Digital Skills and Sustainable Consumption: The Roles of CSR Perception and Perceived Greenwashing

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Abstract: Although corporate social responsibility (CSR) and green marketing have been widely studied, limited attention has been given to the role of consumer digital capabilities in interpreting sustainability information. While prior research has extensively examined corporate communication strategies, limited attention has been paid to the role of consumer capabilities in interpreting CSR-related information.

This study investigates how digital skills influence purchase intention through CSR perception and perceived greenwashing. Survey data were collected from 392 valid respondents in Taiwan. The proposed hypotheses were tested using exploratory factor analysis (EFA) and multiple regression analysis.

The results indicate that digital skills positively influence CSR perception and negatively affect perceived greenwashing. CSR perception significantly enhances purchase intention, whereas perceived greenwashing reduces purchase intention. Furthermore, the findings support the mediating effects of CSR perception and perceived greenwashing in the relationship between digital skills and purchase intention.

By shifting the analytical focus from firm-centered communication strategies to consumer digital capabilities, this study contributes to the literature on sustainable marketing and consumer behavior. The findings suggest that improving digital literacy and enhancing

transparency in CSR communication are critical for fostering sustainable consumption in the digital age.

Keywords: Digital Skills; Corporate Social Responsibility; Greenwashing; Purchase Intention; Sustainable Marketing

1 Introduction

In recent years, digital transformation has fundamentally reshaped the way corporations communicate with consumers. Corporate social responsibility (CSR) information and sustainability claims are increasingly disseminated through digital platforms such as social media, corporate websites, and online marketplaces [4], [8]. While digital channels enhance transparency and accessibility, they also intensify information asymmetry and raise concerns regarding the credibility of corporate sustainability communication [5], [10].

Prior research on CSR and sustainable marketing has primarily focused on firm-driven disclosure strategies and their impact on corporate reputation and financial performance [5], [10]. However, relatively limited attention has been paid to the role of consumer capabilities in interpreting CSR-related information within digital environments. As consumers are increasingly exposed to complex sustainability claims, their ability to evaluate and verify such information may play a critical role in shaping their judgments and behavioral responses.

Drawing on information asymmetry theory [1] and consumer behavior perspectives, digital skills can be conceptualized as a cognitive capability that enables consumers to process and evaluate CSR information more effectively. Higher levels of digital competence may enhance consumers' ability to distinguish authentic CSR efforts from symbolic or misleading claims, thereby influencing perceived greenwashing and purchase intention.

Accordingly, this study investigates whether consumers with stronger digital skills evaluate CSR information differently and how such evaluations influence their purchase intention. Specifically, digital skills are proposed to enhance CSR perception while reducing perceived greenwashing, which subsequently affect purchase intention. Using survey data collected from 392 consumers, this study examines the mediating roles of CSR perception and perceived greenwashing in the relationship between digital skills and purchase intention.

By shifting the analytical focus from firm-centered CSR communication to consumer digital competence, this research contributes to sustainable marketing literature and provides empirical evidence on how digital capability influences sustainable consumption decisions in digital markets.

This study integrates information asymmetry theory with consumer cognitive capability perspectives to propose a dual-path mediation model in digitally mediated markets. By shifting the analytical focus from firm-driven CSR communication to consumer-side digital competence, this research extends sustainable marketing theory and provides a novel explanation of how digital capability shapes evaluative mechanisms and behavioral intention.

This study fills an important gap in sustainable marketing research by positioning digital competence as a cognitive antecedent of CSR evaluation rather than merely a contextual factor.

2 Literature Review and Hypotheses Development

2.1 Digital Skills and CSR Perception

Digital skills refer to an individual's ability to access, evaluate, and effectively utilize digital information [13]. Beyond technical operation, digital competence encompasses critical thinking, information verification, and the ability to assess online content credibility. In digital markets, CSR communication is frequently delivered through online channels, where corporate sustainability claims coexist with marketing narratives.

Consumers with higher digital skills may be better equipped to analyze CSR disclosures, verify sources, and interpret sustainability-related messages. Prior research suggests that individuals with stronger information-processing abilities are more capable of distinguishing substantive CSR engagement from superficial communication [2]. Consequently, higher digital competence may enhance the formation of positive CSR perception when corporate claims are perceived as authentic and credible.

Accordingly, this study proposes:

H1: Digital skills positively influence CSR perception.

2.2 Digital Skills and Perceived Greenwashing

Greenwashing refers to the practice of conveying misleading information regarding a firm's environmental performance [3]. In digitally mediated environments, consumers are increasingly exposed to sustainability-related claims that may exaggerate environmental achievements.

From an information asymmetry perspective [1], firms often possess more information about their actual environmental performance than consumers. Digital skills may reduce this asymmetry by enabling consumers to critically evaluate online CSR claims, compare information across sources, and identify inconsistencies. Consumers with stronger digital skills may therefore be less susceptible to misleading communication and more capable of detecting symbolic CSR activities. Thus, digital competence is expected to reduce perceived greenwashing.

H2: Digital skills negatively influence perceived greenwashing.

2.3 CSR Perception and Purchase Intention

CSR perception reflects consumers' overall evaluation of a firm's social and environmental responsibility. Prior studies have demonstrated that positive CSR perception enhances corporate reputation, trust, and consumer loyalty [10], [5]. According to consumer behavior theory, favorable evaluations of corporate responsibility may increase consumers' willingness to support firms through purchasing behavior.

When consumers perceive CSR initiatives as authentic and aligned with societal values, they are more likely to form positive attitudes toward the company, which in turn strengthens purchase intention.

Therefore:

H3: CSR perception positively influences purchase intention.

2.4 Perceived Greenwashing and Purchase Intention

In contrast, perceived greenwashing may undermine corporate credibility and erode consumer trust. When consumers believe that environmental claims are exaggerated or deceptive, negative evaluations may arise, leading to skepticism and resistance toward the brand [11].

From a behavioral perspective, perceived deception reduces trust and decreases purchase intention. Consumers who suspect greenwashing are less likely to reward firms with purchasing behavior.

Accordingly:

H4: Perceived greenwashing negatively influences purchase intention.

2.5 The Mediating Roles of CSR Perception and Perceived Greenwashing

Based on the above arguments, digital skills may influence purchase intention indirectly through their effects on CSR perception and perceived greenwashing. By enhancing consumers' ability to interpret CSR communication, digital competence shapes evaluative judgments, which subsequently determine behavioral intention.

Therefore, this study further proposes:

H5a: CSR perception mediates the relationship between digital skills and purchase intention.

H5b: Perceived greenwashing mediates the relationship between digital skills and purchase intention.

The conceptual framework of this study is presented in Figure 1.

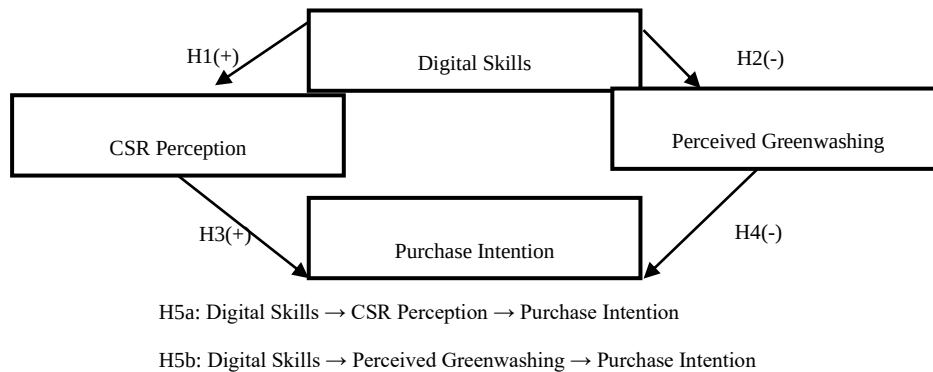


Figure 1
Conceptual Framework

3 Research Methodology

3.1 Research Design and Sample

This study adopted a structured survey design to examine the proposed relationships among digital skills, CSR perception, perceived greenwashing, and purchase intention. Data were collected through an online questionnaire distributed to consumers in Taiwan. Participation was voluntary and anonymous.

A total of 412 responses were received. After eliminating incomplete or invalid responses, 392 valid questionnaires were retained for analysis. The sample included

respondents from diverse demographic backgrounds in terms of gender and age, providing sufficient variability for empirical testing.

3.2 Measurement of Variables

All constructs were measured using previously validated scales adapted from established studies:

Digital Skills (12 items, Cronbach's $\alpha = 0.942$): Adapted from [13], [6]. Items measured respondents' ability to access, evaluate, and critically assess online information. Representative items include "I can verify the credibility of online sources" and "I can effectively compare information across different websites to identify inconsistencies." This scale captures both technical and critical thinking competencies necessary for navigating digital environments.

CSR Perception (8 items, Cronbach's $\alpha = 0.845$): Adapted from [9], [12]. Items reflected consumers' overall evaluation of a firm's social and environmental responsibility. Representative items include "This company genuinely cares about environmental issues" and "I believe this company's CSR efforts are authentic and substantive." These items measure the extent to which consumers perceive CSR initiatives as sincere and impactful.

Perceived Greenwashing (12 items, Cronbach's $\alpha = 0.922$): Adapted from [11]. Items captured the extent to which respondents believed environmental claims were exaggerated or misleading. Representative items include "This company exaggerates its environmental achievements" and "I think this company's environmental claims are not fully supported by evidence." This scale assesses consumer skepticism regarding the authenticity of corporate sustainability communication.

Purchase Intention (8 items, Cronbach's $\alpha = 0.899$): Adapted from [7]. Items indicated respondents' likelihood of purchasing from a socially responsible company. Representative items include "I am willing to purchase from this company" and "I plan to buy products from this company in the near future." These items measure behavioral intention based on consumers' evaluations of corporate responsibility.

All items were measured on a five-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree). The multi-item scales with high reliability coefficients (all $\alpha > 0.84$) provide robust measurement of consumer perceptions and behavioral intentions in the context of digital CSR communication.

3.3 Analytical Strategy

Data analysis was conducted using SPSS. Exploratory factor analysis (EFA) was first performed to assess construct validity. Reliability was evaluated using Cronbach's alpha coefficients. All constructs demonstrated satisfactory internal consistency, with alpha values exceeding the recommended threshold of 0.70.

Multiple regression analysis was then employed to test the hypothesized relationships among variables. The mediating effects of CSR perception and perceived greenwashing were examined using regression-based mediation analysis. Statistical significance was evaluated at conventional levels.

To assess potential common method bias, Harman's single-factor test was conducted, and no single factor accounted for the majority of variance.

4 Results

4.1 Descriptive Statistics and Reliability

Descriptive statistics and reliability results are presented in Table 1. All constructs demonstrated satisfactory internal consistency, with Cronbach's alpha coefficients exceeding the recommended threshold of 0.70. The results indicate that the measurement scales exhibit adequate reliability for subsequent analysis.

Exploratory factor analysis further confirmed the validity of the constructs, as all items loaded significantly on their respective factors. These results provide support for the adequacy of the measurement model.

Construct	Number of Items	Cronbach's α
Digital Skills	12	0.942
CSR Perception	8	0.845
Perceived Greenwashing	12	0.922
Purchase Intention	8	0.899

Table 1 (Reliability Table)

4.2 Hypotheses Testing

Multiple regression analysis was conducted to test the proposed hypotheses. The results are reported in Table 2.

As shown in Model 1, digital skills exert a significant negative effect on perceived greenwashing ($\beta = -.342$, $p < .01$), supporting H2. In addition, digital skills demonstrate a positive association with CSR perception, which provides support for H1.

Model 3 indicates that digital skills positively influence purchase intention ($\beta = .174$, $p < .01$), while CSR perception demonstrates a strong positive effect on purchase intention ($\beta = .682$, $p < .01$), supporting H3. In Model 4, perceived greenwashing shows a significant negative effect on purchase intention ($\beta = -.176$, $p < .01$), supporting H4. The explanatory power of the full model increases to $R^2 = .622$, suggesting that the proposed framework provides substantial explanatory capacity. The model explains 62.2% of the variance in purchase intention, indicating strong explanatory power in the context of consumer behavioral research.

Regression Results	Model 1	Model 2	Model 3	Model 4
Variables	(PG)	(PG)	(PI)	(PI)
Digital Skills (DS)	-.342**		.174**	.132**
CSR Perception (CSR)		-.347**	.682**	.638**
Perceived Greenwashing (PG)				-.176**
R ²	.117	.120	.596	.622
Adjusted R ²	.115	.118	.594	.619
F-value	51.662**	53.352**	286.993**	212.788**

Table 2 (Regression Results)

4.3 Mediation Analysis

The mediating effects were examined using a regression-based mediation approach following the procedures suggested by Baron and Kenny (1986). Specifically, the analysis assessed: (1) the effect of digital skills on the mediators (CSR perception and perceived greenwashing), (2) the direct effect of digital skills on purchase intention, and (3) the effects of the mediators on purchase intention while controlling for digital skills.

This stepwise procedure allows for the identification of indirect effects through changes in coefficient magnitude and statistical significance. In addition, the increase in explanatory power (R^2) across models was used to further evaluate the presence of mediation effects.

Although structural equation modeling (SEM) and bootstrapping techniques are widely recommended for mediation analysis, the present study adopts a regression-based approach to maintain consistency with prior CSR and consumer behavior research and to ensure interpretability of results within an exploratory empirical framework.

The mediation analysis results indicate that digital skills significantly influence purchase intention in the baseline model. However, when CSR perception and perceived greenwashing are introduced simultaneously, the direct effect of digital skills decreases in magnitude while both mediators remain statistically significant.

This pattern is consistent with partial mediation. Specifically, CSR perception serves as a positive mediating mechanism that enhances purchase intention, whereas perceived greenwashing functions as a negative mediating mechanism that suppresses purchase intention.

Furthermore, the increase in explanatory power from Model 3 ($R^2 = 0.596$) to Model 4 ($R^2 = 0.622$) provides additional support for the mediating roles of CSR perception and perceived greenwashing. These findings collectively suggest that digital skills influence purchase intention primarily through evaluative cognitive mechanisms.

Therefore, H5a and H5b are supported.

5 Discussion

The findings provide empirical evidence that digital skills function as a cognitive resource that shapes CSR evaluation under information asymmetry. In digitally mediated markets, consumers are exposed to extensive sustainability claims with varying degrees of credibility. Digital competence enables consumers to differentiate substantive CSR engagement from symbolic communication, thereby influencing both positive evaluations and skepticism simultaneously. This dual-path mechanism highlights the critical role of consumer capability in determining whether CSR communication translates into behavioral intention. Importantly, the findings reveal a dual-path mediation mechanism in which digital skills simultaneously enhance positive CSR evaluations and reduce skepticism toward greenwashing. This dual mechanism highlights that digital competence not only facilitates information processing but also shapes both trust-building and skepticism-reducing processes in consumer decision-making.

Second, CSR perception was found to exert a strong positive influence on purchase intention. This finding is consistent with prior research indicating that consumers are more likely to support firms perceived as socially responsible. When CSR initiatives are viewed as authentic and substantive, they strengthen positive evaluations and encourage behavioral support.

Conversely, perceived greenwashing negatively affects purchase intention. This result highlights the potential risks associated with exaggerated or misleading sustainability communication. When consumers suspect symbolic or insincere CSR efforts, their trust declines, leading to lower purchase intention.

Importantly, the mediation analysis reveals that digital skills influence purchase intention indirectly through both CSR perception and perceived greenwashing. This finding extends existing CSR literature by emphasizing the importance of consumer capabilities rather than focusing solely on firm-driven communication strategies. In digital markets characterized by abundant information and competing claims, consumer digital competence plays a critical role in determining whether CSR communication generates trust or skepticism.

Conclusion and Implications

This study investigates how digital skills shape sustainable consumption decisions through their effects on CSR perception and perceived greenwashing. Using survey data from 392 respondents, the findings demonstrate that digital competence enhances CSR perception, reduces perceived greenwashing, and indirectly influences purchase intention through these evaluative mechanisms.

Theoretical Implications

The present study contributes to CSR and sustainable marketing literature in several ways. First, it shifts the analytical focus from firm-centered CSR communication to consumer digital capability. While prior research has largely emphasized corporate disclosure strategies, this study highlights the importance of consumer-side information-processing ability in shaping CSR evaluations.

Second, the findings extend information asymmetry theory to digitally mediated markets. The results suggest that digital skills may reduce information asymmetry by enabling consumers to critically assess sustainability claims, thereby influencing trust and behavioral intention. This perspective enriches the understanding of how digital competence interacts with CSR communication outcomes.

Managerial Implications

From a managerial perspective, the results suggest that firms must recognize the increasing sophistication of digitally skilled consumers. As consumers become more capable of verifying and cross-checking CSR claims, superficial or symbolic sustainability communication may backfire. Therefore, companies should prioritize transparency, consistency, and verifiable evidence in their CSR strategies.

Moreover, firms should align digital communication strategies with substantive CSR practices to strengthen credibility. In digital environments characterized by rapid information diffusion, authentic CSR engagement becomes essential for sustaining consumer trust and encouraging purchase behavior.

Limitations and Future Research

Despite its contributions, this study has several limitations. First, the data were collected from a single national context, which may limit generalizability. Future research may examine cross-cultural differences in digital competence and CSR evaluation. Second, the study employed a cross-sectional survey design; longitudinal research could further explore causal relationships. Additionally, future studies may adopt advanced mediation techniques, such as bootstrapping procedures, to further validate the robustness of the findings.

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The Economic Case for Housing First – International Research and its Implications for Hungary

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Abstract: International research increasingly suggests that Housing First – a policy that offers unconditional access to permanent housing to homeless people – reduces the public costs associated with homelessness by lowering the use of shelters, emergency healthcare and criminal justice services, resulting in net fiscal savings that exceed the cost of the housing provided. Systematic reviews report substantial cost offsets and benefit to cost ratios above 1 in many North American and Western European programs, even when randomized trials show only modest net savings. At the same time, studies from Central and Eastern Europe remain scarce. In Hungary, existing studies document severe health problems, multimorbidity and limited healthcare access among homeless people, which indicates a high likelihood of crisis driven service use and significant costs, but they do not examine the economic effects of housing led interventions. This paper presents a literature review of international Housing First cost effectiveness research and of the Hungarian empirical literature on homelessness and health. By bringing these two bodies of work together, this study aims to identify where international findings may or may not be transferable to the Hungarian context. It also aims to highlight data and measurement gaps, and formulate a set of research propositions and policy suggestions, rather than new cost estimates. The aim is to bridge a clear gap between the international and the domestic literature and to contribute to debates on how to sustainably combat homelessness in Hungary and in sociologically and economically similar countries.

Keywords: Housing First, homelessness, fiscal policy, cost reduction, sustainability

1 Introduction

Homelessness is among the costliest social problems that modern welfare states face, not only in terms of human suffering but in fiscal terms as well. The chronic use of emergency shelters, hospital emergency departments, crisis mental health services, and the criminal justice system by people who lack stable housing generates substantial and recurring public expenditure, costs that are largely avoidable [1]. Yet for decades the dominant policy response in most countries has followed a ‘staircase’ or ‘treatment-first’ logic. People must demonstrate readiness through sobriety, compliance with treatment, and engagement with services before they can access permanent housing. Therefore, housing is conceptualised as the reward at the top of the stairs, not the precondition for recovery [2].

Housing First (HF) offers a different approach. Originating in the work of Sam Tsemberis and Pathways to Housing in New York City, HF provides immediate, unconditional access to permanent, independent housing to people experiencing chronic homelessness, coupled with voluntary, flexible support services. The thinking behind this is both practical and ethical. Stable housing is not a reward for completing treatment, but rather the foundation that makes treatment possible [3].

Over the past three decades this approach has been tested in large-scale randomised controlled trials (RCTs) in North America and Europe, and has been adopted as national policy in Finland, France, and several other countries.[4, 5]

International research increasingly suggests that Housing First does more than improve housing stability and quality of life. Drawing on the recent systematic economic review by Jacob and colleagues at the CDC [6], programs in the United States that move heavy users of emergency healthcare, shelters and criminal justice services into permanent, community-based housing often generate public cost savings that meet or exceed the cost of the intervention, with a median benefit–cost ratio of about 1.8. At the same time, this evidence is methodologically diverse in study design, follow-up and cost components, and it is almost entirely based on U.S. and Canadian data, so its relevance to Central and Eastern Europe remains largely unknown.

Hungary offers complex but still under-researched case. Recent estimates put the number of people experiencing homelessness at around 30,000, with up to ten times as many living in insecure or inadequate housing [7]. Since a 2018 constitutional amendment and a subsequent 2019 Constitutional Court ruling, rough sleeping has effectively been criminalised, pushing people out of public spaces without creating a clear pathway into stable housing. The homelessness system is still built around an emergency-shelter-and-staircase model and operates under chronic financial pressure: state funding covers only about 60–70% of actual service costs, and all this plays out in a housing market where social housing accounts for less than 2% of the housing stock [8]. Hungarian health studies paint a stark picture of severe illness and multimorbidity among people who are homeless, alongside very limited access to healthcare, pointing to a pattern of crisis-driven rather than preventive service use. Although recent housing-led and Housing First initiatives – including

pilots linked to the Housing First Europe project [9]– have begun to document housing outcomes and hint at potential cost advantages over temporary accommodation, Hungary still lacks peer-reviewed economic evaluations of housing-led programmes, and there is as yet no full cost-effectiveness analysis of Housing First in either the Hungarian or the wider Central and Eastern European context.

Hungary still lacks peer-reviewed economic evaluations of housing-led programmes, and there is as yet no full cost-effectiveness analysis of Housing First in either the Hungarian or the wider Central and Eastern European context. The present review addresses this gap by bringing the international cost-effectiveness evidence into dialogue with the Hungarian epidemiological reality. In doing so, it advances existing knowledge in three ways: it identifies the conditions under which Western benefit–cost ratios may or may not transfer to a CEE welfare setting; it offers regional policymakers a practical framework for choosing between cost-saving and cost-effectiveness strategies depending on local data and fiscal constraints; and it lays out a concrete research roadmap to guide the first generation of Housing First economic evaluations in the region.

2 Materials and Methods

The present study is a narrative literature review. A systematic search for economic evaluations of Housing First programmes was performed in Scopus (Elsevier). The search combined three groups of: (1) intervention terms – ‘Housing First’ OR ‘permanent supportive housing’; (2) economic outcome terms – ‘cost-effectiveness’ OR ‘cost–benefit’ OR ‘economic evaluation’ OR ‘cost analysis’ OR ‘cost offset’; and (3) population terms – ‘homeless’ OR ‘rough sleep’. No geographic restrictions were applied. Google Scholar was searched with the same terms in parallel, and the reference lists of key systematic reviews were screened manually for further eligible papers.

Titles and abstracts were examined for relevance. A study was included if it reported original quantitative economic data (cost-effectiveness, cost–benefit, or cost analysis) for a Housing First intervention delivered to adults experiencing homelessness. Both experimental designs (RCTs) and quasi-experimental designs (pre–post comparisons, matched cohort studies) were accepted. Purely narrative accounts were excluded.

In total, 17 North American and 11 European studies met the criteria and were synthesised qualitatively. Because of heterogeneity in methods and settings, meta-analysis was not conducted, the findings are presented as a structured narrative, with particular attention to the distinction between cost-saving (benefit–cost analysis) and cost-effectiveness designs.

The economic argument for Housing First is straightforward. The core question for any health economist or policymaker is whether the public costs saved by reducing those services exceed the cost of providing housing and support.

3 The International Evidence of Cost-Effectiveness

3.1 Systematic Reviews and Benefit-to-Cost ratios in North America

The most rigorous and up-to-date synthesis of the economic evidence comes from the Community Preventive Services Task Force (CPSTF) systematic economic review published in the American Journal of Preventive Medicine [10]. The review examined 20 evaluation studies of Housing First programmes (17 from the United States, 3 from Canada) and found the following:

- Median intervention cost (US studies): \$16,479 per person per year.
- Median total benefit (US studies): \$18,247 per person per year.
- Benefit-to-cost ratio (BCR) for US studies: 1.80 : 1 — meaning every dollar invested in Housing First generates \$1.80 in economic benefits.
- When Canadian studies were included, the BCR fell to 1.06 : 1, reflecting both the methodological heterogeneity of the evidence and the difficulty of generalising findings across different healthcare and welfare systems.

The CPSTF review followed a standardised economic review protocol developed for the Community Guide. Each included study provided its own estimates of intervention costs and cost offsets (benefits). The review team then converted all monetary values to 2020 US dollars using the Consumer Price Index to adjust for inflation.

The CPSTF review rated the overall certainty of the evidence as ‘moderate’ for cost-effectiveness, not high. The main reasons were: (1) most studies had short follow-up (≤ 2 years); (2) the intervention definition varied across studies; and (3) the comparators (‘usual care’) differed substantially between studies and countries.

The table below summarises the cost categories that appeared across the 20 reviewed studies. This information is taken directly from the Results section of Jacob et al [10], specifically from the description of Table 3.

Cost category	Included as intervention cost?	Included as benefit (offset)?
Housing / rent / utilities	Yes	No
Case management / support services	Yes	No
Administrative / overhead	Yes	No
Emergency shelter stays	No	Yes
Emergency department visits	No	Yes
Hospital inpatient (medical & psychiatric)	No	Yes
Outpatient medical / mental health	No	Sometimes
Criminal justice (police, courts, jail)	No	Yes (in some studies)
Social welfare / public assistance	No	No (excluded as transfer payments)

Table 1.
Cost categories included as intervention costs versus cost offsets in Housing First economic evaluations (based on Jacob et al., 2022 [10])

3.1.1 Comparing the two most extreme cases in the study

The meta-analysis identified two extreme benefit-to-cost ratios: Basu [11] at 4.1 and Latimer [12] at 0.2. Understanding why they differ is essential for designing a reliable HF evaluation in the CEE region.

Basu studied 407 chronically ill, recently hospitalised homeless adults in Chicago. The intervention was low-cost (\$4,177 per person/year) and targeted a population with very high baseline healthcare use. Even modest reductions in hospital days produced large savings, generating the exceptional 4.1 ratio.

Latimer, by contrast, analysed 1,198 homeless adults with moderate mental health needs in the Canadian At Home/Chez Soi trial. The intervention was high-fidelity and expensive (\$14,496 per person/year). The control group also improved, and outpatient costs increased, resulting in a BCR of only 0.2.

However, a BCR below 1 does not mean the intervention is uneconomic. Latimer conducted a cost-effectiveness analysis (CEA), not a benefit-cost analysis. The study found that HF with Intensive Case Management cost \$56 per additional day of stable housing, a price that fell below standard willingness-to-pay thresholds.

They found that at a willingness-to-pay threshold of \$67 per day, there was an 80% chance that HF was cost-effective relative to treatment as usual. From a societal perspective, the intervention was deemed good value for money, even though it did not fully pay for itself in direct cost offsets.

The lesson for Hungary is twofold. First, any future evaluation must decide which question to ask. Basu asked: does HF save money? By targeting high-cost, chronically ill homeless people with a cheap intervention, they got a BCR of 4.1 meaning HF paid for itself. Latimer asked: is HF worth the cost? Using a more expensive, high-fidelity HF model for a broader homeless population, they found a BCR of only 0.2 (it did not pay for itself), but the cost per extra day housed was \$56 – below the \$67 willingness-to-pay threshold, so it was still considered a cost effective effort compared to the alternative. Second, a negative BCR does not automatically disqualify HF. The right metric depends on the policy goal: for fiscal savings, use BCA and target the highest-cost users; for social value, use CEA (Cost-Effectiveness-Analysis) and measure cost per day housed. Hungarian researchers should first conduct a cost-of-homelessness baseline study to estimate local willingness-to-pay, then choose the evaluation design accordingly.

In practice, for Hungary and the wider CEE region, this means starting with administrative data on shelter use, hospital admissions, and police contacts to identify the 5–10% of homeless individuals who generate the majority of crisis costs. If such a high-need, high-cost group exists – as the Hungarian health data suggest – a Basu-style BCA would be feasible and policy-relevant. If instead the goal is to scale HF as a rights-based intervention, then a Latimer-style CEA with a locally calibrated willingness-to-pay threshold (e.g., expressed in HUF per day housed) would provide the appropriate justification.

3.2 Evidence for cost-effectiveness from Europe

3.2.1 Evidence from France

Possibly the strongest European economic evidence on Housing First currently comes from France, where Lemoine and her colleagues conducted a long-term cost-effectiveness analysis based on the *Un Chez Soi d’Abord* randomized controlled trial [13]. This trial included 703 homeless adults with severe mental illness across four cities (Paris, Marseille, Toulouse, and Lille), of whom 353 were assigned to Housing First and 350 to treatment as usual (TAU). Participants were followed for 24 months, and these trial data were then used to inform a Markov model projecting outcomes over a 35-year horizon, corresponding to the cohort’s expected lifetime.

What the French experiment actually provided was not a cash transfer in the ordinary sense, but immediate access to ordinary, independent housing combined with intensive, multidisciplinary support. Participants in the Housing First arm were

offered permanent housing in scattered-site apartments; at first they entered as sub-tenants and paid rent up to a maximum of 30 percent of their income, while the remainder was covered by the programme, and they could later become full tenants through lease transfer when they had sufficient resources. They were also accompanied by an assertive community treatment team composed of a social worker, nurse, doctor, psychiatrist, and peer worker, operating with a 10:1 client-staff ratio. In human terms, the intervention therefore replaced the instability of shelters, the street, hospitals, or prison with an ordinary home and a standing support team, rather than requiring participants to prove “housing readiness” in advance.

Unlike the North American benefit-cost studies reviewed above, the French analysis did not primarily ask whether Housing First fully ‘pays for itself’ in direct fiscal offsets. Instead, it used a cost-effectiveness framework from a societal perspective and defined effectiveness as the number of days spent in independent housing. This is important methodologically, because it shifts the evaluative question from narrow budget neutrality to whether the intervention produces substantially better housing outcomes at an acceptable additional cost within a welfare state characterized by quasi-universal health coverage and a relatively extensive social protection system.

The results of the evaluation were strongly supportive of Housing First. Over the lifetime horizon of the model, the Housing First group was projected to spend an average of 2,684.70 days in independent housing, compared with 774.85 days in the treatment-as-usual group, implying an incremental gain of 1,909.85 days; the corresponding 95 percent confidence intervals were 2,121-2,913 and 513-1,346 days respectively. By contrast, mean survival differed only modestly between groups, at 11.41 years for Housing First and 10.25 years for treatment as usual, suggesting that the principal benefit of the intervention lay in sustained housing stability rather than improved survival. Mean total societal cost was estimated at €320,039.27 in the Housing First group and €309,875.98 in the comparator group, producing an incremental cost of €10,163.29. This translated into an incremental cost-effectiveness ratio of €5.31 per additional day spent in independent housing, a result indicating that substantial housing gains were achieved at relatively low additional cost over the long run.

This figure is especially noteworthy when disaggregated by cost category. Housing First generated savings in health-care costs of €45,138.21 over the modeled lifetime horizon and modest justice-system savings of €1,011.81, but these were partly offset by higher social-service costs of €42,124.25 and higher welfare-benefit costs of €14,189.06. In other words, the French results do not show that Housing First eliminates public expenditure; rather, they show a reallocation of spending away from crisis-oriented health and justice responses toward housing and income-support mechanisms that stabilize people’s lives more effectively.

The temporal pattern of the French findings is equally important for policy design. The authors report that, in the Markov model, Housing First was actually a dominant strategy for the first 14 years, meaning it was both more effective and less expensive

than treatment as usual over that period. Only over the full lifetime horizon did the intervention become slightly more expensive overall, while remaining far more effective in housing terms. This suggests that evaluations limited to very short follow-up periods may either understate or mischaracterize the economic logic of Housing First, especially in systems where the main savings come from reductions in long-run psychiatric hospitalization and other crisis services.

For the Hungarian and wider CEE context, the main lesson is not that the French estimates can simply be transferred mechanically. Rather, the French paper shows how a European Housing First evaluation can be designed in a way that is both methodologically rigorous and policy-relevant. It combines an RCT with long-run modelling, adopts a societal perspective, includes health, justice, housing, and welfare costs, and uses a housing-specific effectiveness outcome instead of forcing the intervention into a purely biomedical quality-adjusted life-year framework. For Hungary, this offers a realistic template: a future pilot should collect repeated individual-level data on housing trajectories, hospital use, psychiatric admissions, emergency department contacts, shelter use, police and detention contacts, and welfare receipt, and then estimate either a French-style ICER in HUF per additional day stably housed or, where possible, a complementary cost-benefit ratio for the highest-cost service users.

3.2.2 Evidence from Finland

Finland has adopted a national Housing First strategy in 2008 [14]. Between 2008 and 2022, the number of people experiencing long-term homelessness in Finland fell by about 68 percent, while the number of people living in shelters and hostels dropped by roughly three quarters as emergency beds were converted into permanent, rented Housing First units. National programmes (PAAVO I and II, and their successors) invested several hundred million euros in new housing and support, with estimates suggesting that more than 4,600 homes were created in the first decade of implementation and that Finland spent over €270 million on the programme between 2008 and 2019. Costs are jointly borne by the central government and municipalities, while interestingly, apartments acquired from the private market are financed through the Finnish Lottery.

From an economic perspective, the Finnish evidence is a bit more scarce in randomized trials than the North American or French literature, but it still provides important cost-savings estimates from pre–post and case-study designs. A key reference is the Ministry of the Environment report “Economical effects of the reduction of homelessness,” which examined an intensified supported housing unit with 22 residents in Härmälä, Tampere. Comparing service use in the five months before moving into Härmälä with the five months afterwards for 15 long-term homeless residents, the study found net cost savings of €93,647 over five months, equivalent to €224,753 per year, or roughly €14,980 in annual savings per person. The largest reductions came from housing and substance-use related services, where

costs fell by about 53 percent, and the report concludes that providing intensified supported housing in existing stock is substantially cheaper than relying on hospitals, substance-abuse units, or prisons for crisis management [15].

These case-study findings are also echoed in official evaluations of Finland's first national Programme to Reduce Long-Term Homelessness (PAAVO I). The programme's final report estimated that by the end of 2011 the new dwellings and supported housing places created under PAAVO I generated approximately €21.3 million (not adjusted for inflation) in annual savings in costs associated with homelessness, primarily through reduced use of institutional care, shelters and other crisis services [16]. Although, like the Härmälä analysis, these calculations rely on pre-post comparisons rather than randomized allocation and focus on high-need users of services, they still provide indicative evidence that, under Nordic welfare-state conditions, Housing First-style supported housing can deliver substantial fiscal benefits for both municipalities and the central government.

For the Hungarian and wider CEE context, the Finnish material has two distinct uses: it is compelling as a policy narrative, but methodologically it does not offer a ready-made experimental design. Politically, the Finnish experience shows that a national strategy which converts shelters into permanent homes, funds scattered-site and congregate Housing First units, and integrates housing support into mainstream social and health services can produce sustained reductions in long-term homelessness. Methodologically, however, the dominant Finnish evaluation tools have been administrative trend analyses and pre-post case studies, not randomized trials with long-run economic modelling like the French *Un Chez Soi d'Abord* study, so the exact benefit-cost ratios remain less precisely estimated.

Translating these lessons into a CEE research agenda suggests a staged approach rather than direct replication. In institutional environments like Hungary—where health, social assistance, and housing systems are structured very differently from Finland—one would first need to carry out Finnish-style cost-of-homelessness case studies, using linked administrative data on hospital use, emergency contacts, shelters, and criminal justice, to identify the high-cost fraction of the homeless population and to obtain baseline cost profiles. Only then would it be realistic to design either (a) focused Housing First pilots for this high-need group, evaluated with experimental or quasi-experimental methods, or (b) broader system-level reforms that, following the Finnish precedent, gradually convert emergency shelters into permanent supported housing, with ongoing tracking of homelessness and service-use trends at the national level.

3.2.3 Other Examples from the EU

Beyond France and Finland, a growing but still heterogeneous body of European evidence suggests that Housing First-type programmes can be both effective and economically attractive, even though study designs and outcome measures vary considerably across countries. In Denmark, one of Europe's largest Housing First

implementations was launched through the National Homelessness Strategy (2009–2013) combining scattered-site housing with assertive community treatment, intensive case management and critical time intervention [17]. The official evaluation reported that roughly nine out of ten participants successfully maintained their tenancies, proving that people with severe mental health or addiction challenges can achieve stability without institutional care. Although macro-level goals like eliminating rough sleeping were not fully met, the intervention’s high individual effectiveness strongly supports shifting systemic resources away from temporary shelters toward permanent housing solutions.

Spain provides the most rigorous Southern European economic evidence to date, centred on the Hábitat Housing First programme. An initial evaluation of the programme found that it achieved a 100 percent housing retention rate at six months alongside substantial improvements in perceived security, family relations, and financial stability [18]. Crucially, it did so at an average cost of €34.01 per participant per day — ranging from €28.61 in Madrid to €42.21 in Barcelona — which researchers found to be directly comparable to the daily cost of existing traditional ‘staircase’ shelter services. A subsequent 18-month evaluation confirmed these successes, reporting a 96 percent long-term housing retention rate from a fiscal perspective [19]. This longer-term study showed that while Hábitat required a higher fixed investment in housing and intensive care, these costs were heavily offset by significant reductions in participants’ use of emergency health care, psychiatric services, and addiction treatments. Most recently, a randomized controlled trial published in the *International Journal of Social Welfare* applied a formal cost-effectiveness analysis to the programme [20]. The trial confirmed that Hábitat significantly increased life satisfaction, reduced the number of homeless nights, and improved institutional coverage. The authors concluded that even though the programme involves high short-term expenditure on accommodation, the net economic effects are demonstrably positive, proving that Housing First is a viable and highly efficient funding allocation compared with treatment as usual.

The United Kingdom has also produced recent cost–benefit evidence, notably through the government-funded Housing First Pilots in England and related analytical work [21]. A national cost–benefit analysis of three regional pilots estimated average programme delivery costs of about £7,700 per person per year and expected annual benefits of approximately £15,880 per person per year, yielding a benefit–cost ratio of 2.1 based on projected outcomes and 1.1 based on observed outcomes at 12 months. These benefits combined reductions in public service costs (particularly in homelessness services and criminal justice) with monetised improvements in wellbeing, and tenancy sustainment across the pilots was reported at around 84 percent after three years, again in line with international findings on housing stability [22].

While the Finnish model relies heavily on long-term, system-wide administrative tracking, the evaluations from Spain and the United Kingdom offer a more immediate, localized blueprint for Hungarian researchers. In Hungary, where

traditional, temporary ‘staircase’ shelters dominate the social provision landscape, the Spanish Hábitat evaluation provides a highly replicable starting point: a local pilot could initially focus on benchmarking the exact daily, per-capita operating costs of existing Hungarian shelters against a small-scale scattered-site Housing First cohort. Wojewódzka and Deák (2024) show that although Hungary recorded the largest reduction in household overcrowding among CEE countries between 2007 and 2022—a decline of 30.4 percentage points—overcrowding remains a deep-seated structural problem, particularly in rural areas where hidden housing deprivation continually feeds the pipeline into homelessness [23]. Furthermore, existing studies indicate that homeless individuals in Hungary often face severe multimorbidity but limited access to mainstream healthcare, relying strictly on direct medical cost offsets might artificially depress the economic results of a pilot [24]. To resolve this, Hungarian research designs should adopt the broader framework seen in the UK’s cost–benefit analysis, which explicitly monetizes improvements in individual wellbeing and factors in reduced expenditures across the criminal justice system and temporary homelessness services. By pairing the Spanish method of quasi-experimental daily cost parity with the UK’s wider societal cost–benefit framework, researchers in Central and Eastern Europe can rigorously test the economic viability of Housing First through targeted pilots, without having to wait for a full, national-level policy transformation.

4 Discussion

4.1 Methodological heterogeneity and its policy implications

The 28 economic evaluations synthesised in Section 3 fall into three broad backgrounds, and their heterogeneity is itself an instructive finding. North American studies (Section 3.1) typically employ benefit–cost designs aimed at the highest-cost users, producing large but context-specific fiscal offsets. French and Canadian analyses (Section 3.2.1) adopt cost-effectiveness frameworks that measure the cost per additional day stably housed against a willingness-to-pay threshold, while Northern and Southern European evaluations (Sections 3.2.2 and 3.2.3) rely on simpler cost-comparison or pre–post designs that benchmark Housing First against the daily operating expenses of existing shelter systems. The critical point is not that one approach is superior, but that the choice of evaluation method pre-defines what counts as success. For Hungary, this means that the first policy decision is not whether Housing First “works,” but which question should be asked: short-term fiscal savings, or long-term housing stability at an acceptable social cost.

4.2 Structural gaps in the Hungarian socioeconomic landscape

When this international evidence is placed against the Hungarian institutional reality, three structural gaps emerge that currently prevent any straightforward transfer of Western benefit–cost ratios. First, the social rental sector is virtually absent: social housing accounts for less than 2 percent of the total stock [8], whereas Finland’s national Housing First strategy succeeded precisely because municipalities could access a large, state-supported affordable rental pool. Without a supply of scattered-site apartments available at below-market rents, a Hungarian Housing First programme risks becoming a time-limited rental subsidy rather than a pathway to lasting tenancy. Second, the data infrastructure required to measure cost offsets is missing. The North American studies that report the highest benefit–cost ratios (e.g., Basu, Section 3.1.1) were built on linked individual-level records across healthcare, shelter, and criminal justice systems; in Hungary, NEAK health data, municipal shelter registries, and police or court records remain siloed, with no common identifier. This makes the empirical core of the economic case – credible cost–offset measurement – currently unfeasible at scale. Third, the fragmentation of public financing weakens the incentive to invest. In the French and UK evaluations, savings from reduced hospital and justice system use were visible within the same public purse that funded the intervention. In Hungary, homelessness services are co-financed by under-resourced municipalities and a capped central budget that covers only 60–70 percent of operating costs, so any savings that materialise in the health or justice systems do not automatically return to the budget line that would fund a Housing First expansion.

4.3 Towards a practical framework: bridging the gaps

These gaps are not merely descriptive; they define what a realistic Hungarian adaptation of Housing First would require. The domestic epidemiological profile – severe multimorbidity, crisis-driven emergency care, and limited access to preventive services – closely matches the high-need, high-cost populations that yielded the most favourable benefit–cost ratios internationally, most notably in the study by Basu and colleagues (Section 3.1.1). That work targeted individuals with chronic illness and recent hospitalisation, a subset already known to be heavy users of costly services. The logical starting point for Hungary is therefore a similar targeted pilot: instead of a fixed percentage, it should enrol homeless persons who, based on linked administrative data, are the highest utilisers of shelters, emergency departments, and hospital inpatient care. Such a pilot would need three components that do not yet exist together in Hungary: (1) a cross-sectoral data protocol linking individual-level NEAK, shelter, and criminal justice records; (2) a dedicated supply of scattered-site apartments, possibly mobilised through municipal housing companies or a social rental agency model; and (3) a dual-metric evaluation design that measures both direct fiscal offsets (benefit–cost analysis) and cost per

additional day housed (cost-effectiveness analysis), so that the results can inform both finance ministries and social policy advocates. This three-condition checklist – data linkage, housing supply, dual-metric evaluation – constitutes the practical framework that the present review offers to regional policymakers, allowing them to assess the feasibility of any proposed pilot before public funds are committed.

4.4 Limitations of the review and pathways for future research

The present review has several limitations that bound its conclusions. The literature search was narrative rather than fully systematic, confined to Scopus and Google Scholar, and restricted to English-language studies; relevant grey-literature evaluations from Central and Eastern Europe may therefore have been missed. The synthesis is qualitative, and the heterogeneity of study designs, cost components, and follow-up periods precluded meta-analytic pooling. Most importantly, the transferability assessment offered here is inferential: it contrasts international findings with documented Hungarian conditions but does not test those inferences against primary Hungarian cost or housing data. These limitations point directly to the next research steps. The most urgent is the construction of a linked administrative dataset – integrating NEAK, municipal shelter, police, and welfare records at the individual level – as a prerequisite for any credible cost-offset study. On that foundation, a focused pilot with a quasi-experimental or randomised design can test whether the cost profiles of high-need homeless individuals in Hungary respond to Housing First as the international evidence predicts. Finally, a local willingness-to-pay study is needed to calibrate the cost-effectiveness threshold (in HUF per day housed) against the preferences of Hungarian decision-makers and taxpayers, without which cost-effectiveness arguments will remain abstract.

Conclusions

Systematic reviews and RCT-based analyses from North America and Western Europe consistently show that Housing First generates substantial reductions in emergency health, shelter, and criminal justice expenditures, producing benefit–cost ratios above 1 in many programmes and cost-effectiveness ratios well below standard willingness-to-pay thresholds even where direct savings fall short. However, these findings cannot be mechanically transferred to Hungary, where a severely constrained social rental market, a fragmented and underfunded shelter system, and a structurally siloed public financing architecture all alter the channels through which cost offsets can materialise. The existing Hungarian health literature documents the high-need, crisis-driven profile that international evidence identifies as the key predictor of Housing First's fiscal viability, but no peer-reviewed economic evaluation of a housing-led intervention has yet been conducted in the country. Closing this gap requires, first, a cross-sectoral data infrastructure linking shelter, NEAK, criminal justice, and welfare records at the individual level, and

second, a focused pilot study with a credible counterfactual, designed to answer whether and to what extent Housing First pays for itself.

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Comparative Analysis of Public and Encrypted Genesis Blocks in Blockchain Systems

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Abstract In the accelerating digital economy, business communication increasingly depends on the fast, secure, and reliable exchange of information between organizations. Traditional communication systems often struggle with limited transparency, fragmented data management, poor traceability, and dependence on centralized intermediaries. Blockchain technology offers a novel approach to these challenges by providing a decentralized, tamper-proof, and auditable communication infrastructure. Trust, transparency, and security are key factors in blockchains, as blockchain acceptance continues to divide people to this day. The aim of the research is therefore to create two blockchains with different properties that can convey trust to users. The first of these is a public blockchain, in which the data is accessible and readable by everyone, but cannot be modified without authorization. The second blockchain is a private blockchain that uses complex data encryption solutions to protect user data, and access to it is strongly restricted. The research compares the Genesis blocks of the two blockchains created due to their different specificities. It can be stated that both blockchains enable secure decentralized data storage, and it is advisable to select them according to usage needs to ensure effective business communication.

Keywords: Public blockchain, private blockchain, data encryption.

Introduction

A blockchain has undergone a huge evolution, drawing upon various disciplines including mathematics, cryptography, and computer science. Central to its operation is decentralization, which enables peer-to-peer transactions, coordination, and collaboration facilitated by features such as timestamps, distributed consensus, data encryption, and economic incentives within the distributed system. These features offer a compelling solution to the inefficiencies and security concerns associated with centralized data storage [1]. Blockchain offers an innovative approach to storing information, executing transactions, performing functions, and establishing trust in an open environment. Besides technological characteristics, user trust, cybersecurity awareness, transparency, and effective communication are

also essential factors influencing blockchain adoption and acceptance [2]. Although blockchain has received growing interest in both academia and industry in recent years, the security and privacy of blockchains continue to be at the centre of the debate when deploying blockchain in different applications [3]. To examine the technology inherent in blockchain, private and public Genesis blockchains are created, with the aim of securely storing data using both solutions.

The research is structured according to the following structure:

- Creating and examining the Genesis block of a public transactional blockchain,
- Creating and verifying the Genesis block of a private, encrypted blockchain.

1 Public transaction blockchain

The characteristic of the blockchain is that the network operates on top of a traditional computer network, such as the internet, and cannot function without it. This is because the blockchain protocol does not propose a new method of connecting different devices but uses the Internet Protocol (IP) for all the transactions between different nodes. Therefore, the nodes cannot communicate without a common network [4]. With a distributed ledger technology, blockchain allows information to be stored in shared databases and protects information from removal. Blockchain also operates with fully shared and unchangeable information in a decentralized system, with the same level of certainty [5]. This condition is also true for the public blockchain. The Genesis block is the starting point of the blockchain, to which all subsequent blocks are logically linked, and therefore forms the basis of the integrity of the system. Its characteristics:

- One of the most important features of the Genesis block is that it has no history, so its previous hash field does not point to a real block, but contains an initial fixed value,
- The index number is usually 0,
- It contains the timestamp. This shows when the blockchain was created,
- In the case of a transaction's blockchain, it may contain a starting transaction, but this field can also be left blank,
- PreviousHash is 0, as there is no previous block,
- Own hash value, which is a unique imprint of the block.

```
using System;  
using System.Collections.Generic;
```

```

using System.Security.Cryptography;
using System.Text;
class Transaction
{
    public string FromAddress { get; set; }
    public string ToAddress { get; set; }
    public decimal Amount { get; set; }

    public Transaction(string fromAddress, string toAddress, decimal amount)
    {
        FromAddress = fromAddress;
        ToAddress = toAddress;
        Amount = amount;
    }
}
class Block
{
    public int Index { get; set; }
    public DateTime Timestamp { get; set; }
    public List<Transaction> Transactions { get; set; }
    public string PreviousHash { get; set; }
    public string Hash { get; set; }
    public Block(int index, DateTime timestamp, List<Transaction> transactions, string previousHash)
    {
        Index = index;
        Timestamp = timestamp;
        Transactions = transactions;
        PreviousHash = previousHash;
        Hash = CalculateHash();
    }
    private string CalculateHash()
    {
        using (SHA256 sha256 = SHA256.Create())
        {
            string rawData = Index.ToString() +
                Timestamp.ToString("o") +
                PreviousHash;
            foreach (var tx in Transactions)
            {
                rawData += tx.FromAddress + tx.ToAddress + tx.Amount.ToString();
            }
            byte[] bytes = sha256.ComputeHash(Encoding.UTF8.GetBytes(rawData));
            StringBuilder builder = new StringBuilder();
            foreach (byte b in bytes)

```

```

        builder.Append(b.ToString("x2"));
        return builder.ToString();
    }
}
}
class Blockchain
{
    private List<Block> chain = new List<Block>();
    public Blockchain()
    {
        chain.Add(CreateGenesisBlock());
    }
    private Block CreateGenesisBlock()
    {
        var genesisTransactions = new List<Transaction>
        {
            new Transaction("0", "NyilvanosHalozat", 0)
        };
        return new Block(
            0,
            DateTime.UtcNow,
            genesisTransactions,
            "0"
        );
    }
}
}

```

Figure 1.
Public blockchain Genesis block code

2 Private encrypted blockchain

The private blockchain is only accessible to registered members with permission, offering instant, shared, and fully transparent information [6]. Before creating the Genesis block of the private blockchain, it is necessary to determine what security solutions we want to apply and what we want to protect the blockchain from. The first step is to consider the possibility of encryption, whether its use is necessary. The purpose of incorporating encryption into the blockchain is to prevent unauthorised reading of your data. In the case of the Genesis block, it is advisable to provide the following data:

- Organisational data belonging to the founder of the blockchain,
- Configuration data,

- Defining initial permissions and
- Private metadata.

Encryption itself does not prove that the data is authentic; it only hides it from unauthorised persons. Security can be increased by adding a digital signature. A digital signature answers the following questions:

- Who created the Genesis block?
- Has the content of the block not changed?
- Does the block come from a credible source?

Blockchains are characterized using hash algorithms. However, in the case of key-based integrity protection, it is advisable to use HMAC-SHA256 (Hash-based Message Authentication Code). This is a method where a plain hash function is used together with a secret key. Its purpose is not only to detect data modification, but also to ensure that only those who know the secret key can create a valid verification value. If the blockchain uses only the SHA-256 hash algorithm, the attacker can overwrite sensitive data and then create a new hash for this new content, so the system may not notice the fraud. In the case of HMAC, the attacker would also need to know the secret key to generate a new, valid HMAC. If they don't know this, the modified data can be easily discovered. In the case of integrating HMAC into a blockchain, network participants use a shared secret key.

Passwords can be used to gain access to specific data, an account, a computer system or a protected space [7], [8]. Weak password protection and insufficient security awareness significantly increase the risk of unauthorized access to sensitive information [8]. There are two different kinds of possibilities to get other users' passwords: stealing and guessing [9]. In the past few years, several security incidents have become known that were somehow related to passwords [10]. For additional data protection of the private blockchain, it is also recommended to use a salt, which makes it difficult to guess the password. A salt is a randomly generated additional data that is usually used in key derivation. This avoids the problem of two people entering the same password, as without a salt, the same key would be created. The danger of this is that it makes it easier for an attacker to recognize identical passwords. After that, it would presumably use pre-computed tables, which would make password cracking easier.

```

using System;
using System.Security.Cryptography;
using System.Text;
class GenesisBlock
{
    private int index;
    private DateTime timestamp;
    private string blockchainName;
    private string creator;
    private string networkType;
    private string version;
    private string encryptedData;
    private string previousHash;
    private long nonce;
    private string hash;
    public GenesisBlock(
        int index,
        DateTime timestamp,
        string blockchainName,
        string creator,
        string networkType,
        string version,
        string encryptedData,
        string previousHash,
        long nonce)
    {
        this.index = index;
        this.timestamp = timestamp;
        this.blockchainName = blockchainName;
        this.creator = creator;
        this.networkType = networkType;
        this.version = version;
        this.encryptedData = encryptedData;
        this.previousHash = previousHash;
        this.nonce = nonce;
        this.hash = CalculateHash();
    }
    private string CalculateHash()
    {
        using (SHA256 sha256 = SHA256.Create())
        {
            string rawData =
                index.ToString() +
                timestamp.ToString("o") +

```

```

        blockchainName +
        creator +
        networkType +
        version +
        encryptedData +
        previousHash +
        nonce.ToString();
    byte[] bytes = sha256.ComputeHash(Encoding.UTF8.GetBytes(rawData));
    StringBuilder builder = new StringBuilder();
    foreach (byte b in bytes)
    {
        builder.Append(b.ToString("x2"));
    }
    return builder.ToString();
}
}
public void PrintBlock()
{
    Console.WriteLine("=== Extended Private Genesis Block ===");
    Console.WriteLine("Index: " + index);
    Console.WriteLine("Timestamp: " + timestamp.ToString("u"));
    Console.WriteLine("Blockchain Name: " + blockchainName);
    Console.WriteLine("Creator: " + creator);
    Console.WriteLine("Network Type: " + networkType);
    Console.WriteLine("Version: " + version);
    Console.WriteLine("Encrypted Metadata: " + encryptedData);
    Console.WriteLine("Previous Hash: " + previousHash);
    Console.WriteLine("Nonce: " + nonce);
    Console.WriteLine("Hash: " + hash);
}
}
class AesEncryptionHelper
{
    public static string Encrypt(string plainText, string password)
    {
        byte[] salt = GenerateRandomBytes(16);
        using (var deriveBytes = new Rfc2898DeriveBytes(
            password,
            salt,
            100000,
            HashAlgorithmName.SHA256))
        {
            byte[] key = deriveBytes.GetBytes(32);
            using (Aes aes = Aes.Create())

```

```

    {
        aes.Key = key;
        aes.GenerateIV();
        aes.Mode = CipherMode.CBC;
        aes.Padding = PaddingMode.PKCS7;
        using (ICryptoTransform encryptor = aes.CreateEncryptor(aes.Key, aes.IV))
        {
            byte[] plainBytes = Encoding.UTF8.GetBytes(plainText);
            byte[] cipherBytes = encryptor.TransformFinalBlock(plainBytes, 0, plainBytes.Length);
            string saltBase64 = Convert.ToBase64String(salt);
            string ivBase64 = Convert.ToBase64String(aes.IV);
            string cipherBase64 = Convert.ToBase64String(cipherBytes);
            return saltBase64 + ":" + ivBase64 + ":" + cipherBase64;
        }
    }
}

private static byte[] GenerateRandomBytes(int length)
{
    byte[] bytes = new byte[length];
    RandomNumberGenerator.Fill(bytes);
    return bytes;
}

}

class PrivateBlockchain
{
    private GenesisBlock genesisBlock;
    public PrivateBlockchain()
    {
        genesisBlock = CreateGenesisBlock();
    }
    private GenesisBlock CreateGenesisBlock()
    {
        string sensitiveMetadata =
            "Validator1;Validator2;Validator3;Consensus=PoA;Permissioned=True";
        string password = "StrongPassword123!";
        string encryptedMetadata = AesEncryptionHelper.Encrypt(sensitiveMetadata, password);
        return new GenesisBlock(
            0,
            DateTime.UtcNow,
            "KGK Private Blockchain",
            "Obuda University KGK",
            "Private Permissioned Blockchain",
            "1.0",

```



```

        encryptedMetadata,
        "0",
        1001
    );
}
public void ShowGenesisBlock()
{
    genesisBlock.PrintBlock();
}
}
class Program
{
    static void Main(string[] args)
    {
        PrivateBlockchain blockchain = new PrivateBlockchain();
        blockchain.ShowGenesisBlock();
    }
}

```

Figure 2.
Private blockchain Genesis block code

3 Comparison of private and public blockchain Genesis blocks

The starting point of the operation of blockchain systems is the Genesis block, which, as the very first element of the chain, not only performs a technical initialization function, but also determines the integrity and trust basis of the entire system. In accordance with the research goal, two blockchains with different properties were developed, such as:

- A public, transaction-oriented blockchain, and
- A private, encrypted data management blockchain.

The primary role of the created public blockchain is security, openness, and transparency, which greatly support the transaction process for both the recipient and the sender.

The Genesis block of a private blockchain, on the other hand, is a much more complex structure. The blockchain is only accessible to authorized members, so special attention was paid to the security mechanisms built into the Genesis block. When creating a blockchain, it is advisable to record organizational data, configuration information, initial permissions, and private metadata in the Genesis

block. This indicates that the private Genesis block not only documents the start of the chain but also includes the initial state of the system's operating rules and security framework.

The private Genesis block is not based on a transaction list, but contains fields such as:

- blockchainName,
- creator,
- networkType,
- version,
- encryptedData,
- previousHash,
- nonce, and
- hash.

This Genesis block structure highlights that the Genesis block carries institutional and access control features even in the initial phase.

One of the most important differences between the two genesis blocks can be seen in the visibility and protection of data, since in the public blockchain, the data in the blocks is visible to everyone, while in the case of the private blockchain, access is highly restricted. The difference is also visible on a technical level. In the private Genesis block, the sensitiveMetadata content is stored using AES-based encryption, while the key is generated using PBKDF2-based derivation using SHA-256 and 100,000 iterations. During the encryption, a salt and an IV are also generated, which increases the security of the key derivation and symmetric encryption. Based on this, it can be concluded that the private Genesis block does not simply contain hidden data but implements a multi-layered protection approach that ensures data confidentiality at the boot level.

Public blockchains are characterized by complete decentralization, whereas private blockchains necessarily require some degree of access control and organizational management. The public genesis block, therefore, includes minimal organizational metadata.

In contrast, the private genesis block explicitly contains the institution name, network type, version, and also encrypted information referring to validators and PoA consensus, since in the private blockchain, the genesis block is not only a technical basic unit, but also a kind of regulated entry and operation framework.

Aspect	Public block	Genesis block	Differences between private and public blockchains
Basic goal	The chain is open, transaction-based data	The chain is protected, highly regulated	The public blockchain ensures transactional launch, the other ensures controlled launch
Data visibility	Visible to all participants	Only accessible to authorized actors	The public block is transparent, the private block contains encrypted metadata
Content structure	Index, timestamp, transactions, previous hash, hash	Index, timestamp, name, creator, network type, version, encrypted data, nonce, hash	The private block has an expanded security field structure.
Initial data type	Initiating transaction	Organizational and configuration metadata	The public block contains transaction. The private block contains encryptedData.
Data protection	It is not based on concealment, but on public verifiability.	Protects sensitive content with encryption	The private block uses AES + PBKDF2 + salt + IV.
Trust model	Trust based on transparency	Trust based on entitlement and protection	The public model is transparent; the private one is permission-only.

Table 1.
Comparison of private and public blockchain characteristics

Conclusions

Both public and private blockchains can store data appropriately and securely. Before using a blockchain, it is always recommended to examine your needs and select the blockchain that best suits your purpose. In the case of a public blockchain, the data contained therein is visible to everyone, while in the case of a private blockchain, it is not.

Before creating a private blockchain, it is advisable to examine the level of data protection required and, based on this, build the appropriate protection mechanisms

into both the entire blockchain and the Genesis block itself. When encrypting data, the best solution is to apply multiple encryption methods in parallel within the blockchain itself to increase security.

Public blockchains are characterized by complete decentralization, which is not entirely clear in the case of private blockchains. This problem stems from the structure of the blockchain itself, since with private blockchains, it is necessary to regulate who can access the blockchain and under what conditions they can use it.

In conclusion, proper communication is one of the most important factors when choosing a blockchain solution. If developers clearly communicate the characteristics, security mechanisms, and intended use of the blockchain, users can make more informed decisions and select the most appropriate solution for their needs. This observation is consistent with previous research emphasizing that user awareness, cybersecurity, transparency, and effective communication significantly influence the acceptance of digital technologies [2].

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Beyond the Checkout: Driving Operational Excellence through Strategic HRM at Carrefour, UAE

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Abstract: This study offers a detailed analysis of the implementation of Strategic Human Resource Management (SHRM) at Carrefour UAE, a major retail company under Majid Al Futtaim. In a fast-moving, labor-driven sector, it highlights the importance of SHRM for sustaining operational efficiency and customer service standards. The research focuses on three key areas: work system design, adherence to UAE labor laws, and the success of HR best practices. It uses a quantitative approach that combines employee surveys and interviews and is supported by theoretical models, including the Job Characteristics Model, Atkinson's Flexible Firm, and the AMO (Ability, Motivation, Opportunity) Model. Several important insights are uncovered. The report concludes with a strategic action plan to enhance training structures and reward systems. By aligning these HR functions more closely with organizational objectives, Carrefour-UAE can transition from an administrative HR approach to a people-focused strategy that improves employee capabilities, motivation, and long-term retention.

Keywords: Job design, Employment law, Strategic HRM practices.

1 Introduction

Carrefour UAE, part of Majid Al Futtaim, is a leading retail company in the region with a diverse, multinational workforce across hypermarkets, supermarkets, and online platforms. The fast-paced, labor-intensive retail sector in the UAE demands effective staffing, flexible schedules, and strong HR practices. Consequently, Strategic Human Resource Management (SHRM) is essential for maintaining operational performance, customer service quality, and workforce stability [1] [2].

The nature of retail—characterized by shift work, high customer interaction, frequent merchandise turnover, and demand fluctuations—means HR decisions directly impact business results. Work system design influences employee motivation and productivity, and employment relationships are governed by legal compliance. HR best practices in staffing, skill development, retention, and organizational capability are critical [3]. This report examines the SHRM application at Carrefour UAE across three areas (independent variables), with organizational development as the dependent variable: Section 1 evaluates work system design using questionnaire data on job design and flexibility models. Section 2 assesses how UAE labor laws affect employment relationships, based on employee interviews. Section 3 reviews HR best practices—including staffing, training, performance management, compensation, and retention—and develops SHRM strategies informed by data analysis and theory. The report aims to integrate employee feedback, theoretical insights, and practical HR applications to provide a fact-based evaluation of Carrefour UAE's HR systems. Based on the findings, strategic recommendations are made to better align HR practices with organizational goals and improve workforce effectiveness.

1.1 Significance of the Study

Work Systems: While Carrefour excels in role clarity and functional flexibility to meet operational demands, there is a notable deficiency in employee autonomy and scheduling flexibility.

Legal Relationship: The organization largely adheres to UAE labor regulations, particularly regarding health and safety; however, there is a need to improve communication on overtime policies and clarify contracts.

HR Practices: Staffing processes are perceived as fair, but gaps exist in training consistency, performance appraisal timeliness, and the motivational impact of compensation.

The primary aim of this report is to integrate employee feedback, theoretical perspectives, and practical human resources to evaluate Carrefour UAE's HR systems. The specific objectives are:

- *To evaluate Work System Design:* by assessing existing job design and flexibility models within the company's hypermarkets and supermarkets.
- *To assess Legal Impact:* by determining how the UAE Labor Law influences the employment relationship and employee perceptions of fairness.
- *To analyze HR Best Practices:* by evaluating the effectiveness of staffing, training, performance management, and compensation systems.

- *To formulate SHRM Strategies:* by developing an evidence-based action plan that aligns HR practices with organizational goals and enhances workforce effectiveness.

1.2 Background to the study

Carrefour UAE, operated under Majid Al Futtaim, is one of the largest retail entities in the region. It manages a diverse, multinational workforce across hypermarkets, supermarkets, and e-commerce platforms.

Industry Context

The retail sector in the UAE is characterized by its fast-paced and labor-intensive nature. Success in this environment depends on several critical operational factors:

For staffing & scheduling, the business requires effective staffing and flexible work schedules to meet fluctuating demands. Regarding operational challenges, retail HR must manage specific pressures such as shift rotations, constant customer contact, high merchandise turnover, and significant peaks and troughs in demand. The performance impacts are crucial because of these characteristics; HR decisions directly influence the company's business results, customer service levels, and overall workforce stability [4].

The Role of SHRM

Within Carrefour UAE, Strategic Human Resource Management (SHRM) is considered essential rather than optional. The study is built on the premise that:

Work design: the way work systems are designed directly affects employee motivation and productivity. Legal compliance in the employment relationship is rooted in strict adherence to UAE labor laws. Additionally, best practices for high-quality staffing, skill nurturing, and retention strategies determine the organization's long-term capability.

1.3 Research Gap

Although much research has been conducted on SHRM in the context of international retailers, the number of empirical studies examining the combined impact of work system design, compliance with UAE labor laws, and HR best practices on organizational development in dynamic multinational retail settings such as Carrefour UAE remains limited. In current studies, employee perceptions, operational realities, and regulatory frameworks are seldom combined into a single model [5]. This means there is limited knowledge of how frontline staff perceive job design, schedule flexibility, performance systems, and compensation in the

UAE retail context. Moreover, the interplay of different HR practices in influencing organizational competence has received insufficient attention in the existing literature. The present study seeks to address these limitations by providing a context-specific, evidence-based evaluation of Carrefour UAE's HR systems, incorporating employee feedback, theoretical frameworks, and practical applications of strategic human resource management.

2 Literature Review

This section presents the concepts of independent variables from various reviews.

2.1 Work-design

Work-system design is closely related to employee motivation and organizational responsiveness. Another study points out that the structure, job content, and employee attitudes enable firms to respond promptly to changing conditions and maintain high levels of resources. His work demonstrates that designing jobs to be flexible rather than fixed can be strategically valuable, particularly when customer demand changes quickly[6]. Hackman and Oldham's model of job characteristics continues this debate[7]. It emphasizes the importance of skill variety, task identity, task significance, autonomy, and feedback in shaping factors that make employees find their work meaningful and feel accountable for outcomes. Occupations with higher levels of these characteristics are likely to provide stronger motivation and performance, and the model is commonly used to determine whether an occupational system encourages authentic involvement or is simply operating to achieve operational effectiveness. Contemporary work design is also informed by the so-called flexible firm theoretical framework, as expanded by Atkinson [8] on flexible working, as well as Rees and Smith [9].

Atkinson identifies functional, numerical, and temporal flexibility, which serve various organizational purposes. Functional flexibility refers to the number of tasks employees can perform; numerical flexibility concerns the number of employees; temporal flexibility pertains to work hours. These dimensions are particularly applicable to the retail sector, where customers come and go daily, goods move and need to be stocked, and tasks are reallocated in seconds. The psychological contract provides an extra point of understanding. Schein's initial definition and Rousseau's subsequent one define it as the unwritten expectations between the organization and its employees[10], [11]. These expectations are framed by flexible working arrangements, and employees perceive fairness and support through the schedule, workload, independence, and communication. When a work system is perceived to be overly demanding or rigid, it may seem that the psychological contract has been violated, leading to a lack of commitment and trust. Collectively, these views

indicate that the work-system design should be effective at balancing the employee experience with operational efficiency. The balance is the foundation of Carrefour UAE's day-to-day evaluation and management of its retail operations.

2.2 Employment regulations

The employment law outlines the rights, responsibilities, and expectations that shape the employment relationship. In the UAE, labor laws offer clear guidance on working hours, overtime, leave, health and safety, termination procedures, and non-discrimination. These regulations aim to promote equality and protect both employers and employees. Rees and Smith also argue that an effective legal system is essential for ensuring equality and preventing workplace discrimination. They note that how organizations respond to these laws typically influences employees' feelings of security, respect, and inclusion. Their chapter on equality and diversity highlights that fair treatment must be the minimum standard legally upheld, while organizational culture shapes how laws are put into practice. Literature further suggests that although laws alone cannot fully define the employment relationship, employee perceptions are equally crucial. When employees believe their organization consistently upholds legal standards, they are more likely to trust management and stay committed [12]. Conversely, ambiguity or inconsistent application of their rights can leave employees feeling vulnerable or unsupported. This aligns with Rees and Smith's discussion on the psychological and social factors of equality: perceptions of fairness influence behavior, satisfaction, and engagement. The UAE labor legislation covers employment contracts, working hours, required breaks, annual leave, sick leave, and protections against discrimination—all of which impact workplace experiences. Understanding how employees perceive and experience these regulations offers valuable insights into the strength of the employment relationship at Carrefour UAE.

2.3 Strategic HRM

Human resource best practices encompass policies and systems designed to improve employee capabilities, motivation, and change, thereby boosting organizational performance. Rees and Smith highlight that staffing, training, performance evaluations, compensation, and retention are vital for cultivating a committed and effective workforce. Proper staff selection ensures the hiring of high-quality employees, while training enhances their knowledge and skills for optimal performance. Performance appraisals provide a systematic way to measure inputs and guide improvements. Compensation serves as motivation, and retention strategies preserve institutional knowledge and stability by rewarding performance[13]. The literature on strategic HRM emphasizes alignment: according to the best-fit approach, HR practices should align with an organization's strategic goals, industry conditions, and internal environment. The AMO model suggests that

employees are most effective when they are supported through training, motivated by rewards, and given opportunities via well-designed jobs and feedback systems[14]. These models show that HR should be seen not as isolated practices but as interconnected processes that contribute to overall performance. Rees and Smith advise organizations to move beyond administrative HR to develop strategic, integrated systems that enhance capability and competitiveness. These perspectives can be applied to assess Carrefour UAE's HR practices, allowing analysis of each function and their interactions to determine their impact on strategic objectives.

2.4 Research Questions

To achieve the objectives above, the study sought to answer the following key questions through surveys and interviews:

1. Work System Design

To what extent do employees understand their roles and utilize a variety of skills related to their workload?

2. Employment Law & Relationships

Do employees feel legally protected and treated fairly under the UAE Labor Law, and do they receive clear communication about it?

3. HR Best Practices

How effective are the HR best practices, current training, and performance appraisal systems in driving employee improvement and retention?

3 Methodology

To assess the implementation of Strategic Human Resource Management at Carrefour UAE, this study used a quantitative research design with a structured questionnaire and interviews. The methodology involved randomly selecting 100 employees from various hypermarkets, supermarkets, and online commerce divisions to ensure a diverse multinational workforce. Participants responded to questions about work system design, compliance with UAE labor laws, and the effectiveness of HR practices, including staffing, training, and compensation. This approach enabled a fact-based evaluation by combining individual responses with theoretical frameworks, such as the AMO model and the Job Characteristics Model, to identify strategic gaps and develop a practical improvement plan.

The survey was based on the following questions asked of Carrefour UAE employees:

Work design and redesign

- I clearly understand my daily job responsibilities.
- My job allows me to use a variety of skills.
- I am given freedom to decide how I perform my work.
- My work schedule is flexible enough for my personal life.
- My workload is reasonable during normal shifts.
- I receive regular feedback from my supervisor.
- I feel supported by my team members.
- My job design helps me perform efficiently.
- My job feels meaningful to the organization.
- I am satisfied with the overall design of my job.

Employment regulations

- Do you clearly understand the terms in your employment contract?
- Are you aware of your rights regarding working hours and overtime pay?
- How well does the company explain leave entitlements, such as sick and annual leave?
- Have you ever experienced confusion regarding overtime or shift extensions?
- Do you feel the company treats employees fairly in accordance with UAE labour law?
- How satisfied are you with the company's health and safety procedures?
- Do you know who to contact if you face a labor-related problem?
- Do you feel legally protected in your job?

SHRM

- The recruitment process was fair and transparent.
- I received sufficient training to perform my job effectively.
- Training opportunities are provided regularly.
- My performance is evaluated fairly.
- Performance feedback helps me improve my work.
- My salary reflects my workload and responsibilities.
- I am satisfied with the reward and recognition system.
- The company provides opportunities for career growth.
- I feel motivated to perform well at my job.
- I intend to stay with the company long-term.

4 Data Analysis

4.1 Work System Design Chart

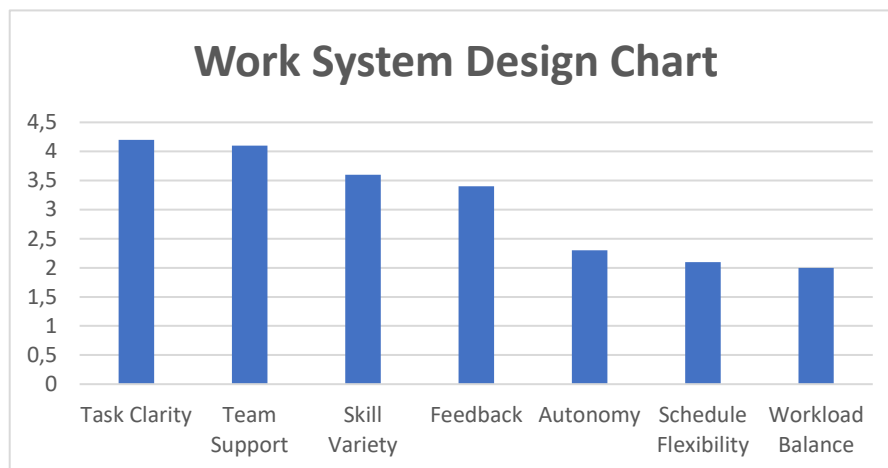


Figure 1
Work-design

The study shows that Carrefour's work system mainly emphasizes operational efficiency over employee empowerment. The high levels of task variety and skill use reflect Atkinson's concept of functional flexibility, where employees handle numerous responsibilities. This structure enables quick responses to changes in demand and helps maintain service standards. Clear role definitions also point to organized workflow routines typical of large retailers. However, low scores on autonomy and scheduling flexibility suggest limited support for employee motivation. Hackman and Oldham's model highlights autonomy as a key motivator; its lack may decrease employees' sense of ownership and interest. Moreover, inflexible scheduling can strain work-life balance, an issue discussed in the chapter on flexible working, which often favors the employer. Perceptions of heavy workload add to the burden, potentially harming job satisfaction and loyalty over time. These findings can be understood through the psychological contract framework, in which employees expect support but face high demands and low control, eroding trust and commitment—a dynamic especially critical in high-turnover sectors. Overall, Carrefour's work system effectively meets operational needs but needs improvements in autonomy, flexibility, and workload management to boost employee well-being, sustain high performance, and improve retention.

4.2 Employee Awareness of Labor Rights

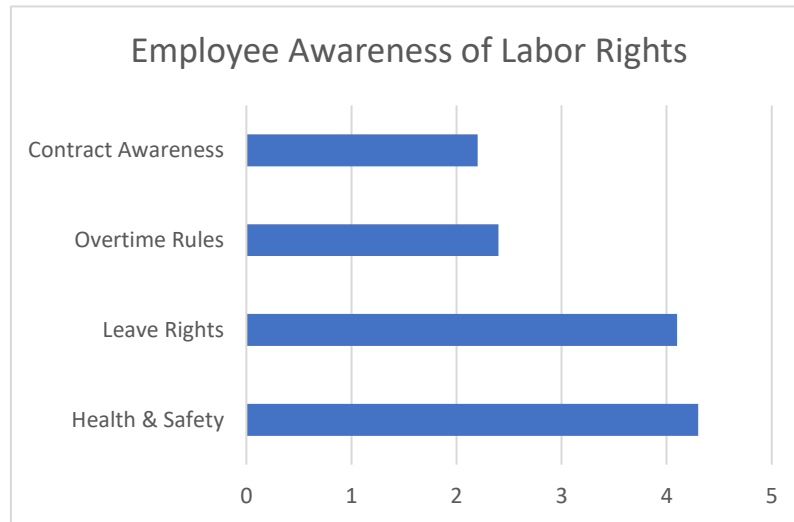


Figure 2
Employment regulations

The feedback is diverse in awareness and experience. The majority of employees understand the fundamentals of their employment contracts, but lack details unless something goes wrong. Work hours usually match the working schedule, but peak periods may extend shifts. Overtime salary is paid, but some interviewees do not know how the rate is determined or how the additional time is granted. Entitlements to leave are more obvious; employees tend to be on an annual leave basis. Nevertheless, some find it difficult to understand how they will handle it in the event of an emergency or sick leave. There is a positive perception of health and safety. Procedures are communicated effectively and implemented systematically. Nonetheless, regarding fairness and general protection, certain employees believe the company acts within the bounds of the law, yet some rights are not communicated properly, particularly to new employees or those who have not yet gained the necessary experience in their field.

4.3 HR best practices

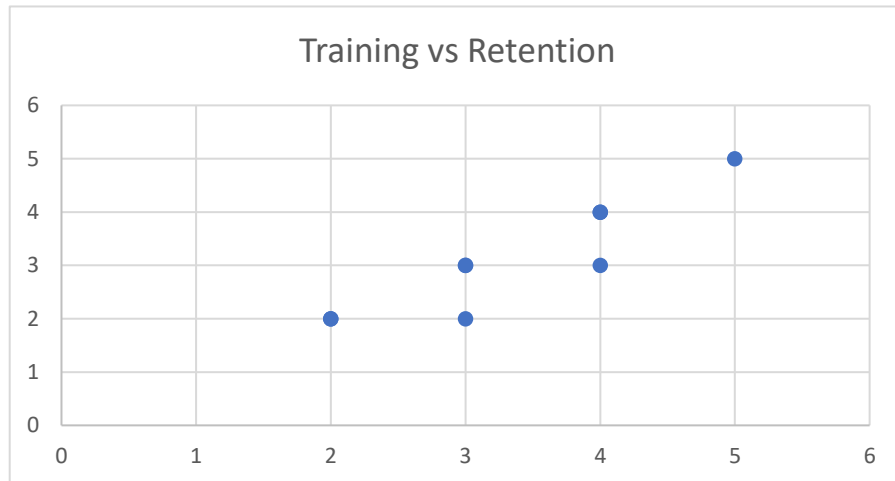
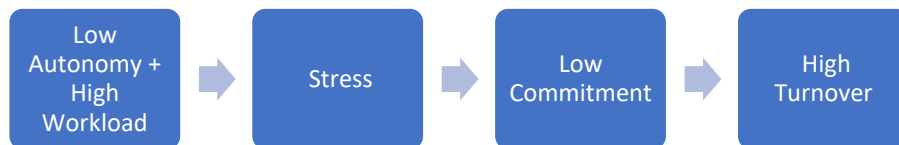


Figure 3
HR practices

Psychological Contract



The answers refer to a workplace characterized by people doing diverse work and being well aware of their roles, but with limited autonomy and flexibility. The employees report that their jobs involve many tasks and require a wide range of skills, so job descriptions are broad and can meet a variety of operational requirements. They also observed stable team support, which aligns with the collaborative nature of retail. But autonomy scores were low, suggesting that employees are not given much autonomy in how they arrange or carry out tasks. Flexibility in scheduling was also low, indicating that deterministic shifts and busy schedules reduce it. Workload was considered a demanding factor, meaning it is fast-paced and comes with intense expectations. There was moderate supervisory feedback associated with inconsistent communication about performance. The quality of job design is average overall, with both positive and negative experiences.

The staffing process is generally viewed positively by employees, particularly regarding fairness and clarity. The practice of training was considered moderately effective and inconsistent; some employees were developed through structured training, whereas most were developed through on-the-job training. A weakness was the performance appraisal. Employees complained that appraisals were untimely, unresponsive, or failed to provide specific, actionable developmental steps. Pay was deemed adequate but not very motivating, especially against the workload and intensity of the retail environment. These opinions were captured in retention scores: staff rated team cohesion and job security highly, but expressed limited long-term commitment due to low career development opportunities and rewards. To analyze their relationship further, we expressed the relationship between these HR functions in the following correlation table:

Dimensions	Staffing	Training	Performance	Compensation	Retention
Staffing	1	0.62	0.55	0.48	0.52
Training	0.62	1	0.71	0.57	0.65
Performance	0.55	0.71	1	0.66	0.69
Compensation	0.48	0.57	0.66	1	0.74
Retention	0.52	0.65	0.69	0.74	1

The correlation matrix indicates that the five Human Resource Management categories, Staffing, Training, Performance, Compensation, and Retention, are highly positively correlated with each other. This means that if you get better at one thing, you get better at other things too. The high correlations between Training and Performance (0.71) and Training and retention (0.65) suggest that investing in skill development can increase productivity and employee retention in the long run. The highest correlation coefficient is 0.74 for retention and salary. So pay and benefits are the biggest drivers of employee retention. Training (0.71) and compensation (0.66) were the significant predictors of performance. It means better performance means skill development and fair wages. The staffing variable is somewhat correlated with the other variables. Recruitment quality is considered important but less so than training and income. The matrix shows that a universal HR approach, especially in the training and remuneration fields, can have a significant impact on the organization's overall performance and employee retention outcomes.

5 Findings & Discussion

The findings of this study at Carrefour UAE illustrate a complex interaction between operational efficiency and employee psychological well-being. Data from the 100-employee sample show that, while the organization achieves high functional flexibility, there is a notable lack of autonomy, which Hackman and Oldham identify as a key element of internal work motivation and task significance. This rigid structure, driven by the fast-paced retail environment, seems to strain the "psychological contract," a concept Rousseau describes as the unwritten expectations that define employee trust and commitment. Additionally, the strong correlation between compensation and retention (\$0.74\$) confirms that, in labor-intensive sectors, the "Motivation" element of the AMO Model relies heavily on tangible rewards to offset high workloads. These results align with the views of Rees and Smith, who argue that SHRM success in multinational contexts relies on balancing strict legal compliance—such as UAE Labor Law—with strategic "best practices" that promote long-term employee development and organizational stability.

The study indicates that Carrefour's work system mainly focuses on operational efficiency rather than employee empowerment. The high task variety and skill utilization reflect Atkinson's concept of functional flexibility, where employees undertake multiple responsibilities. This setup allows for quick adaptation to changes in demand and helps maintain service standards. Clear role definitions also suggest organized workflow routines typical of large retailers. However, low scores in autonomy and scheduling flexibility imply limited support for employee motivation. According to Hackman and Oldham's model, autonomy is a key motivator; its absence may reduce employees' sense of ownership and engagement. Additionally, inflexible scheduling can negatively impact work-life balance, a point discussed in the context of flexible working, which often favors employers. Perceived heavy workloads add to employee stress, potentially decreasing job satisfaction and loyalty over time. These findings can be explained through the psychological contract framework, in which employees expect support but face high demands and low control, eroding trust and commitment—especially in sectors with high turnover. Overall, Carrefour's work system effectively addresses operational needs but requires improvements in autonomy, flexibility, and workload management to enhance employee well-being, sustain high performance, and improve retention.

5.1 Action Plan

The HR analysis of Carrefour UAE shows that the two segments that could benefit most from strategic intervention are training and compensation. To ensure the suggested improvements are implemented successfully, the action plan is organized as follows. In this plan, specific problems are defined, remedies suggested, and

responsibilities and time frames set so that accountability is clear. This aims to develop practical, realistic steps that align with operational requirements and strategic HR goals to enable Carrefour to enhance employee capability, motivation, and retention.

Issue Identified	Strategic Action	Timeline	Responsible Department
There are inequalities in the training opportunities, and there is no formality in development.	Establish standardized training modules and introduce task-based learning paths as well as scheduling recurring coaching sessions	3–6 months	Learning & Development (L&D) and Store Management
It shows a weak relationship between performance evaluation and training.	Incorporate training results into performance reviews and provide developmental feedback on completed training.	2–4 months	HR Department and Line Managers
The pay is considered insufficient to retain employees in the long term.	Implement performance-based bonuses and rewards, including recognition schemes and non-monetary incentives, including career advancement opportunities.	4–6 months	HR Department and Senior Management
The eligibility of rewards is not visible.	Fully express compensation schemes and make the employees aware of the way rewards are won.	1–2 months	HR Communication Team
Employees who perform well do	Develop career development schedules and	6–9 months	HR Development and Talent Management

not have long-term incentives.	promote interdepartmental growth.		
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Figure 4

The action plan will help Carrefour UAE transition its day-to-day HR activities to a strategic and integrated practice. It will create a working environment that enhances immediate performance and, in the long run, employee retention and workforce stability by tightening training structures and making compensation more motivating.

Carrefour UAE needs to shift from basic functional flexibility to full job enrichment. Based on Hackman and Oldham's Job Characteristics Model (1980), the company should give front-line staff more autonomy and decision-making power to enhance the sense of meaningfulness in their roles. Additionally, since the study's correlation analysis showed a strong connection between development and performance, the ability aspect of the AMO Model should be strengthened through a structured, task-oriented certification program.

To tackle the strong link between compensation and retention, a comprehensive 'Total Rewards' approach should be adopted, integrating clear performance-based bonuses with non-monetary recognition to keep motivation high. Additionally, to bolster the 'psychological contract' highlighted by Rousseau (1995), Carrefour needs to improve legal transparency by holding regular communication sessions about UAE Labor Law. This can help build trust and a sense of organizational support, ultimately reducing turnover in the competitive retail industry.

Conclusion

This report is an overview of Strategic Human Resource Management as applied by Carrefour UAE. It will examine the work system design, the impact of the UAE labor law on employment, and the impact of current HR practices. The findings indicate that Carrefour operates a structured, efficient work system that encourages flexibility but constrains employee autonomy, work-life balance, and flexibility in work schedules. These trends reflect the conflict between operational requirements and employee needs, a common theme in the HR literature on flexible work. Carrefour largely adheres to the UAE's regulations, in particular those concerning health and safety and leave provisions, according to the law review. However, the employees believe that communication about overtime policies, contract information, and legal rights should be improved. This highlights why transparency is required to maintain a good employment relationship and ensure that employees feel informed and safe under the law. The HR best-practice appraisal revealed that staffing was fairly satisfactory, and training, performance appraisal, and compensation may be enhanced. Correlation analysis examined the relationships among training, performance, and retention and reaffirmed that compensation is one

of the main drivers of employee commitment. These results are consistent with the established SHRM models, which require integrated systems that enhance ability, motivation, and opportunity. The strategies of the action plan, particularly training and compensation, are designed to ensure that HR activities are more aligned with organizational objectives. Carrefour should be able to enhance performance and retention by implementing systematic training, providing more explicit feedback, and offering more rewards. Overall, the review demonstrates that although Carrefour already has strong HR fundamentals, the key to future success will be more strategic, people-focused HR practices.

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Green but trusted? Perceptions of Generation Z and Millennials toward sustainability claims in an emerging market: Evidence from Albania

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Sustainability claims have become a routine part of brand communication, yet their credibility remains uncertain in markets where independent verification is limited. This study examines how Generation Z and Millennial consumers in Albania evaluate sustainability communication from local brands, how perceived greenwashing relates to trust, and whether trust is associated with purchase intention. The study combines a consumer survey of 348 eligible respondents with semi-structured interviews with representatives of 15 Albanian firms which are engaged in sustainability-oriented practices. The measurement model was developed through confirmatory factor analysis. It showed that perceived greenwashing is better understood as two related but distinct dimensions: cue-based greenwashing, linked to misleading words and visual signals, and substantiation-based greenwashing, linked to vague or weakly evidenced claims. The findings show that environmental concern increases the perceived relevance and appeal of green communication, but favourable attention to such communication does not translate into stronger trust. Instead, green-communication relevance/appeal and cue-based perceived greenwashing are associated with lower trust in sustainability claims. Trust itself is not associated with purchase intention, which is shaped more by environmental concern and by the perception that green attributes signal quality and justify a premium. Generation Z emerges as more environmentally concerned, more attentive to green communication, more sceptical of greenwashing, less trusting, and still more willing to buy green products than Millennials. Interview evidence suggests that Albanian firms often use sustainability communication to aim for reputation, export readiness, and donor-supported business development, while certification and documentation remain costly and weakly rewarded domestically. The paper contributes evidence from a low-verification Western Balkan market and identifies why engaged young consumers may remain sceptical of the brands they nevertheless intend to buy from.

Keywords: green marketing; greenwashing; consumer trust; Albania; sustainability communication

1 Introduction

Environmental claims now appear on packaging, in advertising, and across the social media feeds of brands, in almost every consumer category. Green marketing has moved from a niche positioning strategy three decades ago to a routine element of brand communication [1] [2] [3]. In branding, environmental claims do more than describe a product's ecological performance. They also influence how consumers perceive the brand, how satisfied they are with it, and whether they regard it as trustworthy [4]. As such claims become more common, separating genuine environmental commitment from promotional rhetoric becomes increasingly difficult [5] [6] [7] [8]. Recent evidence suggests that trust, rather than awareness alone, constitutes a significant limitation to the effectiveness of green marketing initiatives.

Generational variation constitutes a salient dimension in the analysis of environmental attitudes and behaviours. Generation Z is frequently characterised as climate-aware and placing greater importance on brand accountability, while Millennials are identified as the cohort instrumental in mainstreaming sustainable consumption [9] [10] [11]. Direct comparisons between the two cohorts remain limited, especially in Albania and the Western Balkans. Some studies suggest that younger consumers express stronger pro-environmental intentions, while older groups may be more consistent in turning environmental values into behaviour [9] [12]. These divergences may reflect not only differences in the degree of environmental concern, but also cohort-specific modes of interpreting firm communications regarding environmental responsibility. Albania provides a useful context in which to examine this issue. The market is young and digitally active: internet penetration reached 88.4 percent and social media reached 61.1 percent of the adult population [13]. Generation Z and Millennials together account for approximately 894,000 people, or 37.8 percent of the resident population [14], which makes them a central consumer segment rather than a marginal audience. The firm side of the market is dominated by micro and small firms that often manage brand communication through social platforms [13]. The Albanian market still lacks consistent standards for environmental claims. This leaves consumers with limited means of assessing what firms say and widens the information gap between producers and buyers. Where formal certification is missing or difficult to access, consumers often rely on other cues, including trust in the producer, product origin, prior experience, and perceived quality [15] [16] [17] [18]. Environmental claims are therefore becoming easier to encounter than reliable evidence to support them. The study addresses three questions. First, how is environmental concern, green-communication relevance/appeal, perceived greenwashing, trust, and purchase intention related among Albanian consumers? Second, do Generation Z and Millennial consumers differ in their construct profiles or in the structural relationships among constructs? Third, how do Albanian brands describe the organisational conditions under which sustainability claims are produced and substantiated? The contribution is empirical and contextual. The paper tests whether a trust-centred model developed largely in mature markets holds in a low-

verification Western Balkan setting, and it links the consumer-side results to firm-side evidence from 15 brands.

2 Literature Review and Hypothesis Development

2.1 Green Marketing Communication and Environmental Concern

Green marketing encompasses product, pricing, distribution, and promotional practices aimed at reducing environmental harm [1] [2] [3]. The communicative dimension remains the most visible and contested part of the field. The present study uses the narrower term green-communication relevance/appeal to capture whether consumers perceive brand messages about sustainability as informative, relevant, and appealing. Chen's green brand equity model adds that green brand image, green satisfaction, and green trust can contribute to green brand equity [4]. This perspective is useful here because Albanian consumers evaluate sustainability claims as brand cues, not as isolated pieces of information. Prior green-consumer research has repeatedly linked environmental concern to the attention consumers give to environmental messages and to their willingness to consider green products [19] [20]. Prior Albanian evidence similarly indicates that environmental awareness and message appeal matter for green purchase attitudes, while credibility contributes less consistently [15]. This supports the expectation that environmental concern will be positively associated with the relevance/appeal of green-communication.

H1. Environmental concern is positively related to green-communication relevance/appeal.

2.2 Greenwashing, Trust, and Purchase Intention

Greenwashing refers to misleading communication about a firm's environmental performance or about the environmental benefits of its products [5] [8]. It may appear through words, visual cues, vague claims, selective disclosure, or even the absence of verifiable evidence [6] [21]. Where regulation is weak, firms may face weaker pressure to substantiate claims, and on the other hand, consumers bear more of the burden of credibility assessment [5]. Trust is usually treated as the mechanism through which green communication becomes behaviour. Chen's green brand equity model situates the green trust within a broader brand equity system, alongside green brand image and green satisfaction [4]. Later trust-centred consumer models reveal that greenwashing has the potential to undermine green trust, while green trust supports green purchase intention [7] [8]. The trust-centred sequence therefore

remains a reasonable theoretical expectation, even if it may operate differently in markets where claims are weakly verified.

H2. Green-communication relevance/appeal is positively related to trust in sustainability claims.

H3. Perceived greenwashing is negatively related to trust in sustainability claims.

H4. Trust in sustainability claims is positively related to purchase intention for environmentally responsible products.

2.3 Generational Cohorts

Generational cohort theory proposes that people who come of age under shared social and historical conditions may develop durable commonalities in values and behaviour [22]. Applied to sustainability, the theory does not imply a simple hierarchy. Generation Z has grown up with climate change as an everyday issue and with sustainability content embedded in digital advertising. Millennials entered adulthood as sustainable consumption became more mainstream, but before the present saturation of branded green content [10] [11] [12] [23]. These different media and socialisation environments may produce two kinds of difference. The cohorts may differ in levels of concern, trust, scepticism, and intention. They may also differ in the strength of the relationships among communication, greenwashing, trust, and purchase intention.

H5a. Generation Z and Millennial consumers differ in their levels of environmental concern, green-communication relevance/appeal, perceived greenwashing, trust in sustainability claims, green quality-price association, and purchase intention. H5b. Generational cohort moderates the relationships among green-communication relevance/appeal, perceived greenwashing, trust in sustainability claims, and purchase intention.

2.4 Emerging-Market and Albanian Context

In mature and developed markets, consumers can sometimes rely on certification schemes, regulatory enforcement, and third-party ratings. In emerging markets such as Albania, these mechanisms may be weaker or less trusted, leaving credibility judgments to consumers themselves [5] [19]. Earlier Albanian SME work shows that brand-consumer interaction runs heavily through social platforms, with owners often managing communication themselves and having limited marketing capability [24]. Evidence from Albania and the Western Balkans shows that consumers do not always look first to technical labels when deciding whether a product is credible. They often place greater trust in where the product comes from, who sells it, their own experience with it, and its reputation for quality or health benefits [16]. Evidence from Albanian market also suggests, that consumers remain sceptical of brands' environmental claims and that domestic pressure on firms to validate their sustainability efforts is still limited [17] [18]. Demographic conditions may

therefore shape both concern and intention. Urban upbringing can increase exposure to environmental discourse and green communication, while household income is identified as affecting both affordability and the interpretation of green premiums [11] [19].

H6. Environmental concern and purchase intention for environmentally responsible products differ by place of upbringing and household income.

2.5 Conceptual Framework

The tested framework links environmental concern to green-communication relevance/appeal, which is then examined in relation to trust in sustainability claims. Perceived greenwashing is also tested as a predictor of trust, following the CFA results that separated it into cue-based and substantiation-based dimensions. Trust is then examined in relation to purchase intention. Generation enters the analysis in two ways: first as a cohort profile comparison between Generation Z and Millennials, and second as a moderator of the model relationships. Place of upbringing and household income are treated as demographic grouping variables, while the green quality-price association is added in the extended purchase-intention model because green attributes may also operate as quality and premium-price cues in this market.

3 Method

3.1 Research Design

The study used a convergent mixed-methods design [25]. The quantitative strand tests associations among consumer perceptions, trust, and purchase intention. The qualitative strand examines the organisational conditions under which Albanian brands communicate sustainability. The two strands are integrated in the interpretation: the survey identifies the consumer response pattern, while the interviews explain why sustainability claims may be treated with caution.

Participation in this study was voluntary. Survey respondents and interview informants were informed about the purpose of the study, and prior consent was obtained. Responses were analysed anonymously, and no personally identifying information is reported. Because Albania is a small market and some firms are easily recognisable, interview evidence is reported by anonymised code, sectoral pattern, and aggregate count rather than by brand name.

3.2 Quantitative Phase: Sample, Procedure, and Measures

The survey was administered online in Albania in January 2026. The initial dataset had 441 records. The respondents unfamiliar with the concept of a green brand or unable to identify at least one Albanian green brand were excluded from the substantive sections, as were respondents outside the two target generational cohorts. The finalised eligible sample consisted of 348 respondents aged 18–45. Seven cases with missing item-level data on the retained measures were excluded from CFA and regression models, leaving 341 complete cases. Cohort membership was derived from reported age group rather than from the administrative COHORT field in the raw workbook. Respondents aged 18–24 and 25–29 were coded as Generation Z; respondents aged 30–36 and 37–45 were coded as Millennials, following Pew Research Center boundaries [23]. This produced 175 Generation Z and 173 Millennial respondents in the eligible sample, and 168 Generation Z and 173 Millennials in the complete-case analytical sample. All substantive constructs used five-point Likert scales anchored at 1, strongly disagree, and 5, strongly agree. Perceived greenwashing and trust were adapted from Chen and Chang [7] [8]. The environmental concern and purchase intention were adapted from Chan [19] and Maichum et al. [20], and the green quality-price association scale was developed for this study with reference to green perceived quality literature [26]. After CFA refinement, environmental concern was measured with EC1–EC5; green-communication relevance/appeal with PGM3–PGM4; cue-based perceived greenwashing with PGW1–PGW2; substantiation-based perceived greenwashing with PGW3 and PGW5; trust with TR1, TR3 and TR4; green quality-price association with GQP1–GQP3; and purchase intention with PI1–PI4.

3.3 Qualitative Phase: Brand Interviews

Between January and February 2026, semi-structured interviews were conducted with representatives of 15 Albanian brands. All firms served Albanian consumers directly and were already engaged in sustainability practices or green communication. The brands were purposively selected because they aligned with the study's focus. It included a strong food and agro-processing component, several olive-oil and olive producers, two vegetable-pickle producers, one agro tourism case, one natural household-products case, one natural cosmetics case, one farm-to-table platform, and one dairy-processing case. Most firms were micro or small, family-run businesses. The interview guide covered motivations for sustainability communication, evidence behind claims, certification and documentation, perceived consumer scepticism, and the targeting of younger consumers. The qualitative archive contained company notes, thematic summaries, and translated interview excerpts. It was analysed thematically following Braun and Clarke [27]. Counts are used only to describe the presence of themes in this purposive sample, not to estimate population prevalence.

3.4 Analytical Procedure

Measurement quality was assessed using CFA, Cronbach's alpha, McDonald's omega, composite reliability, AVE, and HTMT [28] [29] [30] [31]. Models were estimated using maximum likelihood. The initial six-factor model fit poorly, and perceived greenwashing split into two dimensions. The revised model therefore included seven factors: EC, PGM, PGW-CUE, PGW-SUB, TR, GQP, and PI. Three factors had only two indicators, so findings related to them should be interpreted with caution.

Multi-group CFA was used to assess cohort measurement invariance. Configural and full metric invariance were tested across Generation Z and Millennials. Since full metric invariance did not meet the strict change-in-fit criteria, scalar invariance was not interpreted and cohort comparisons are reported as observed-composite profile differences rather than as latent mean differences [32] [33]. Hypotheses were then tested with composite scores rather than full structural equation modelling because the revised structure was exploratory and included several two-item factors; this approach also facilitated the inclusion of controls, interactions and robustness checks. Results are therefore interpreted as associations among composite measures, not causal effects among latent constructs.

H1–H4 were tested with standardised regression models using complete cases.

H3 was divided into H3a, addressing cue-based greenwashing, and H3b, addressing substantiation-based greenwashing; the extended purchase-intention model added environmental concern and green quality-price association. VIFs assessed collinearity. Cohort profile differences were tested with independent-samples t-tests, moderation with mean-centred interaction terms, and demographic differences with t-tests and one-way ANOVA. Statistical significance was set at $p < .05$. Common method variance was assessed with Harman's single-factor test on the retained 21 items. The first unrotated factor explained 26.1% of the variance, below the commonly used 50% threshold. Although not conclusive, this result suggests that the measures are unlikely to be accounted for by a single response factor.

4 Results

4.1 Sample Profile

Among the 348 eligible respondents of the survey, 173 were female, 173 were male, and two did not disclose their gender. Generation Z accounted for 175 respondents and Millennials for 173. Most respondents reported an urban place of upbringing ($n=253$; 72.7 percent). The sample was relatively educated and digitally active, potentially reflecting the online recruitment strategy. Household income was skewed toward higher bands, with 180 respondents reporting monthly household

income¹ above 200,000 ALL, 96 reporting 130,001-200,000 ALL, 60 reporting 90,001-130,000 ALL, and only 12 reporting 50,001-90,000 ALL.

4.2 Measurement Model

The initial 25-item six-factor CFA did not meet acceptable fit standards ($\chi^2=1037.28$, $df=260$, $\chi^2/df=3.99$, $CFI=.830$, $TLI=.803$, $RMSEA=.094$, $SRMR=.110$). Item diagnostics indicated that the broad perceived greenwashing construct separated into two dimensions, while several items reflected similar but empirically distinct content. So the final 21-item seven-factor model fit the data substantially better for this study ($\chi^2=419.90$, $df=168$, $\chi^2/df=2.50$, $CFI=.938$, $TLI=.923$, $RMSEA=.066$, $SRMR=.070$)

Model	χ^2	df	χ^2/df	CFI	TLI	RMSEA	SRMR
Initial 25-item 6-factor CFA	1037.28	260	3.99	.830	.803	.094	.110
Final 21-item 7-factor CFA	419.90	168	2.50	.938	.923	.066	.070
Configural invariance across cohorts	539.33	336	1.61	.939	.924	.042	.075
Full metric invariance across cohorts	601.00	357	1.68	.927	.914	.045	.091

Note. N = 341 complete cases. Cohort was recoded from age group. Since full metric invariance was not supported under strict change criteria, scalar invariance was not interpreted.

Table 1
CFA model fit and measurement invariance

Most constructs showed acceptable reliability and convergent validity. The exception was PGM, which remained the weakest construct because it was measured with only two items and its AVE fell slightly below the recommended .50 threshold. For this reason, PGM is interpreted as reflecting the relevance or appeal of green communication rather than the broader concept of green marketing communication. Retaining the two-indicator factors was a pragmatic choice. They produced a better-fitting and more focused solution, but their limited coverage calls for caution and further testing with broader measures. Discriminant validity was examined using HTMT. All HTMT values were below the .85 threshold, with the highest value found between EC and PGM (HTMT = .676), supporting the distinction between the retained constructs.

¹ Income categories are reported in Albanian lek (ALL). As an indicative reference, EUR 1 $\approx$ ALL 94 according to the Bank of Albania official exchange rate during the study period.

Construct	Items	λ range	α	ω	CR	AVE	M (SD)
EC	EC1-EC5	.540-.950	.849	.858	.858	.558	3.99 (.68)
PGM	PGM3- PGM4	.649-.745	.652	.655	.655	.488	4.17 (.71)
PGW-CUE	PGW1- PGW2	.662-.862	.713	.739	.739	.591	3.99 (.77)
PGW-SUB	PGW3, PGW5	.724-.935	.805	.821	.821	.699	4.02 (.69)
TR	TR1, TR3, TR4	.767-.995	.867	.917	.917	.789	2.97 (.54)
GQP	GQP1- GQP3	.508-.941	.826	.846	.846	.661	3.41 (.72)
PI	PI1-PI4	.732-.933	.893	.904	.904	.704	4.69 (.48)

Note. N = 341 complete cases. λ = standardised CFA loading; α = Cronbach's alpha; ω = McDonald's omega; CR = composite reliability; AVE = average variance extracted. Omega and CR were derived from the same standardised congeneric CFA solution and should not be read as independent corroboration. PGM is retained as a narrow two-item relevance/appeal measure and should be interpreted cautiously, while PI shows a ceiling risk.

Table 2.
Reliability, convergent validity, and descriptives for retained measures

4.3 Descriptive Evidence and Correlations

The descriptive statistics show high environmental concern among respondents ($M = 3.99$) and very strong purchase intention ($M = 4.69$), while trust remained noticeably lower ($M = 2.97$). Scores for both perceived-greenwashing dimensions were also close to 4.0, pointing to a generally sceptical reading of sustainability-related claims. The correlations followed the same pattern. Environmental concern was positively associated with green-communication relevance/appeal (PGM; $r = .507$, $p < .01$), the green quality–price association (GQP; $r = .303$, $p < .01$), and with purchase intention (PI; $r = .239$, $p < .01$). Statistics showed that trust moved in the opposite direction: it was negatively associated with PGM ($r = -.234$, $p < .01$) and cue-based perceived greenwashing (PGW-CUE; $r = -.228$, $p < .01$). The data show that its association with purchase intention was weak and not statistically significant ($r = -.058$).

4.4 Hypothesis Tests

Environmental concern was a positive predictor of green-communication relevance/appeal ($\beta = .507$, $p < .001$), explaining 25.7 percent of the variance. H1 is supported. The trust model did not follow the expected sequence for trust-building. Green-communication relevance/appeal was negatively associated with trust ($\beta = -.172$, $p = .003$), so H2 is not supported. Cue-based perceived

greenwashing was also negatively associated with trust ($\beta = -.162$, $p = .004$), supporting H3a. Substantiation-based perceived greenwashing was not significant ($\beta = .001$, $p = .980$), so H3b is not supported. With place of upbringing and income added as controls, the negative associations for PGM ($\beta = -.140$, $p = .020$) and PGW-CUE ($\beta = -.152$, $p = .008$) remained significant, whereas the controls were not. Collinearity was low in the controlled trust model, with all VIF values at or below 1.32. H4 was not supported, as the findings reveal that trust was not significantly associated with purchase intention ($\beta = -.058$, $p = .284$). In the extended model, this result remained unchanged as trust once more showed no significant effect ($\beta = .006$, $p = .911$). In contrast, findings show both environmental concern ($\beta = .205$, $p < .001$) and the green quality-price association ($\beta = .116$, $p = .036$) were positively associated with purchase intention. Overall, the model accounted for 6.9% of the variance, and collinearity was not a concern, with all VIF values at or below 1.25. Given that purchase intention was already close to the upper end of the response scale, the absence of a significant trust effect should be interpreted as a finding specific to this sample rather than as evidence that trust has no role in purchase decisions more broadly.

Hyp./model	Path or test	Result	Decision
H1	EC $\rightarrow$ PGM	$\beta = .507$, $p < .001$, $R^2 = .257$	Supported
H2	PGM $\rightarrow$ TR	$\beta = -.172$, $p = .003$	Not supported; negative
H3a	PGW-CUE $\rightarrow$ TR	$\beta = -.162$, $p = .004$	Supported
H3b	PGW-SUB $\rightarrow$ TR	$\beta = .001$, $p = .980$	Not supported
H4	TR $\rightarrow$ PI	$\beta = -.058$, $p = .284$, $R^2 = .003$	Not supported
Extended PI	TR, EC, GQP $\rightarrow$ PI	TR: $\beta = .006$, $p = .911$; EC: $\beta = .205$, $p < .001$; GQP: $\beta = .116$, $p = .036$; $R^2 = .069$	EC and GQP significant
H5b	Cohort interactions	All focal interactions n.s.	Not supported
H6	EC and PI by upbringing/income	EC: $p = .018$ / $< .001$; PI: $p = .233$ / $.069$	Partially supported

Note. $N = 341$ complete cases for all analyses. β = standardised coefficient; n.s. = not significant. For H6, the first p-value refers to place of upbringing and the second to household income. H5a is reported separately in Table 4.

Table 3.
Hypothesis-test summary

4.5 Cohort and Demographic Findings

H5a is supported at the observed-composite level. Generation Z scored higher than Millennials on environmental concern, the relevance and appeal of green communication, both dimensions of perceived greenwashing, the association between green quality and price, and purchase intention. Millennials scored higher on trust. The largest differences were observed for environmental concern, PGM, and cue-based perceived greenwashing. These effect sizes are unusually large for consumer research and therefore require cautious interpretation.

These differences emerged in the survey data but should not be generalised to all Albanian consumers in either generation. They may partly reflect the sample itself, including the green brand-awareness screening, online recruitment, and the age cutoffs used to define the cohorts. Because full metric invariance was not established, the results are treated as differences in observed response patterns rather than definitive differences in the underlying constructs.

Construct	Gen Z M (SD)	Millennial M (SD)	t	p	Cohen's d
EC	4.50 (.44)	3.50 (.48)	20.16	<.001	2.18
PGM	4.66 (.38)	3.70 (.64)	16.89	<.001	1.82
PGW-CUE	4.37 (.64)	3.62 (.69)	10.34	<.001	1.12
PGW-SUB	4.15 (.68)	3.89 (.67)	3.48	<.001	.38
TR	2.84 (.54)	3.10 (.52)	-4.44	<.001	-.48
GQP	3.68 (.67)	3.14 (.67)	7.38	<.001	.80
PI	4.79 (.25)	4.59 (.61)	3.81	<.001	.41

Note. Complete-case cohort counts: Gen Z n=168, Millennials n=173. Positive Cohen's d values indicate higher Gen Z scores.

Table 4.
Cohort profile differences

H5b was not supported. Cohort did not significantly moderate any of the focal relationships in either the trust model or the extended purchase-intention model. The two cohorts therefore differed more in their average scores than in the way the variables were related to one another. The post-hoc power analysis showed about 75% power to detect small interaction effects and almost complete power to detect medium-sized effects. These findings provide reasonable confidence that no moderate differences in the structural relationships were present, although smaller differences may have gone undetected. The results should therefore not be taken to mean that the underlying mechanisms were identical across cohorts. In the mean-centred moderation models, VIF values remained below 10, although they were higher than those observed in the main regression models. The highest VIF was 7.53 in the trust model and 5.13 in the purchase-intention model.

H6 was partially supported. Environmental concern was higher among respondents with an urban upbringing than among those with a rural upbringing ($M = 4.05$ vs. 3.86 ; $t = 2.38$, $p = .018$, $d = .28$). It also differed significantly by household income, with the highest concern in the lower income bands and the lowest concern in the highest income band ($F = 12.33$, $p < .001$, $\eta^2 = .099$). Purchase intention did not differ significantly by upbringing ($p = .233$) or by household income ($p = .069$). The inverse income pattern is consistent with national evidence that sustainability-compatible behaviour in Albania is often strongest among financially constrained households, a pattern described as green by necessity rather than green by affluence [18].

4.6 Organisational Perspectives from Brand Interviews

The interview findings offer additional context for interpreting the survey results. Consumers' caution toward environmental claims appear consistent with what firms reported during the interviews. All firms indicated that they had adopted sustainability-related practices, yet only six out of fifteen actively communicated those efforts. As a result, many sustainability initiatives remain largely invisible to consumers because they are not supported by clear, verifiable communication. The interview evidence revealed a consistent gap between sustainability practice, substantiation and communication. All 15 firms reported sustainability-related practices and consumer scepticism, managed their social media internally, regarded green branding as costly in a domestic market unwilling to pay more, considered consumer education necessary, and reported no concrete government support. Yet only 6 firms actively promoted their green practices. 5 firms used solar panels, but only 2 communicated this fact. Certification was rare, with only 1 firm already certified, while all 5 firms engaging third parties for ISO or certification were export-related. 4 firms were not convinced that green practices or their promotion generated commercial returns. Finally, 11 firms reported that visits to shops, sites or production facilities reduced consumer scepticism, indicating that direct experience can partly substitute for formal verification.

4.6.1 Sustainability as reputation and market access

The company notes indicate that firms use sustainability as a reputational cue in the domestic market and as an access requirement in external markets. Export transactions are especially important: the firms engaging third parties for ISO or certification were the firms linked to export activity. One olive oil producer explained the sequence plainly: *“We had no idea. Once we made contact with the export market we understood immediately that without communicating sustainability we could not break in. We changed the packaging, added a QR code on the label that leads to the website. Without an external expert we would not have known; we cannot be professionals in everything. What we know is how to make good olive oil”* (February 2026). The engaged firms in this study show that the

documentation of sustainability appears to be pulled by buyers and external partners rather than pushed by domestic consumers.

4.6.2 Substantiation constrained by cost and capability

The interviews also highlighted the practical challenges that local firms face when communicating sustainability. While participants generally recognised the value of green communication, many described certification, documentation, professional marketing, and claim verification as expensive and difficult to sustain. Across all 15 cases engaged, social media platforms were managed internally, most often by the owner or another family member rather than a marketing specialist. Certification was repeatedly mentioned as a particular obstacle. As one producer explained, *“The certifications of our products require a lot of knowledge of regulatory framework, skilled people and a lot of money; we have neither of those. And in the Albanian market, holding a certification does not mean your product sells at a higher price”* (January 2026). These accounts suggest that sustainability claims may outpace the systems needed to document and verify them, particularly in small firms with limited or no marketing and compliance resources.

4.6.3 Scepticism as a market condition

All 15 firms engaged in this study reported consumer scepticism. This scepticism was linked not only to environmental claims but also to broader experiences with product quality, adulteration, and exaggerated market promises. One olive oil producer connected scepticism to concrete local market experience: *“Consumers have faced many bad experiences in the Albanian market; people have bought final product with blended other oil, and I do not blame them. We try to show them our laboratory analyses, but even there, we notice scepticism. These cases have gone public in media”* (January 2026). Eleven of the fifteen firms reported that visits to the shop or production facility helped reduce customer doubts and often encouraged these customers to recommend the business to others. What emerges from these interviews is that trust is earned through transparency and first-hand experience rather than through general sustainability claims.

4.6.4 Generational differences observed but not systematically tracked

Formal data are not collected by any of the interviewed companies on generational differences, but interviewees repeatedly observed that younger consumers tended to pay more attention to websites, online ratings, packaging, traceability, and other visible signs of product credibility than other generations. They described Millennials as more price-sensitive and more likely to consider a quality justification before accepting a premium. A producer summarised the distinction in terms that mirror the survey result: *“Strangely, the young consumer associates green with both a higher price and higher quality, while the more mature ones associate it more with a higher price they do not much want to pay. A more mature*

generation, like 50 years up, they have more fixed ideas is difficult to change or convince them” (February 2026). This aligns with the finding that Generation Z combines strong green interest with lower trust and a stronger green quality-price association.

5 Discussion

The results qualify the standard trust-centred model rather than simply confirming it. Environmental concern was clearly associated with the relevance and appeal of green communication, but favourable attention to such communication did not build trust. On the contrary, PGM was negatively associated with trust. This finding should be interpreted carefully because the retained PGM measure is short and borderline, but the negative direction is consistent with evidence from other Central and South-Eastern European settings where environmental communication, scepticism and distrust may coexist rather than follow a simple persuasion sequence [34] [35]. In low-verification markets, closer attention to green communication may expose consumers to claims they cannot independently verify.

An important finding is that the two dimensions of perceived greenwashing behaved differently. Cue-based greenwashing, related to misleading words and visual signals, was negatively associated with trust. Substantiation-based greenwashing, related to vague or weakly evidenced claims, did not independently predict trust once PGM and cue-based greenwashing were included. One possible interpretation is that Albanian consumers respond more strongly to visible promotional cues than to the absence of formal evidence, especially in a market where weak substantiation may already be common.

Trust was not associated with consumers' purchase intention in this study. This should not be read as a rejection of trust theory. Purchase intention for green brands is close to the scale ceiling, limiting the explanatory variance. The findings suggest that, among consumers already aware of green brands, purchase intention is driven more by environmental concern and quality-price perceptions than by brand trust. Consumers may want to purchase green products while still doubting the claims around them.

The cohort evidence is the clearest substantive contribution, but it should not be overstated. Albanian Generation Z is not simply more environmentally concerned. It is also more responsive to the retained relevance/appeal items, more likely to perceive both types of greenwashing, less trusting, more likely to connect green attributes with quality and price, and more willing to buy green products. The green quality-price result is consistent with recent evidence that green consumption may serve as a status or distinction signal for the brand among younger consumers [36]. However, the cohort effect sizes are unusually large, especially for environmental concern and green-communication relevance/appeal. Because full metric invariance

was not supported, these gaps are treated as observed profile differences rather than as latent mean differences.

The income results require the same caution. Lower-income respondents in this sample reported stronger environmental concern, yet this does not mean that the domestic market supports green price premiums that easily. National evidence suggests that many sustainability-compatible behaviours in Albania are resource-saving practices which are mainly shaped by financial constraints rather than by lifestyle consumption [18]. The present results therefore separate two phenomena: engagement with marketed green claims, where Generation Z is most attentive and sceptical, and necessity-driven sustainable practice, which may be stronger among older or financially constrained consumers.

The qualitative findings help explain why this credibility gap exists. The interviewed firms reported sustainability-related practices, but evidence production, certification and professional communication remain costly, while domestic consumers do not reliably reward substantiation through higher prices. Verification is often pulled by export markets rather than domestic demand. The credibility gap is therefore structural as well as communicative.

For firms, the implication is direct: more green communication alone is unlikely to strengthen trust. Credibility depends on verifiable information, such as QR-code traceability, documented production processes, independent verification where feasible and clear explanations of production methods. For policymakers and business-support institutions, the findings point to the need for accessible verification systems, practical guidance for small firms and consumer education. Certification alone is not enough if consumers do not understand or trust how it was obtained. Without more transparent and understandable substantiation, consumers will continue to rely on their own judgement, making it difficult for genuinely green firms to stand apart from weak or unsupported environmental claims.

Conclusion

This study examined how Generation Z and Millennial consumers in Albania respond to green and sustainability claims made by local brands. Using survey data from 348 consumers and interviews with representatives of 15 firms, the paper shows that Albania is an emerging green-brand environment but also a low-trust communication environment. The revised CFA-based measurement model distinguished between cue-based and substantiation-based perceived greenwashing, allowing a more precise interpretation of how consumers evaluate sustainability claims.

The main finding is that environmental concern is positively associated with green-communication relevance/appeal, but this attention does not translate into stronger trust. Instead, green-communication relevance/appeal and cue-based greenwashing are negatively associated with trust. Trust itself is not detectably associated with purchase intention, which is more closely linked to environmental concern and to the perception that green attributes signal quality and justify a premium.

Generation Z appears as the more engaged but also more sceptical cohort: it reports higher concern, stronger purchase intention, higher perceived greenwashing and lower trust than Millennials. These findings should be read in light of the study's constraints. The sample was non-probabilistic and digitally active, with urban and higher-income respondents more strongly represented.

The measurement model still has its limitations. PGM was captured with only two items, and the two greenwashing dimensions need to be tested with a broader set of indicators. Some of the retained items also warrant further validation. Full metric invariance was not established, so the cohort results reflect observed response patterns rather than latent mean differences. The cross-sectional design and the use of self-reported purchase intention warrant caution, especially given that responses were clustered near the top of the scale. The model should now be tested with probability or panel samples, in other Western Balkan markets, and through behavioural or experimental studies that examine whether clearer evidence behind sustainability claims can rebuild trust.

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Monitoring Sustainability: Can Social Security Fund Ownership Curb ESG Greenwashing?

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Abstract: This study investigates whether ownership by China's National Social Security Fund (NSSF) reduces ESG greenwashing among listed firms over the period 2011–2022. Against the backdrop of growing concerns about the credibility of ESG disclosures, we examine the governance role of a large public institutional investor in constraining opportunistic reporting. Using a panel dataset of Chinese A-share firms, we find that higher NSSF shareholdings are significantly associated with lower levels of ESG greenwashing, indicating that firms with greater NSSF ownership are less likely to overstate their sustainability performance. Further analysis shows that this effect operates through enhanced monitoring and stronger incentives for credible disclosure, and is amplified in firms with greater analyst attention, highlighting the complementary role of external information intermediaries. In addition, the effect is more pronounced in state-owned enterprises, where alignment between institutional oversight and state governance structures strengthens monitoring effectiveness. The findings provide new evidence on the governance role of public institutional investors in improving the credibility of ESG disclosures and offer important implications for promoting more transparent and sustainable capital markets.

Keywords: Social security fund; ESG greenwashing; Analyst attention; Corporate governance

1 Introduction

In recent years, environmental, social, and governance (ESG) practices have become increasingly central to corporate strategy, driven by growing pressure from investors, regulators, and other stakeholders. A large body of evidence suggests that sustainable and responsible business conduct is associated with improved long-term financial performance [1]. Moreover, recent studies show that climate risk disclosure can significantly affect stock market outcomes such as liquidity, highlighting the economic consequences of credible ESG information [2]. As a result, firms are increasingly motivated to disclose ESG-related information to signal their commitment to sustainability. However, the rapid expansion of ESG disclosure has also raised concerns about its credibility. In particular, firms may engage in “greenwashing,” selectively disclosing favorable information while concealing poor ESG performance, thereby misleading investors and undermining market transparency [3], [4].

Existing research highlights the important role of external monitoring mechanisms in mitigating greenwashing behavior. Institutional and regulatory environments, such as China’s Social Credit System and environmental audits, have been shown to reduce greenwashing and enhance disclosure credibility [5]. Corporate governance factors, including board characteristics and ownership structure, also play a significant role in constraining opportunistic ESG reporting [6]. In addition, external information intermediaries, such as media and financial analysts, can improve transparency and exert reputational pressure on firms, thereby discouraging greenwashing [7]. In particular, recent studies show that investor attention and online information environments can significantly enhance corporate environmental disclosure and transparency [8]. More recently, studies have emphasized the monitoring role of institutional investors, showing that higher institutional ownership and active engagement can reduce information asymmetry and curb greenwashing behavior [9]. Moreover, the presence of green-oriented investors has been shown to influence corporate behavior and improve market outcomes, further underscoring the governance role of sustainability-focused capital [10].

Despite these advances, the existing literature has largely focused on private institutional investors, while the role of public institutional investors remains underexplored. In particular, state-level investors, such as sovereign or national funds, possess unique characteristics that may distinguish their governance effects. These investors often combine governmental objectives with market-oriented investment strategies, potentially leading to stronger monitoring incentives and greater influence on corporate behavior. However, empirical evidence on how such public institutional investors affect ESG disclosure credibility, especially in emerging markets, remains limited.

This study addresses this gap by examining the role of China's National Social Security Fund (NSSF) in curbing corporate ESG greenwashing. As one of the largest public institutional investors in China, the NSSF holds significant stakes in listed firms and operates with a long-term investment horizon. Its dual identity, balancing state objectives with market-based investment rationality, positions it as a potentially effective monitor of corporate behavior. Using a panel dataset of Chinese A-share listed firms from 2011 to 2022, this study investigates whether NSSF ownership reduces ESG greenwashing and explores the underlying mechanisms.

The empirical results show that higher NSSF ownership is associated with significantly lower levels of ESG greenwashing, suggesting that the NSSF plays an important governance role in enhancing disclosure credibility. Furthermore, the monitoring effect is stronger in firms with greater analyst attention, highlighting the complementary role of external information intermediaries. The effect is also more pronounced in state-owned enterprises, where institutional oversight is more closely aligned with state governance structures.

This study contributes to the literature in several ways. First, it extends research on ESG greenwashing by providing new evidence on the role of public institutional investors in improving disclosure credibility. Second, it enriches the literature on institutional investors by highlighting the unique governance function of state capital in emerging markets. Third, it offers important policy implications for strengthening ESG regulation and promoting high-quality capital market development in China.

The remainder of the paper is organized as follows. Section 2 describes the data, variables, and empirical methodology. Section 3 presents the empirical results. Section 4 provides robustness checks and additional analyses. Section 5 concludes.

2 Methodology

2.1 Sample selection and data source

This study uses a panel dataset of Chinese A-share listed firms from 2011 to 2022. The sample is constructed from multiple databases to ensure comprehensive coverage of financial and ESG-related information. Specifically, firm-level financial and accounting data are obtained from the China Securities Market and Accounting Research (CSMAR) database. ESG performance data are collected from the Wind Database, while ESG disclosure data are sourced from Bloomberg.

Following standard practice in the literature, several screening procedures are applied. First, financial firms are excluded due to their distinct regulatory

environment and financial structure. Second, firms designated as ST or *ST are removed to avoid the influence of financial distress. Third, observations with missing key variables are excluded. The final sample consists of 2,529 firm-year observations.

2.2 Dependent variable

The dependent variable in this study is ESG greenwashing (Greenwashing), which captures the extent to which firms overstate their sustainability performance. Following prior literature, greenwashing is measured as the standardized difference between ESG disclosure and ESG performance:

$$\text{Greenwashing} = \left(\frac{ESG_{dis,i,t} - \text{mean}(ESG_{dis})}{\text{std}(ESG_{dis})} \right) - \left(\frac{ESG_{per,i,t} - \text{mean}(ESG_{per})}{\text{std}(ESG_{per})} \right)$$

where $ESG_{dis,i,t}$ denotes the ESG disclosure score of firm i in year t , and $ESG_{per,i,t}$ represents the firm's actual ESG performance. The terms $\text{mean}(ESG_{dis})$ and $\text{std}(ESG_{dis})$ refer to the sample mean and standard deviation of ESG disclosure, while $\text{mean}(ESG_{per})$ and $\text{std}(ESG_{per})$ denote those of ESG performance.

2.3 Independent variable

The key independent variable is the shareholding of China's National Social Security Fund (NSSF). It is measured as the percentage of shares held by the NSSF in a given firm-year.

As a large public institutional investor with long-term investment horizons, the NSSF has both the incentive and capacity to monitor corporate behavior. Its ownership is expected to mitigate managerial opportunism and enhance the credibility of ESG disclosures through improved governance and oversight.

2.4 Control variables

To mitigate potential omitted variable bias, this study controls for a set of firm-level characteristics that may influence ESG greenwashing behavior. Specifically, leverage (Leverage) is measured as the ratio of total liabilities' book value to total assets to capture firms' reliance on external financing; firm size (Firm_size) is included as an indicator of firm scale. Return on assets (ROA) is a measure of profitability. In addition, a state-owned enterprise indicator (SOE) is included to account for state ownership. Corporate governance factors are further controlled for by including CEO-board chair duality (CEO_Duality) to assess the separation of managerial roles, the shareholding ratio of the top 10 shareholders (Top10) to measure ownership concentration, and board size (Boardsize) as an indicator of

internal governance. Finally, industry and year fixed effects are included to control for unobservable heterogeneity across industries and time.

2.5 Model specification

To examine the impact of NSSF ownership on ESG greenwashing, the following baseline regression model is estimated:

$$\text{Greenwashing}_{i,t+1} = \beta_0 + \beta_1 \text{NSSF}_{i,t} + \text{Controls}_{i,t} + \text{IndustryFE} + \text{YearFE} + \varepsilon_{i,t+1}$$

where $\text{Greenwash}_{i,t+1}$ represents the level of ESG greenwashing for firm i in year $t+1$, and $\text{NSSF}_{i,t}$ is the NSSF's shareholding in year t . Control variables account for firm-specific characteristics, while industry and year fixed effects capture systematic differences across sectors and time periods.

The coefficient of interest, β_1 , measures the effect of NSSF ownership on ESG greenwashing. A negative and significant coefficient would support the hypothesis that NSSF shareholding reduces firms' greenwashing behavior by strengthening monitoring and improving disclosure credibility.

3 Results

3.1 Descriptive statistics

Table 1 reports the descriptive statistics of the main variables used in this study. The results show that the mean ESG greenwashing score is relatively low, suggesting that, on average, Chinese listed firms do not exhibit severe discrepancies between ESG performance and disclosure. However, the variation across firms is considerable, indicating substantial heterogeneity in greenwashing behavior.

The average shareholding of the National Social Security Fund is relatively small, but the standard deviation suggests meaningful variation across firms. This implies that although the NSSF typically holds a modest equity stake, its presence differs significantly across firms, providing sufficient variation for empirical analysis.

Regarding control variables, firm size, leverage, and profitability display reasonable distributions consistent with prior literature. Therefore, the descriptive statistics indicate that the sample is well-balanced and suitable for subsequent regression analysis.

Variable	N	Mean	Std. Dev.	Min	Median	Max
Greenwashing	2529	-0.463	1.261	-3.250	-0.481	2.850
NSSF	2529	1.622	1.354	0.006	1.190	12.360
Leverage	2529	0.469	0.189	0.0504	0.483	0.962
Firm_size	2529	23.397	1.242	20.202	23.320	26.159
ROA	2529	0.0618	0.0531	-0.320	0.0535	0.217
CEO_Duality	2529	0.213	0.410	0	0	1
SOE	2529	0.548	0.498	0.000	1.000	1.000
Top10	2529	62.963	14.860	22.435	63.350	94.655
Boardsize	2529	9.066	1.763	5.000	9.000	14.000

Table 1.
Descriptive statistics.

3.2 The relationship between NSSF and ESG greenwashing

Table 2 presents the baseline regression results examining the relationship between NSSF ownership and ESG greenwashing. The coefficient on NSSF is negative and statistically significant, indicating that higher NSSF shareholding is associated with lower levels of ESG greenwashing.

This finding supports the hypothesis that the NSSF, as a large public institutional investor, plays an effective monitoring role in corporate governance. Its long-term investment horizon and alignment with state objectives enable it to curb managerial opportunism and promote more credible ESG disclosure. The economic magnitude of the effect is also meaningful, suggesting that even relatively small ownership stakes by the NSSF can significantly reduce firms' tendency to overstate sustainability performance.

Variables	Greenwashing _{t+1} (1)	Greenwashing _{t+1} (2)
<i>NSSF</i>	-0.0491*** (0.0182)	-0.0413** (0.0182)
<i>Leverage</i>		-0.6458*** (0.2001)
<i>Firm_size</i>		0.1274*** (0.0296)
<i>ROA</i>		-0.1362 (0.5576)
<i>CEO_Duality</i>		0.1979*** (0.0657)
<i>SOE</i>		-0.1538*** (0.0592)
<i>Boardsize</i>		-0.0227 (0.0157)
<i>Industry FE</i>	Yes	Yes
<i>Year FE</i>	Yes	Yes

<i>Observations</i>	2529	2529
<i>Adj. R²</i>	0.013	0.028

Note: Robust standard errors are shown in parentheses, *p < 0.1; **p < 0.05; ***p < 0.01, respectively.

Table 2.

The relationship between NSSF and ESG greenwashing.

3.3 Do analysts play a crucial role in monitoring the firms?

Table 3 reports the moderating effect of analyst attention on the relationship between NSSF ownership and ESG greenwashing. The interaction term between NSSF and analyst attention is negative and statistically significant, indicating that NSSF's inhibitory effect on greenwashing is stronger in firms with higher analyst coverage.

This result suggests that external information intermediaries, such as financial analysts, enhance the effectiveness of institutional monitoring. By increasing transparency and information dissemination, analyst attention complements the NSSF's governance role, further constraining opportunistic disclosure behavior.

The findings highlight the importance of a joint monitoring mechanism in which internal governance by institutional investors and external scrutiny by analysts work together to improve the credibility of ESG reporting.

<i>Variables</i>	Greenwashing _{t+1} (1)
<i>NSSF</i>	0.0388 (0.0332)
<i>AnaAttention</i>	0.0111*** (0.0042)
<i>NSSF x AnaAttention</i>	-0.0030** (0.0012)
<i>Leverage</i>	-0.7328*** (0.2598)
<i>Firm_size</i>	0.1808*** (0.0393)
<i>ROA</i>	-0.6927 (0.7972)
<i>CEO_Duality</i>	0.2101** (0.0953)
<i>SOE</i>	-0.1775** (0.0837)
<i>Boardsize</i>	-0.0499** (0.0199)
<i>Industry FE</i>	Yes
<i>Year FE</i>	Yes

<i>Observations</i>	1431
<i>Adj. R²</i>	0.034

Note: Robust standard errors are shown in parentheses, *p < 0.1; **p < 0.05; ***p < 0.01, respectively.

Table 3
Do analysts play a crucial role in monitoring the firms?

3.4 Heterogeneity analysis

Table 4 presents the heterogeneity analysis based on firms' ownership structure. The results show that the negative relationship between NSSF ownership and ESG greenwashing is more pronounced in state-owned enterprises (SOEs) than in non-state-owned firms.

This finding can be explained by the closer alignment between the NSSF and state governance structures in SOEs. As a public institutional investor, the NSSF may exert stronger influence in firms where state ownership facilitates coordination and strengthens monitoring effectiveness.

In contrast, its governance impact is relatively weaker in non-SOEs, where institutional constraints and ownership fragmentation may limit its influence. In summary, the heterogeneity analysis reinforces the view that institutional context plays a crucial role in shaping the effectiveness of NSSF monitoring.

<i>Variables</i>	Non-SOE Greenwashing _{t+1} (1)	SOE Greenwashing _{t+1} (2)
<i>NSSF</i>	-0.0237 (0.0281)	-0.0484** (0.0241)
<i>Leverage</i>	0.1232 (0.3162)	-1.2561*** (0.2648)
<i>Firm_size</i>	-0.0238 (0.0510)	0.2154*** (0.0364)
<i>ROA</i>	0.4891 (0.8016)	-1.2750 (0.8048)
<i>CEO_Duality</i>	0.2272*** (0.0813)	0.0037 (0.1153)
<i>Boardsize</i>	-0.0255 (0.0254)	-0.0071 (0.0201)
<i>Industry FE</i>	Yes	Yes
<i>Year FE</i>	Yes	Yes
<i>Observations</i>	1144	1385
<i>Adj. R²</i>	0.010	0.046

Note: Robust standard errors are shown in parentheses, *p < 0.1; **p < 0.05; ***p < 0.01, respectively.

Table 4.
Heterogeneity analysis.

Conclusions

This study examines the role of China's National Social Security Fund in curbing corporate ESG greenwashing using a panel dataset of Chinese A-share listed firms from 2011 to 2022. Against the backdrop of increasing concerns about the credibility of ESG disclosures, this paper provides new evidence on whether and how a large public institutional investor can improve the authenticity of corporate sustainability reporting.

The empirical results show that NSSF ownership is significantly associated with lower levels of ESG greenwashing, suggesting that the NSSF plays an effective monitoring role in corporate governance. Despite relatively small shareholdings, its presence exerts a meaningful influence on firms' disclosure behavior, underscoring the importance of long-term, state-backed institutional investors in promoting transparency and reducing managerial opportunism.

Further analysis reveals that this monitoring effect is strengthened by external information environments. Specifically, the negative relationship between NSSF ownership and greenwashing is more pronounced among firms with greater analyst attention, suggesting that external scrutiny complements institutional monitoring. In addition, the NSSF's governance effect is stronger in state-owned enterprises, where alignment with state objectives enhances its ability to influence corporate behavior.

This study contributes to the literature by extending research on ESG greenwashing from the perspective of public institutional investors and by highlighting the unique governance role of state capital in emerging markets. It also provides practical implications for policymakers and regulators, suggesting that strengthening the participation of long-term institutional investors can improve the credibility of ESG disclosures and support the development of more transparent capital markets.

Nevertheless, this study has several limitations. First, the measurement of ESG greenwashing relies on an index constructed from disclosure and performance data, which may not fully capture all dimensions of opportunistic behavior. Second, although various control variables and empirical strategies are employed, potential endogeneity concerns cannot be entirely ruled out. Future research could explore alternative identification strategies, such as natural experiments, and examine the role of other types of institutional investors or cross-country settings.

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Why Do Students Choose Certain Mobility Destinations? An Exploratory Study of Decision Factors and Post-Mobility Satisfaction

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Abstract: Justify International student mobility has become an increasingly important component of higher education, offering significant academic, cultural, and personal benefits. However, the decision-making process behind selecting a mobility destination is complex and influenced by multiple interrelated factors. This study aims to identify and analyze the key determinants that shape students' mobility choices and to examine how these factors relate to their post-mobility satisfaction.

The research adopts a mixed approach, combining a structured literature review with a questionnaire-based exploratory study. The literature review synthesizes existing findings on student mobility decision-making, while the empirical component is based on survey responses collected from university students with and without prior mobility experience. The questionnaire focuses on the perceived importance of academic, economic, social, cultural, and geographic factors, as well as satisfaction levels among students who have already completed their mobility period.

The findings indicate that, in addition to academic considerations such as course compatibility and institutional reputation, non-academic factors—including city attractiveness, lifestyle, and cost of living – play a significant role in shaping student decisions. Furthermore, preliminary results suggest that factors influencing initial choice are not always aligned with those contributing to post-mobility satisfaction.

This study contributes to a deeper understanding of student mobility behavior and highlights the importance of integrating both academic and lifestyle-related factors in the design of decision-support tools for mobility planning.

Keywords: Student mobility, Mobility decision-making, Post-mobility satisfaction, Internationalisation of higher education

1 Introduction

International student mobility has become a central element of modern higher education, contributing significantly to academic development, intercultural competence, and employability [1]. Participation in mobility programmes enables students to gain international experience, broaden their perspectives, and acquire skills that are increasingly valued in a globalised labour market [2]. As a result, studying abroad is no longer considered a supplementary opportunity but an integral part of many students' academic trajectories [3].

Despite its well-documented benefits, the process of selecting a mobility destination remains complex and often challenging. Students are required to evaluate multiple criteria simultaneously, including academic compatibility, financial feasibility, cultural environment, and personal preferences [4]. These decisions are typically made based on fragmented sources of information, such as university websites, informal recommendations, and prior student experiences, which vary significantly in structure and reliability [5]. Consequently, the decision-making process is characterised by uncertainty, cognitive overload, and limited transparency.

Existing research has identified a wide range of factors influencing student mobility decisions, often categorised into academic, economic, social, cultural, and geographic dimensions. However, less attention has been paid to the relationship between the factors that influence students' initial choices and those that contribute to their satisfaction after completing mobility [6]. This potential mismatch raises important questions regarding the effectiveness of current decision-making processes and the adequacy of available support mechanisms.

The aim of this study is to identify and analyse the key determinants that shape students' mobility choices and to examine how these factors relate to post-mobility satisfaction. By combining insights from the literature with empirical data collected through a questionnaire-based survey, the study seeks to provide a more comprehensive understanding of student mobility behaviour. Furthermore, the findings aim to contribute to the development of more effective decision-support approaches by highlighting the importance of aligning decision factors with actual student experiences.

2 Literature Review

2.1 Student Mobility and Its Growing Importance

Student mobility has become an increasingly significant component of higher education systems worldwide, contributing to both individual student development

and the internationalisation of universities [1]. Participation in mobility programmes enables students to acquire intercultural competencies, develop language skills, and enhance their employability, positioning mobility as a key instrument in academic and professional growth [7].

The growing importance of student mobility is reflected in its expansion over recent decades, as internationalisation has evolved from a peripheral activity into a central strategic objective of higher education institutions [8]. Consequently, an increasing number of students consider studying abroad as an integral part of their academic trajectory, making the decision-making process surrounding mobility both more relevant and more complex

2.2 Determinants of Student Mobility Decisions

The decision to participate in student mobility is influenced by a wide range of factors, commonly conceptualised in the literature as “push” and “pull” factors [9]. Push factors refer to conditions in the home environment that encourage students to seek opportunities abroad, while pull factors describe the characteristics of the destination that attract them. Academic considerations are consistently identified as primary determinants of mobility decisions. These include course availability, compatibility with the home curriculum, and the perceived quality and reputation of the host institution. Economic factors also play a critical role, particularly in relation to cost of living, financial support, and travel-related expenses.

However, the literature increasingly highlights the importance of non-academic factors in shaping student preferences [10]. Elements such as city attractiveness, cultural environment, lifestyle, climate, and opportunities for social interaction significantly influence destination choice. In many cases, these lifestyle-related aspects are equally important as academic considerations, demonstrating the multidimensional nature of student decision-making. Beyond these structural factors, personal and psychological aspects also contribute to the decision process. Individual motivation, risk perception, prior international exposure, and peer influence can shape both the willingness to participate in mobility and the final choice of destination. This highlights that mobility decisions are not purely rational but involve subjective and context-dependent elements.

2.3 Complexity of the Decision-Making Process

Despite the well-documented benefits of student mobility, the decision-making process remains complex and often challenging [7]. Students are required to evaluate multiple criteria simultaneously, often without clear prioritisation or structured guidance. This multi-criteria nature of the decision increases cognitive load and makes it difficult to identify optimal choices.

One of the primary challenges lies in the fragmentation of available information. Students typically rely on multiple heterogeneous sources, including university websites, course catalogues, administrative guidelines, and informal recommendations. These sources vary significantly in structure, terminology, and level of detail, making direct comparison difficult. As a result, students often rely on subjective interpretation, which can lead to uncertainty and suboptimal decisions.

A further difficulty is the evaluation of academic compatibility between institutions. Course descriptions are typically unstructured and differ in terminology, making it challenging to assess equivalence between courses. This issue is particularly critical in structured programmes, where prerequisite knowledge and curriculum alignment are essential. Consequently, students must invest significant effort in manually comparing course content, often without sufficient support.

Administrative requirements, such as the preparation of learning agreements and the management of credit recognition processes, introduce additional complexity. These tasks are frequently time-consuming and require navigating institutional procedures that may not be transparent or standardised.

2.4 The Hungarian and Institutional Context

These challenges are also evident in the Hungarian higher education context, where student mobility is primarily facilitated through programmes such as Erasmus+ and the Pannónia Programme [11]. These initiatives provide structured opportunities and financial support, contributing to the expansion of mobility participation [10].

However, the coexistence of multiple programmes, institutional frameworks, and mobility formats increases the complexity of the decision-making environment. Differences in eligibility criteria, curriculum structures, and application procedures across universities make it difficult for students to compare options effectively [12]. At the institutional level, particularly in engineering and informatics programmes such as those at Óbuda University, mobility planning is further constrained by structured curricula and prerequisite dependencies. Students must carefully select courses that align with their home programmes, making academic compatibility a critical factor in decision-making. From the student perspective, these structural and institutional characteristics result in a fragmented and cognitively demanding process [13]. The lack of standardised and integrated support mechanisms reinforces reliance on informal information sources and increases the likelihood of uncertainty during decision-making [14].

Overall, the literature demonstrates that student mobility decisions are shaped by a complex interaction of academic, economic, social, and personal factors, while the decision-making process itself is characterised by fragmented information and high cognitive demands. At the same time, existing studies tend to focus either on the

determinants of mobility decisions or on the outcomes of mobility experiences, with relatively limited attention given to the relationship between these two perspectives. In particular, the extent to which the factors influencing students' initial choices align with those contributing to their post-mobility satisfaction remains insufficiently explored.

Understanding this relationship is essential, as discrepancies between expectations and experiences may lead to suboptimal decisions and reduced overall satisfaction. Therefore, examining both decision factors and post-mobility outcomes within a unified framework can provide a more comprehensive insight into student mobility behaviour and support more effective decision-making processes.

3 Methodology

This study employed a quantitative, questionnaire-based exploratory research design to investigate the factors influencing students' mobility destination choices and their post-mobility satisfaction. Data were collected through an online questionnaire developed using Google Forms.

The survey targeted students of Óbuda University, including both students who had already participated in an international mobility programme and those who had not yet gained mobility experience. This allowed the study to examine both anticipated decision factors and reported post-mobility experiences.

A total of 127 valid responses were collected, consisting of 71 female and 56 male respondents, with an average age of 23.2 years. The sample included students from all study levels, predominantly Bachelor's students (102 respondents), complemented by Master's (12) and PhD students (13).

The questionnaire consisted of four main sections. The first collected demographic information, while the second examined the perceived importance of various destination-selection criteria using a five-point Likert scale. The evaluated factors covered academic, economic, geographic, cultural, and social dimensions, including course compatibility, scholarship opportunities, cost of living, safety, accommodation, university reputation, lifestyle, language, and travel opportunities.

Students with previous mobility experience completed an additional section measuring their satisfaction with different aspects of their mobility experience, including courses, hosting university, accommodation, city, social life, university support, and overall satisfaction. Finally, respondents were asked open-ended questions regarding the primary reason behind their destination choice, whether they would select the same destination again, and what advice they would give to future mobility participants.

Descriptive statistical analysis was applied to compare the relative importance of the examined factors and to identify similarities and differences between demographic groups and between expectations and post-mobility experiences.

4 Results

The results demonstrate that students consider a broad range of factors when selecting a mobility destination, confirming the multidimensional nature of mobility decision-making identified in the literature.

Among all examined criteria, safety emerged as the most important consideration, receiving the highest average score from both male (4.63) and female (5.03) respondents. Cost of living also ranked among the highest priorities, followed by the attractiveness of the destination country, language-related considerations, and academic factors such as course compatibility and course availability. These findings suggest that although academic considerations remain essential, practical and lifestyle-related aspects have become equally influential during destination selection.

Some gender differences were also observed. Female respondents consistently assigned higher importance to most decision factors, particularly safety, cost of living, travel opportunities, teaching language availability, and city attractiveness. In contrast, male respondents placed slightly greater emphasis on international university reputation. Nevertheless, both groups displayed remarkably similar overall ranking patterns, indicating a broadly shared perception of what constitutes an attractive mobility destination. Table 1 presents the mean importance ratings assigned to each decision factor. The "Diff" column represents the difference between the average ratings of female and male respondents.

Factors	Male	Female	Total	Diff
Travel opportunities	4.07	4.49	4.30	-0.42
Safety	4.63	5.03	4.85	-0.40
Teaching language availability	4.18	4.58	4.40	-0.40
Cost of living	4.45	4.84	4.66	-0.39
Distance from home	3.38	3.77	3.59	-0.39
Attractiveness of the city	4.32	4.57	4.46	-0.24
Available courses	4.32	4.55	4.45	-0.23
Attractiveness of the country	4.43	4.65	4.55	-0.22
Scholarship amount	4.27	4.43	4.36	-0.17
Language of country	4.39	4.54	4.47	-0.14
Weather/climate	3.70	3.81	3.76	-0.12
Cultural life	4.00	4.10	4.06	-0.10
Career opportunities	4.39	4.45	4.42	-0.06
Accommodation	4.36	4.35	4.35	0.01
Compatibility of subjects	4.43	4.41	4.42	0.02
Recommendations from friends	4.05	4.03	4.04	0.02
University reputation	3.93	3.90	3.91	0.03
International reputation	4.23	4.06	4.14	0.17

The satisfaction analysis among students who had already completed a mobility

Table 2

Mean importance ratings of mobility destination selection factors by gender programme revealed generally positive experiences. Social life (4.01), the destination city (4.05), and overall mobility satisfaction (3.98) achieved the highest average evaluations, while accommodation (3.89), the hosting university (3.90), and courses (3.83) also received favourable assessments. These results indicate that participants were generally satisfied with both the academic and non-academic dimensions of their mobility experience.

Factors	Male	Female	Total	Diff
Accommodation	4.00	3.80	3.89	0.20
University support	4.00	3.91	3.95	0.09
Overall with your mobility experience	3.98	3.97	3.98	0.01
Social life	4.00	4.01	4.01	-0.01
Courses	3.82	3.84	3.83	-0.02
City	3.98	4.10	4.05	-0.12
Hosting university	3.79	3.99	3.90	-0.20
Food	3.82	4.06	3.95	-0.24

Table 3

Mean satisfaction ratings among students with previous mobility experience

Recommendation	Frequency
Preparation and prior research	7
Financial planning	6
Safety considerations	6
Administrative preparation	5
Social openness	5
Language barriers	4
Adjustment and loneliness	3
Cultural adaptation	2

Table 4

Most frequently mentioned recommendations for future mobility participants

Students also identified several recurring challenges that future participants should consider. The most common recommendations concerned realistic financial planning, adapting to cultural differences, overcoming language barriers, managing administrative procedures, and preparing for the initial adjustment period. Many respondents emphasised the importance of conducting thorough research before departure and maintaining an open attitude towards new social and cultural experiences.

Overall, the findings reinforce previous research suggesting that mobility decisions cannot be explained solely by academic considerations. Instead, students evaluate destinations through a combination of educational, financial, social, and lifestyle-related factors. The results also demonstrate that while academic quality remains important, factors associated with everyday life abroad strongly shape both destination choice and overall mobility experience.

5 Discussion

The findings of this study support previous research suggesting that student mobility decisions are inherently multidimensional. While academic considerations remain essential, respondents consistently assigned high importance to practical and lifestyle-related aspects, particularly safety, cost of living, and destination attractiveness. These findings are consistent with the growing body of literature emphasising the influence of non-academic factors on mobility decisions.

An interesting observation is that respondents with previous mobility experience generally reported high levels of satisfaction, especially regarding social life and the destination city. This suggests that successful mobility experiences extend beyond academic outcomes and are shaped by everyday living conditions and social integration.

The qualitative responses reinforce these findings. Students repeatedly emphasised financial preparation, administrative readiness, and openness toward cultural

adaptation, indicating that successful mobility depends not only on institutional factors but also on personal preparedness.

Taken together, the results suggest that universities should provide more holistic mobility guidance that addresses both academic planning and practical aspects of studying abroad.

Conclusion

International student mobility represents a complex decision-making process in which students simultaneously evaluate academic, financial, social, cultural, and personal considerations. The results of this study demonstrate that no single factor determines destination choice; rather, students weigh multiple dimensions before making their decision.

Safety and cost of living emerged as the most influential decision criteria, while destination attractiveness and lifestyle-related characteristics also proved to be highly important. Although academic factors such as course compatibility and institutional quality remain essential, they are only part of a considerably broader decision framework.

The satisfaction results indicate that students generally evaluate their mobility experiences positively, particularly regarding social life, the host city, and their overall experience. The qualitative responses further highlight the importance of adequate preparation, realistic financial expectations, and openness towards cultural adaptation.

These findings suggest that effective mobility guidance should extend beyond providing academic information. Universities and mobility coordinators should also support students in evaluating practical and lifestyle-related aspects of potential destinations, thereby enabling more informed decisions and improving the overall mobility experience.

The present study is limited to students of Óbuda University and therefore cannot be considered representative of all higher education institutions. Future research involving larger and more diverse samples would allow comparisons across universities, disciplines, and countries, providing a broader understanding of the factors influencing international student mobility decisions. Therefore, mobility planning should be understood not only as an academic matching process, but as a broader decision-making challenge involving practical, social, and lifestyle-related expectations.

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Revalorizing Transhumance as a Mediating Mechanism in Experiential and Sustainable Tourism Systems: Evidence from Northern Albania and the Western Balkans

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Abstract: The study revalorizes transhumance as a strategic mechanism for integrating pastoral heritage into experiential and sustainable tourism systems in mountain regions, focusing on Northern Albania within a Western Balkans comparative context. It examines how seasonal livestock mobility generates cultural landscape value, enables place-based co-creation, and reinforces rural resilience in socio-economically restructuring peripheries. Building on Pine and Gilmore’s experience economy and recent sustainable tourism system frameworks, the study proposes an extended conceptual model in which transhumance mediates the relationship between intangible cultural heritage and tourism-driven income diversification. Methodologically, the analysis employs secondary data from official national statistics and international datasets (FAO, World Bank) and combines them with cross-regional comparative analysis. The findings indicate that intangible cultural heritage is positively associated with tourism income diversification. In contrast, transhumance contributes primarily as a territorial and ecological component rather than as the proposed mediating mechanism. The study contributes theoretically by distinguishing the complementary roles of intangible cultural heritage and transhumance within experiential tourism systems and by integrating cultural, ecological, and economic dimensions into a unified analytical framework. It highlights its role in strengthening rural multifunctionality and systemic resilience, offering a transferable framework that aligns cultural heritage valorization, biodiversity conservation, and tourism innovation in mountain regions.

Keywords: Transhumance, Experiential tourism, Sustainable tourism, Rural resilience, Cultural heritage, Western Balkans

1 Introduction

Rural and mountain regions are now central to debates on sustainable tourism. Global tourism demand is shifting toward authentic, nature-based, and experience-driven places. Traditional practices within cultural landscapes are thus more important [1], [2]. Transhumance, the seasonal movement of livestock across mountain landscapes, has emerged as an increasingly important yet insufficiently theorized component of sustainable tourism systems. It ties together cultural heritage, environmental sustainability, and rural economic growth. Recent literature shows that tourism systems are moving from product-based models to experience-based value creation. Authenticity, participation, and cultural involvement now drive competitiveness [3], [4]. Within this perspective, intangible cultural heritage is increasingly conceptualized as a productive territorial resource rather than merely a symbolic cultural asset. Its economic value is well known, but how heritage turns into measurable effects remains unclear. Rural development research also focuses on multifunctionality and diversification to increase resilience in outlying areas [5], [6]. Tourism combines with agriculture and local production to create models such as agrotourism and experiential rural tourism. Transhumance performs both ecological and socio-economic functions within mountain rural systems. They help maintain ecological balance and biodiversity and provide unique experiences for visitors. Despite progress, studies treat transhumance in isolation. They view it as a heritage or ecological practice, not as part of tourism systems. Most work is descriptive or case-based. Few studies offer an organized framework for linking transhumance and income diversification through clear mechanisms [7], [8]. The study addresses this gap by treating transhumance as a mediating part of experiential and sustainable tourism systems. It conceptualizes transhumance as a process through which cultural heritage is transformed into tourism-based economic outcomes. By combining ideas from the experience economy and rural resilience, the study offers a new perspective that integrates culture, ecology, and economics. The focus on Northern Albania and the Western Balkans is appropriate. The region has high agrobiodiversity, strong traditions, and rising tourism demand. It also faces challenges such as weak institutions and migration. These conditions make it ideal for studying how traditional practices fuel development in new tourism systems. The study suggests the following conceptual structure:

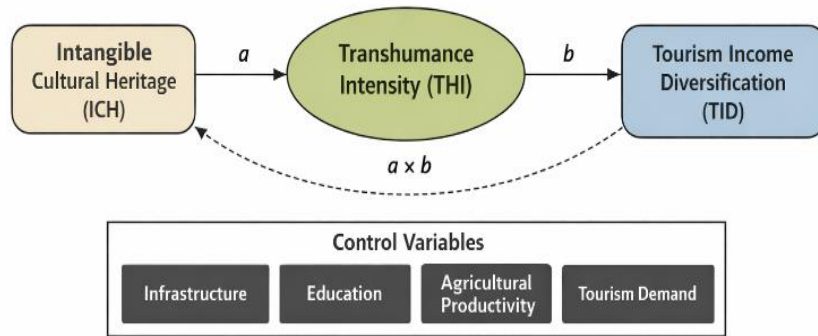


Figure 1
The Conceptual Structure

The study's conceptual model combines several frameworks. Drawing on the experience economy perspective [3], it also incorporates co-creation theory in tourism [4], tourism systems and resilience frameworks [2], [6], and heritage landscape approaches [7], [8]. By combining these frameworks, the model offers a detailed perspective on how intangible cultural heritage yields economic outcomes via mechanisms such as transhumance. Specifically, it spotlights the roles of stakeholder cooperation, knowledge exchange, and community participation in cultural tourism. Based on the proposed conceptual framework, the following hypotheses are formulated.:

- H1:** Intangible cultural heritage positively affects tourism income diversification.
- H2:** Intangible cultural heritage positively influences the intensity of transhumance.
- H3:** Transhumance intensity positively affects tourism income diversification.
- H4:** Transhumance mediates the relationship between intangible cultural heritage and tourism income diversification.
- H5:** The effect of transhumance on tourism income diversification varies with the level of regional tourism development.

Despite the expanding literature on sustainable tourism, cultural heritage, and rural development, three important gaps continue. First, studies usually see intangible cultural heritage as fixed. They focus on its symbolic value, not its role in live economic processes. The ways in which heritage becomes tourism outcomes are often not defined or tested. Second, transhumance is predominantly analyzed within ecological or anthropological frameworks, with limited inclusion in tourism system models. This has led to a fractured understanding of its value as a development mechanism, particularly for income diversification and experiential tourism. Third, few studies use multi-method approaches. Most rely on case or qualitative data,

thereby missing the complexity of rural tourism systems. This limits their range and theory-building. By addressing these gaps, the study advances tourism scholarship by proposing and empirically evaluating an integrated analytical framework linking intangible cultural heritage, transhumance, and tourism income diversification.

2 Literature Review

Recent tourism research increasingly recognizes the convergence of cultural heritage, rural livelihoods, and experiential tourism within integrated territorial development frameworks. Among these, transhumance, the seasonal movement of livestock through ecological gradients, has drawn new scholarly interest as a socio-ecological system. It encourages biodiversity conservation, cultural sustainability, and rural economic diversification.

Recent evidence suggests that transhumance should be understood as an adaptive socio-ecological system rather than as a residual agricultural practice [1], [7]. In mountain areas, it creates landscape diversity, boosting ecosystem services and, in turn, tourism appeal [8]. This is consistent with tourism frameworks, which view destinations as human-natural systems. In these, biodiversity and cultural heritage shape tourist experiences and sustained resilience [1]. In parallel with this ecological perspective, the experience economy paradigm [3], which has been revisited in recent tourism applications, has increasingly been operationalized in rural and peripheral destinations. Tourism demand has shifted toward immersive, authentic, and participatory experiences in which visitors interact directly with local practices and cultural narratives [4], [17]. Within experiential tourism systems, transhumance provides a distinctive platform for value co-creation by connecting visitors with living pastoral traditions. These forms of engagement improve perceived authenticity and affective value, which are key determinants of tourist satisfaction and destination competitiveness [11]. The combination of agriculture and tourism has also been conceptualized through the lens of multifunctionality and rural diversification. Agrotourism and related combined models are increasingly recognized as mechanisms that stabilize rural incomes while preserving traditional practices [13]. Empirical evidence suggests that zones with stronger linkages between agricultural production and tourism services show greater levels of income diversification and reduced vulnerability to external shocks [5]. Within this system, transhumance serves as a bridging mechanism, connecting primary production to experiential consumption and thereby extending the tourism value chain. Despite these advances, the functional role of transhumance within tourism systems remains insufficiently specified in causal terms. Most studies treat it either as a heritage asset or as an ecological practice, without explicitly examining how it converts intangible cultural heritage into marketable tourism experiences and, ultimately, into diversified income streams. Recent tourism systems research increasingly

emphasizes the importance of intermediate mechanisms linking territorial resources to economic outcomes [2], [10]. Accordingly, transhumance is better conceptualized as a potential intermediary process operating within broader tourism value-creation systems. Furthermore, rural resilience has emerged as a central concept in tourism and regional development literature, particularly in the context of socio-economic restructuring and demographic decline in peripheral areas [6], [16]. Resilience is increasingly understood as the capacity of rural systems to adapt, reorganize, and sustain livelihoods in the face of environmental and economic stresses [6]. Tourism is often identified as a key driver of resilience, especially when it is integrated with local resource systems and cultural practices. In this regard, transhumance contributes to resilience by sustaining ecological balance, sustaining cultural identity, and enabling income diversification through tourism-related activities.

In the Western Balkans, and particularly in Northern Albania, these dynamics are especially pronounced. The region is defined by high levels of agrobiodiversity, strong cultural traditions, and emerging tourism development.

Structural challenges such as restricted institutional support, fragmented value chains, and migration pressures constrain the full realization of tourism potential [9], [15]. Within this context, integrating transhumance into tourism systems may strengthen both destination competitiveness and rural resilience. Building on these theoretical perspectives, the study conceptualizes transhumance as a potential mediating mechanism linking intangible cultural heritage with tourism income diversification. It evaluates this proposition empirically using a multi-method econometric framework. By embedding transhumance within the experience economy and rural resilience paradigms, the study helps bridge the gap between cultural-ecological resources and tourism-based development outcomes.

3 Methodology

The study adopts a quantitative multi-method panel econometric framework to examine transhumance as a mediating mechanism linking intangible cultural heritage and tourism income diversification. The analysis is based on a balanced panel of five Western Balkan countries (2015–2025), constructed from harmonized data obtained from the World Bank, FAOSTAT, UNESCO Intangible Cultural Heritage Lists, and national cultural heritage inventories.

Tourism Income Diversification (TID) is specified as the dependent variable and captures the capacity of rural economies to generate tourism-related economic activity. Intangible Cultural Heritage (ICH) is the principal explanatory variable and is operationalized as a composite index that integrates internationally recognized heritage assets and nationally documented cultural heritage indicators.

Transhumance Intensity (THI) is introduced as a mediating variable that reflects the structural importance and continuity of pastoral livestock systems, using FAOSTAT livestock indicators. Control variables include GDP per capita, rural population, agricultural employment, tourism demand, and other macroeconomic characteristics that may influence tourism diversification.

The baseline relationship is estimated using a two-way fixed-effects panel model:

$$TID_{it} = \beta_0 + \beta_1 ICH_{it} + \beta_2 THI_{it} + \beta_3 X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

where TID_{it} denotes tourism income diversification for country i in year t , ICH_{it} represents the Intangible Cultural Heritage Index, THI_{it} denotes the Transhumance Intensity Index, X_{it} is a vector of control variables, μ_i captures unobserved country-specific effects, λ_t represents common time effects, and ε_{it} is the idiosyncratic error term.

The mediating role of transhumance was evaluated using a causal mediation framework by sequentially estimating the relationships. $ICH \rightarrow THI$, $ICH \rightarrow TID$, and $THI \rightarrow TID$. Indirect, direct, and total effects were estimated using bias-corrected bootstrap procedures based on 5,000 resamples.

To evaluate the robustness of the empirical findings, the analysis was complemented by quantile regression, nonlinear panel estimation, and a series of robustness diagnostics. Quantile regression was employed to examine whether the estimated relationships differ across the conditional distribution of tourism income diversification, while potential nonlinear effects were assessed using the following quadratic specification:

$$TID_{it} = \beta_0 + \beta_1 THI_{it} + \beta_2 THI_{it}^2 + \beta_3 X_{it} + \varepsilon_{it} \quad (2)$$

Model robustness was further assessed by testing for heteroskedasticity, serial correlation, and cross-sectional dependence, followed by estimation with Driscoll–Kraay heteroskedasticity- and dependence-consistent standard errors. In addition, a leave-one-country-out sensitivity analysis was performed to verify that no individual country drove the estimated relationships.

The composite Intangible Cultural Heritage (ICH) Index was constructed as a theory-driven, multidimensional index that integrates UNESCO-recognized elements of pastoral heritage with nationally documented heritage indicators. All variables were standardized using z-score normalization prior to aggregation, ensuring cross-country comparability while preserving the multidimensional nature of intangible cultural heritage. The empirical framework combines Principal Component Analysis (PCA), two-way fixed-effects panel estimation, bootstrap mediation analysis (5,000 resamples), quantile regression, nonlinear specification, and complementary robustness analyses. Robustness was further assessed through panel diagnostic tests, Driscoll–Kraay heteroskedasticity- and dependence-consistent standard errors, and leave-one-country-out sensitivity analysis. Although the analysis relies on harmonized international secondary datasets, proxy-based

indicators may not fully capture the complexity of intangible cultural heritage and transhumance. Future research should complement macro-level panel evidence with micro-level surveys and qualitative approaches to provide a more comprehensive assessment of heritage-based tourism development.

4 Results

Prior to the econometric analysis, the ICH, THI, and TID indices were constructed using Principal Component Analysis (PCA). Measurement adequacy was assessed using the Kaiser–Meyer–Olkin (KMO) measure, Bartlett's test of sphericity, Cronbach's alpha, Composite Reliability (CR), and Average Variance Extracted (AVE), with the first principal component retained for each index.

The results indicate satisfactory measurement quality across all three indices. Bartlett's test was highly significant for each construct ($p < 0.001$), confirming that the correlation matrices were appropriate for PCA.

Construct	Indicators	KMO	Bartlett χ^2 (p)	Cronbach α	CR	AVE	Variance Explained
ICH	4 UNESCO pastoral, Transhumance tradition, Historical routes, Pastoral festivals	0.75	427.19 (<0.001)	0.97	0.985	0.941	76.0%
THI	11 livestock, land and pastoral intensity indicators	0.67	1766.76 (<0.001)	0.89	0.913	0.518	52.0%
TID	6 Tourism arrivals, receipts, expenditures and tourism intensity indicators	0.44	503.96 (<0.001)	0.75	0.799	0.557	56.0%

Table 1

Validation of Composite Indices (Standardized using z-score normalization before PCA estimation)

The extracted first principal component explained between 52% and 76% of the total variance. Reliability statistics also exceeded commonly accepted thresholds ($CR > 0.70$; $AVE > 0.50$), with the ICH Index exhibiting particularly strong internal consistency ($CR = 0.985$; $AVE = 0.941$). Although the THI Index produced a comparatively lower KMO value, it remained within the acceptable range for exploratory PCA and demonstrated satisfactory reliability and convergent validity.

Construct	ICH	THI	TID
ICH	0.970	0.172	-0.620
THI	0.172	0.720	0.357
TID	-0.620	0.357	0.746

Table 2
Fornell-Larcker Criterion

The results provide evidence of adequate discriminant validity. For each construct, the square root of the AVE exceeds the corresponding inter-construct correlations, indicating that each index shares more variance with its own indicators than with those of the other constructs. These findings confirm that cultural heritage, transhumance intensity, and tourism income diversification constitute empirically distinct latent dimensions suitable for inclusion in subsequent multivariate analyses.

Indicator	ICH	Indicator	THI	Indicator	TID
UNESCO pastoral	0.94	Goats	0.66	Population	0.92
Transhumance tradition	0.98	Sheep	0.99	Livestock per land	0.78
Historical routes	0.98	Cattle	0.85	Livestock per pasture	0.51
Pastoral festivals	0.98	Agricultural land	0.70	Livestock per rural inhabitant	0.85
		Permanent pastures	0.16	Tourism arrivals	0.76
		Employment in agriculture	0.85	Tourism receipts	-0.57
		Rural population	0.78	Tourism expenditures	0.92
		Population	0.77	Tourism arrivals per capita	0.78
		Livestock per land	0.44	Tourism receipts per capita	0.51
		Livestock per pasture	0.88	Tourism receipts per arrival	0.85
		Livestock per rural inhabitant	0.39		

Table 3
Standardized PCA Loadings

Table 4 reports the descriptive statistics for all variables included in the empirical analysis. The balanced panel comprises 55 country-year observations covering five Western Balkan countries over the period 2015–2025. The standardized composite indices have means close to zero and unit standard deviations, reflecting the normalization inherent in PCA construction while preserving substantial cross-country and intertemporal variation. The remaining variables also display considerable dispersion. GDP per capita ranges from approximately US\$4,200 to

over US\$15,200, agricultural employment ranges from 4.2% to 41.1%, and international tourism arrivals range from fewer than 120,000 to more than 6.4 million annually. Comparable variability is observed for tourism receipts and expenditures, indicating pronounced differences in tourism specialization and economic structure across the Western Balkan countries. The descriptive statistics reveal substantial cross-country and intertemporal heterogeneity across the three composite indices. The Intangible Cultural Heritage (ICH) Index captures variation in the institutional recognition and preservation of pastoral heritage, including UNESCO-recognized pastoral elements, transhumance traditions, historical routes, and pastoral festivals, reflecting the multidimensional role of pastoral heritage in cultural continuity, environmental stewardship, and rural development [7], [14]. The Transhumance Intensity (THI) Index similarly exhibits considerable variation, indicating differences in livestock resources, land use, pasture availability, and agricultural characteristics across the observed countries, consistent with the contemporary understanding of transhumance as an adaptive socio-ecological production system [7], [14].

The Tourism Income Diversification (TID) Index also demonstrates substantial variability, reflecting heterogeneous levels of tourism specialization and tourism-related income generation. Collectively, these descriptive patterns are consistent with integrated tourism system perspectives that emphasize the functional interdependence between cultural heritage, pastoral systems, and tourism development within territorial development processes [2], [10]. While descriptive statistics do not imply causal relationships, the observed variation across the three indices provides an appropriate empirical basis for the subsequent multivariate panel analyses.

Variable	Mean	SD	Minimum	Maximum
Intangible Cultural Heritage Index (ICH)	0.000	1.000	-1.777	2.308
Transhumance Intensity Index (THI)	0.000	1.000	-1.439	1.508
Tourism Income Diversification Index (TID)	0.000	1.000	-1.070	2.666
GDP per capita (US\$)	8,117.0	3,012.5	4,199.5	15,262.0
Employment in agriculture (%)	18.48	11.63	4.19	41.09
International tourism arrivals	1,342,073	1,518,772	118,000	6,406,000
International tourism receipts (US\$)	947,709,091	634,381,532	180,000,000	2,458,000,000
International tourism expenditures (US\$)	600,618,182	664,746,610	38,000,000	2,000,000,000

Table 4
Descriptive Statistics of the Study Variables

Overall, the validation results and descriptive evidence support the use of the three composite indices in the subsequent empirical analysis. Their measurement properties and observed variation across countries and time provide an appropriate basis for examining the hypothesized associations among intangible cultural heritage, transhumance intensity, and tourism income diversification.

4.1 Correlation Structure and Preliminary Relationships

The Pearson correlation coefficients among the principal variables included in the empirical analysis are presented. The correlation matrix indicates statistically significant linear associations among several variables and provides no preliminary evidence of severe multicollinearity. The strongest positive correlation is observed between the Transhumance Intensity Index (THI) and agricultural employment ($r = 0.850$, $p < 0.001$), reflecting the structural linkage between pastoral production systems and agricultural labor allocation in mountain rural economies. Comparable relationships between livestock-based production systems and agricultural employment have been documented in previous studies of pastoral and mountain regions [7], [14].

Variable	1	2	3	4	5	VIF
1. ICH	1.000					2.20
2. THI	0.172	1.000				5.27
3. TID	−0.620***	0.357**	1.000			—
4. GDP per capita	0.608***	−0.185	−0.270*	1.000		1.83
5. Employment in agriculture	−0.127	0.850***	0.550***	−0.347**	1.000	5.08

Table 5
Pearson Correlation Matrix and Variance Inflation Factors

The Tourism Income Diversification (TID) Index is positively correlated with THI ($r = 0.357$, $p < 0.01$) and with agricultural employment ($r = 0.550$, $p < 0.001$), indicating that territories with stronger pastoral production systems also tend to exhibit higher levels of tourism-related income diversification. Conversely, the ICH Index is negatively associated with TID ($r = -0.620$, $p < 0.001$) and positively associated with GDP per capita ($r = 0.608$, $p < 0.001$). These bivariate relationships are consistent with recent studies emphasizing the multidimensional interactions among cultural heritage, rural economic structures, and tourism development [2], [10], [14].

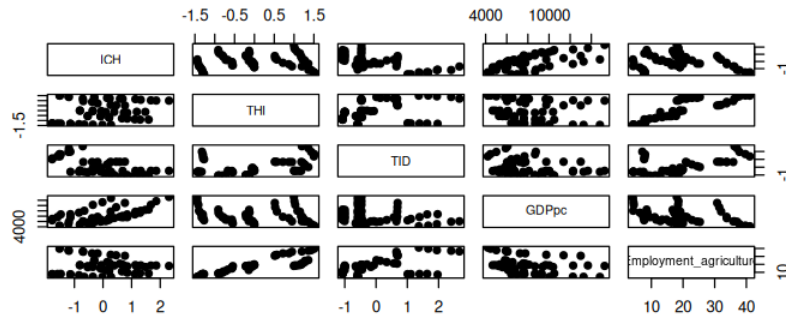


Figure 2
The Correlation Matrix and Variance Inflation Factors

Because correlation coefficients alone are insufficient for assessing multicollinearity, additional diagnostic tests were performed using the Variance Inflation Factor (VIF). The estimated VIF values range from 1.83 to 5.27, remaining below the critical threshold. They are well within the range generally considered acceptable for a multivariate regression model.

Although THI and employment in agriculture exhibit comparatively high VIF values, these variables represent theoretically distinct constructs and were therefore retained in the empirical specification. Overall, the correlation structure and multicollinearity diagnostics indicate that the explanatory variables satisfy the assumptions required for the subsequent panel econometric analysis.

4.2 Mediation Analysis: Mechanism Validation

To examine whether transhumance intensity serves as the mechanism linking intangible pastoral heritage to tourism income diversification, a regression-based mediation analysis was conducted, followed by a nonparametric bootstrap procedure with 5,000 resamples. The analysis estimated the direct and indirect effects of the (ICH) Index on the (TID) Index through the (THI) Index. Statistical inference for the indirect effect was based on bias-corrected and accelerated (BCa) bootstrap confidence intervals, which provide robust estimates without relying on the normality assumption of the sampling distribution of mediation effects.

Path	β	SE	t	p-value
ICH $\rightarrow$ THI (a)	-0.001	0.255	-0.005	0.996
THI $\rightarrow$ TID (b)	0.271	0.400	0.678	0.502
ICH $\rightarrow$ TID (c')	1.864	0.621	3.003	0.005

Table 6
Estimated Mediation Paths

The estimated mediation paths indicate that the proposed transmission mechanism is not supported. The association between intangible pastoral heritage and transhumance intensity is not statistically significant. In contrast, transhumance intensity is not significantly associated with tourism income diversification after controlling for intangible cultural heritage and the remaining covariates. In contrast, the direct relationship between intangible pastoral heritage and tourism income diversification remains statistically significant, providing preliminary evidence that pastoral heritage's contribution to tourism development operates independently of changes in transhumance intensity.

Effect	Estimate	95% BCa Cf Interval	Interpretation
Indirect effect (ICH → THI → TID)	−0.0003	−0.351 to 0.405	Not significant
Direct effect (ICH → TID)	1.864	0.107 to 3.157	Significant
Total effect	1.863	0.318 to 3.083	Significant

Table 6

Mediation Analysis Effects (5,000 Bootstrap Replications)

The bootstrap results indicate that transhumance intensity does not mediate the relationship between intangible pastoral heritage and tourism income diversification, as the indirect effect is statistically indistinguishable from zero.

Conversely, the direct effect remains significant, indicating that the economic contribution of pastoral cultural heritage operates independently of transhumance intensity. These findings suggest that heritage contributes to tourism diversification primarily through cultural valorization, destination attractiveness, and experiential tourism rather than through changes in pastoral production intensity, consistent with recent heritage-tourism literature [7], [10], [14].

From a theoretical perspective, the results distinguish cultural heritage from productive pastoral systems, indicating that they constitute complementary but empirically distinct dimensions of mountain rural development [2], [7], [14].

4.3 Robustness Analysis

To evaluate the stability of the estimated relationships, several complementary robustness analyses were conducted. Specifically, the empirical findings were examined using quantile regression, nonlinear panel estimation, panel diagnostic tests, Driscoll–Kraay robust standard errors, and leave-one-country-out sensitivity analysis. Together, these procedures assess whether the principal results remain consistent across alternative model specifications, different segments of the conditional distribution of tourism income diversification, and corrections for

common panel-data violations. The robustness analyses consistently support the principal empirical conclusions. Quantile regression demonstrates that the association between transhumance intensity and tourism income diversification varies across the conditional distribution of the dependent variable, with larger estimated coefficients observed at higher quantiles ($\beta = 0.229\text{--}0.343$). At the same time, the effect of the Intangible Cultural Heritage Index becomes progressively stronger across quantiles, suggesting that heritage-related resources contribute differently according to the level of tourism diversification.

The nonlinear specification provides no evidence of quadratic effects (THI^2 : $\beta = 0.164$, $p = 0.502$), indicating that the linear model adequately represents the relationship between transhumance intensity and tourism income diversification within the observed sample.

Consequently, the baseline specification does not appear to suffer from functional-form misspecification. Panel diagnostic procedures reveal the presence of heteroskedasticity (Breusch–Pagan: $\text{BP} = 10.655$, $p = 0.031$), serial correlation (Wooldridge: $\chi^2 = 27.773$, $p = 0.004$), and cross-sectional dependence (Pesaran CD: $z = -2.270$, $p = 0.023$).

To account for these violations, the principal fixed-effects model was re-estimated using Driscoll–Kraay heteroskedasticity- and dependence-consistent standard errors. The statistical significance and direction of the principal coefficients remained unchanged: the Intangible Cultural Heritage Index remained positively associated with tourism income diversification ($\beta = 1.864$, $p < 0.001$). In contrast, Transhumance Intensity continued to exhibit no statistically significant direct effect ($\beta = 0.271$, $p = 0.258$). These findings indicate that violations of conventional panel-data assumptions do not drive the principal conclusions.

Analysis	Main result	Interpretation
Quantile regression ($\tau = 0.25, 0.50, 0.75$)	THI positive across all quantiles ($\beta = 0.229\text{--}0.343$); ICH negative and increasing in magnitude ($\beta = -0.600$ to -1.079)	The association varies across the conditional distribution of tourism income diversification, indicating heterogeneous effects.
Nonlinear specification	$\text{THI}^2 = 0.164$ ($p = 0.502$)	No evidence of nonlinear effects; the linear specification adequately captures the relationship.
Breusch–Pagan test	$\text{BP} = 10.655$ ($p = 0.031$)	Heteroskedasticity detected.
Wooldridge test	$\chi^2 = 27.773$ ($p = 0.004$)	Serial correlation detected.
Pesaran CD test	$z = -2.270$ ($p = 0.023$)	Cross-sectional dependence detected.
Driscoll–Kraay estimation	ICH $\beta = 1.864$ ($p < 0.001$); THI $\beta = 0.271$ ($p = 0.258$); GDPpc $\beta = -0.00019$ ($p = 0.002$);	Core conclusions remain robust after correcting for panel dependence.

	Employment $\beta = -0.053$ ($p = 0.010$)	
Hausman test	$\chi^2 = 1.453$ ($p = 0.835$)	Random effects could not be statistically rejected; two-way fixed effects were nevertheless retained to control for unobserved country- and time-specific heterogeneity.
Leave-one-country-out	ICH remained positive in all specifications and statistically significant in four of the five estimations	No single country drives the principal findings.

Table 7
Robustness analyses

This pattern is consistent with the mediation analysis and suggests that tourism income diversification is primarily associated with heritage-related cultural resources rather than with differences in pastoral production intensity. Collectively, the robustness analyses provide additional support for the reliability of the empirical findings and strengthen the credibility of the proposed conceptual framework.

5 Discussion

The findings suggest that intangible pastoral heritage represents an economically relevant territorial resource within rural tourism systems, extending its role beyond cultural preservation toward tourism-related value creation.

Empirical evidence suggests that intangible pastoral heritage functions as a territorial development resource whose economic relevance emerges primarily through cultural differentiation rather than through pastoral production itself. This interpretation is consistent with recent tourism research that conceptualizes heritage as an active component of tourism systems rather than solely as a cultural asset [2], [10].

Contrary to the proposed mediation hypothesis, the results indicate that transhumance intensity is not the principal mechanism by which intangible pastoral heritage is associated with tourism income diversification. Although transhumance remains an important component of mountain pastoral systems, its contribution appears to be primarily structural rather than mediating. These findings suggest that cultural heritage and pastoral production represent complementary, yet analytically distinct, dimensions of rural tourism development. While heritage is more closely associated with tourism diversification through cultural valorization and experiential tourism, transhumance appears to provide the territorial and ecological context in which these cultural assets are maintained. This interpretation extends

previous studies that have generally examined both concepts jointly without distinguishing their respective economic functions [7], [14]. From a systems perspective, the results are consistent with the proposition that tourism development emerges from interactions among cultural, ecological, and economic subsystems rather than from isolated sectoral dynamics. Such an interpretation aligns with tourism systems theory, which emphasizes interdependence, adaptive processes, and multifunctionality in destination development [6]. Within this framework, traditional pastoral practices can be viewed as components of broader territorial systems whose contribution depends on their integration with tourism markets, institutional arrangements, and local governance rather than on pastoral production alone.

The robustness analyses further reinforce the proposed framework's consistency. The stability of the principal findings across alternative model specifications, distributional assumptions, robust estimators, and sensitivity analyses indicates that the estimated relationships are not driven by model specification or by any single country in the sample. This methodological consistency aligns with recent recommendations for multi-method validation in tourism research and strengthens the empirical credibility of the proposed analytical framework [2].

Overall, the study contributes to the tourism literature by distinguishing the respective roles of intangible cultural heritage and transhumance within mountain rural tourism systems. Rather than suggesting that transhumance constitutes the principal transmission mechanism, the findings indicate that heritage-based tourism development is more closely associated with the direct valorization of cultural resources. At the same time, pastoral production provides an enabling territorial context.

This perspective supports more integrated and process-oriented approaches to rural tourism development, emphasizing the interaction among cultural heritage, pastoral landscapes, and institutional capacity to promote sustainable tourism systems [7], [10].

Conclusions

The study examined the relationships among intangible pastoral heritage, transhumance intensity, and tourism income diversification in mountainous rural systems of the Western Balkans using an integrated panel econometric framework. The findings indicate that intangible pastoral heritage is consistently associated with greater diversification of tourism income, supporting the view that cultural heritage is an economically relevant territorial resource in rural tourism systems rather than solely a cultural or symbolic asset. Contrary to the proposed mediation hypothesis, the empirical evidence does not support the claim that transhumance intensity is the principal mechanism linking intangible cultural heritage to tourism income diversification. Instead, the findings suggest that pastoral heritage and transhumance perform complementary but distinct functions within mountainous

rural systems. While cultural heritage appears to be more directly associated with tourism diversification through heritage valorization and experiential tourism, transhumance primarily reflects the productive and ecological characteristics of pastoral landscapes that sustain these cultural assets. Robustness analyses further strengthen these conclusions. The consistency of the estimated relationships across quantile regression, nonlinear specification, panel diagnostic corrections, Driscoll–Kraay estimation, and leave-one-country-out sensitivity analysis indicates that the principal findings remain stable under alternative model specifications and estimation procedures. Collectively, these results increase confidence in the empirical validity of the proposed analytical framework.

From a theoretical perspective, the study contributes to tourism literature by distinguishing the respective roles of intangible cultural heritage and transhumance within rural tourism systems. Rather than conceptualizing both dimensions as a single development mechanism, the findings suggest that heritage-related cultural resources and pastoral production systems influence tourism development through different yet complementary pathways.

This perspective extends existing research by integrating cultural, ecological, and economic dimensions into a unified systems framework and provides empirical evidence from rural mountain destinations. The findings also have practical implications for rural development policy. Strategies aimed at strengthening tourism diversification should prioritize the conservation, interpretation, and promotion of intangible pastoral heritage alongside the sustainable management of pastoral landscapes.

Policies that integrate heritage conservation with tourism planning, cultural routes, experiential tourism products, and community-based initiatives may provide greater opportunities for strengthening the resilience and competitiveness of mountain rural destinations.

Several limitations should be acknowledged. The analysis relies on harmonized secondary international datasets and proxy-based composite indicators, which cannot fully capture the social, institutional, and experiential complexity of pastoral heritage and transhumance. Future research should combine macro-level panel evidence with micro-level household- or destination-level data and comparative case studies to further investigate the mechanisms by which heritage resources contribute to tourism development across different territorial contexts.

Overall, the study supports a more integrated understanding of sustainable rural tourism by demonstrating that intangible pastoral heritage is a strategic territorial asset for diversifying tourism income. At the same time, transhumance provides an important territorial context rather than the dominant transmission mechanism. The study contributes to tourism scholarship by demonstrating that intangible pastoral heritage and transhumance represent complementary rather than interchangeable components of sustainable mountain tourism systems. Distinguishing their respective functions provides a more precise explanation of how cultural resources

contribute to tourism income diversification and offers a transferable analytical framework for future research on heritage-based tourism development.

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The Role of Trust Among University Students

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Abstract: The rapid pace of change in recent decades has led to significant transformations in the educational environment. This has encompassed institutional changes, as well as individuals' ability to adapt and the confidence placed in them. Based on the analysis of a questionnaire completed by 46 respondents, this study draws conclusions regarding the extent to which university students' trust in the institution and in one another is changing and how it is evolving. Based on this, it can be said that trust in the degree remains very high among students. Although a similar survey conducted in 2013 yielded slightly lower trust scores, this may be because that survey surveyed Hungarian students, whereas this survey primarily surveyed international students. The baseline trust, which may influence other factors, is likely the level of trust in people. When compared via correlation with other trust levels, it showed no significant result, as it is practically impossible to demonstrate a correlation between the two. Thus, it showed no connection with either institutional or general levels of trust in people.

Keywords: Trust, Education, university, institutions

1 Introduction

The rapid pace of change in recent decades has led to significant transformations in the educational environment. This has encompassed institutional changes, as well as individuals' ability to adapt and the confidence placed in them [1]. The global economic crisis of 2008 and the 2019–2020 COVID-19 pandemic have altered trust in colleges and social institutions and its level [2]. However, the level of trust is not influenced solely by the changing environment. Researchers have identified 37 characteristics that may influence the level and extent of trust. These characteristics contribute to both the acquisition and loss of trust. These characteristics can be categorized into Competence, Integrity, Affinity, and Non-personal factors. Traits such as cooperative and ethical behavior, academic skills, and higher grades are more common factors in building trust; that is, those who possess them appear in a better light in the eyes of others [3]. The definition of trust leads us in several directions. There is no consensus in the literature regarding the definition of trust. One definition follows the network model. According to this, trust can emerge in

shared social environments, institutions, or spaces where participants expect and hold others accountable for behaving in accordance with expectations. According to this definition, “trust exists not so much as a relationship between two individuals (who already know each other), but as a possibility between individuals insofar as they share and interact within a common social environment, institution, or space.” According to this definition, if students and teachers participate in shared programs that are meaningful to both of them, then trust between them can be built and strengthened [4]. Another definition is the belief-based approach, which can be traced back to Kumar’s 1996 work. According to him, trust is synonymous with reliability. Two main approaches can be identified: the trust-based and the risk-based perspectives. Kumar (1996) argues that trust can be stronger than fear, and therefore companies where parties trust one another generate higher profits, serve customers better, and are more adaptable [5]. According to Doney et al. (1998), trust is the sum of belief and expectations. It also involves the intention that the parties will act accordingly. Based on their findings, trust can reduce certain types of costs, helps build relationships between different partners, and can improve the quality of the relationship between managers and their subordinates [6]. According to the risk-based approach, as described by Das-Teng (2004), trust is a positive belief in the other party’s behavior, such that the other party will not act opportunistically should circumstances change in any way. Trust is risk-taking. It is related to risk-taking and willingness. When an individual perceives low risk, they are willing to approach the other party with trust [7]. Very often, an individual trusts another if the latter fulfills their obligations [8]. When we look at universities, the presence of trust has several positive effects. It fosters cooperation, raises standards, and increases motivation toward an academic career. Students’ trust in faculty and university administration has a positive and strong correlation with the fulfillment of their expectations regarding higher education—that is, with their level of satisfaction. However, the relationship is inverse with regard to their academic performance. Trust in teachers does not decline upon graduation [9,10]. The results show that skepticism and congruence significantly influence students’ level of trust, their social engagement, and their sense of social responsibility [11]. There is an inverse relationship between student loyalty and dropout rates. There is also a correlation between student trust and the university’s reputation; that is, dropout rates are lower at universities with a better reputation. Community projects, environmental sustainability programs, and a commitment to social causes can significantly contribute to improving an organization’s reputation [12]. Students’ trust in their peers is strongly linked to how much they identify with their school. It shows a strong, though weaker, correlation with their motivation to learn. These correlations persist even when teachers support them [13].

2 Data and methodology

We conducted a questionnaire survey at the Keleti Károly Faculty of Economics at Óbuda University, which concluded on April 22, 2026. The questionnaire was completed by 46 students. In addition to using simple statistical methods, the analysis sought to identify relationships between variables, including the calculation of correlations.

3 Results

About half of the respondents were men and the other half were women. The average age of the respondents was 21.5 years. The average level of trust in people was 5.18, which is slightly above average. If the respondent knows the other person personally, the level of trust rises to 7.6. In terms of educational background, 71% do not have a degree, meaning they are enrolled in an undergraduate program, while the rest are pursuing a master's degree. The group consists mostly of international students.

Gender
46 válasz

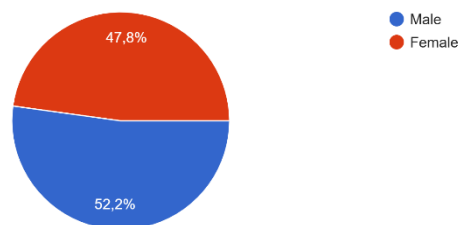


Figure 1
Gender distribution

Students trust the university the most, although it is unclear whether respondents were concerned that the survey was not anonymous, and thus how honest they were. The level of trust in institutions is low. Students trust the media the least, and overall, trust in institutions is below average—very low.

	Survey of Óbuda University	Results in 2013	Dif
Parliament	2,78	2,21	0,57
Police	3,01	2,63	0,38
Civil service	2,94	2,18	0,76
The courts	3,10	2,65	0,45
Political parties	2,07	1,9	0,17
The armed forces	2,84	2,6	0,24
The civil service	2,81	2,19	0,62
The media	1,91		
The banks	2,61	2,04	0,57
Major companies	2,74		
University	3,60	3,2	0,40

Table 1:
Levels of Trust in 2026 and 2013. Source: own survey and Fábri (2018) [14]

When it came to the questions regarding levels of trust in various actors, a very mixed picture emerged.

The government spends too much on higher education.	2,25
College/ University students protest and argue too much; they should be studying instead.	2,34
You can't get into college, university if you come from a family with limited financial means.	2,45
Only people with a degree should be allowed to hold leadership positions.	2,59
Young people should learn a trade/profession rather than try to go to college/university.	2,61
College/ University graduates are more valuable members of society than those with lower levels of education.	2,77
Anyone who earned a degree with state funding should be required to work in Hungary for at least as long as the duration of their university studies after graduation.	2,80
It is easier to find a job today with a degree than without one.	3,05
First, the economy must improve; then we can spend more on higher education.	3,05
The unemployment rate is particularly high among graduates.	3,09
There are too many college/university graduates because many people do not want to do manual labor.	3,14
Graduates look down on those with lower levels of education.	3,16
A college/university graduate should earn significantly more than someone with a lower level of education.	3,25
There should be more college graduates, because they are the ones who will drive the country forward.	3,48
Today, many graduates are doing jobs that don't even require a degree.	3,59
Higher education improves Hungary's reputation around the world.	3,64
The economy will improve if more is spent on higher education first	3,66
A degree often doesn't reflect real knowledge. Many people just get a piece of paper in higher education.	3,66

Table 2
Level of Trust in 2026. Source: own survey

Students are less confident about the future, but they agreed that the government should focus more on training, as investing in education will have long-term positive effects on the economy as well.

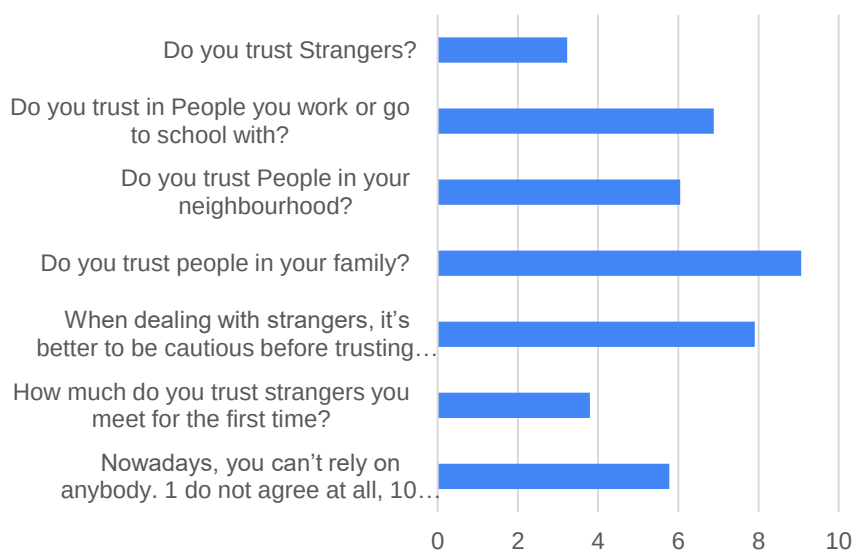


Figure 2
Trust issues

The second figure shows that the closer the familiarity, the higher the level of trust.

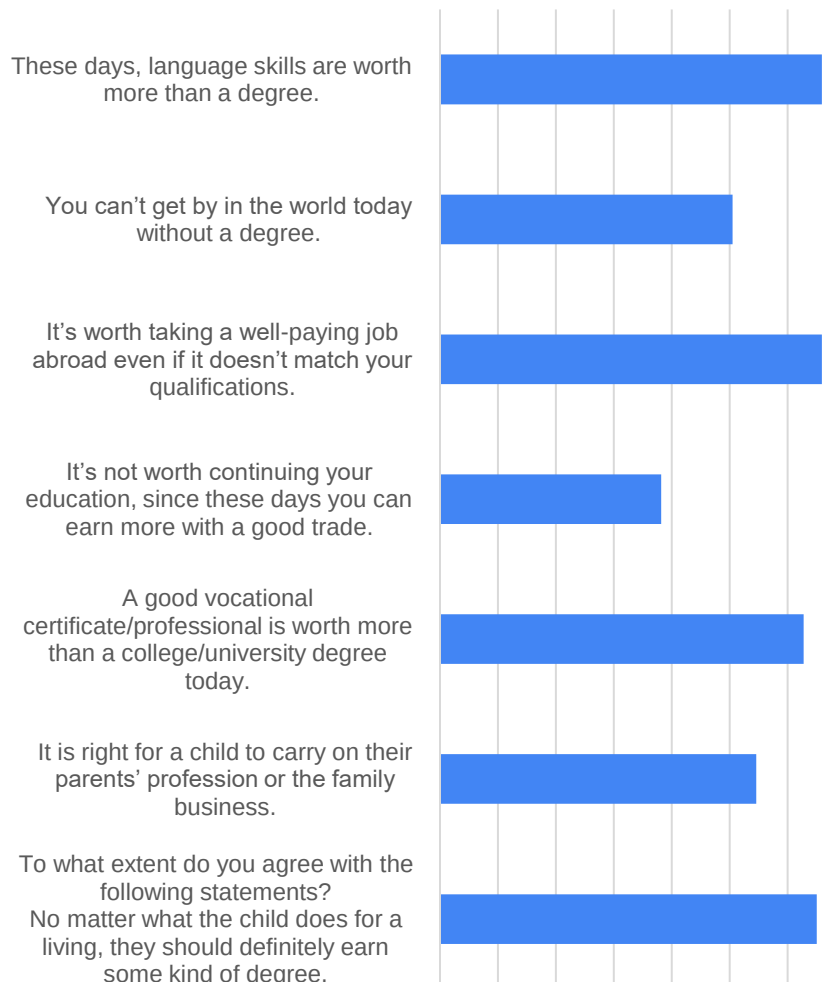


Figure 3
Trust issues II

It can be said that confidence in the degree remains very high among students. Although a similar survey conducted in 2013 yielded slightly lower confidence scores, this may be because that survey surveyed Hungarian students, whereas this survey primarily surveyed international students. The baseline level of trust, which may influence other factors, is likely the level of trust in people. When compared via correlation with other trust levels, it did not yield any results, as it is practically impossible to demonstrate a correlation between the two. Thus, it showed no connection with either institutional or general levels of trust in people.

Conclusions

The following findings stand out from the survey.

- Trust has improved compared to the previous survey
- This is partly because the previous survey was typically Hungarian, whereas this one was international.
- People trust family members more than strangers
- There is no universal truth when it comes to higher education. In some cases it is valuable; in others, it is not.
- There is no correlation between trust in institution and trust in people general

According to this definition, if students and teachers participate in joint programs that are meaningful to both of them, trust between them can be built and strengthened [4]. Such joint activities include joint classes and off-campus programs, which strengthen the teacher-student relationship and the students' level of trust. It is recommended that instructors organize and participate in such programs and show interest in their students, which also strengthens student trust. According to Kumar (1996), a key advocate of the trust-based principle, trust is interpreted as reliability. Teachers and the university, insofar as they demonstrate reliability, also strengthen student trust. This includes maintaining high standards in the classroom, providing assistance, and keeping the promises they make [5]. When an individual perceives low risk, they are willing to approach the other party with trust [7]. This is how predictability is demonstrated to students—that is, by establishing a set of expectations that is clearly communicated and published in advance, as well as by setting expectations that students believe they can meet. Very often, an individual trusts another person if the latter fulfills their obligations [8].

So these steps are certainly important for building student trust. Students' trust in their peers is closely linked to the extent to which they identify with their school. In other words, it is necessary to define common goals that students believe in and are willing to follow [13].

Acknowledgement

Thank you to the students for completing the survey.

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From Fragmentation to Systems: A Configurational Perspective on HRM and Organizational Performance

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Abstract: Research in the field of human resource management (HRM) highlights a significant relationship between human resource management practices and organizational performance; however, it also emphasizes the persistent fragmentation of knowledge and the insufficient explanation of the mechanisms through which these relationships operate. Existing studies focus on isolated practices or partial models, leading to ambiguous results. The aim of the paper is to conceptualize and empirically substantiate a comprehensive model of relationships between human resource management practices, mediating variables, and organizational performance based on the analysis of their configurations and mutual relationships, with implications for its further modeling. The model is developed based on a theoretical literature review and verified using a combined research approach. A sample of 450 respondents from Slovakia, the Czech Republic, and Poland is used. Spearman correlation analysis in the form of correlation heatmaps is conducted to verify the strength and direction of relationships among individual constructs of the model. Fuzzy-set Qualitative Comparative Analysis is applied to identify configurations of HRM practices and mediating variables that lead to higher organizational performance. The results indicate multiple configurations of HRM practices and mediating variables associated with higher organizational performance, while statistically significant relationships confirmed their mutual interconnections. These findings suggest the theoretical and empirical coherence of the model and provide a basis for its further testing using advanced analytical approaches, particularly PLS-SEM. The paper emphasizes the importance of systematic model verification prior to its application in complex analyses and contributes to a better understanding of HRM as an integrated system.

Keywords: HRM practices, organizational performance, V4

1 Introduction

The relationship between human resource management practices (HRMP) and organizational performance represents one of the key research areas in strategic human resource management (SHRM). Existing studies confirm that effective HRMP positively influence employee behavior, organizational effectiveness, and long-term organizational outcomes [1]. At the same time, organizations increasingly perceive human capital as a strategic source of competitive advantage and sustainable performance [2].

Despite extensive empirical research, the HRM–performance relationship remains fragmented and inconsistent. Previous studies frequently focus on isolated HR practices or partial explanatory models, resulting in insufficient understanding of the mechanisms through which HRMP influence organizational performance. This issue is commonly described as the “HRM black box” [3]. Recent literature therefore emphasizes the need to examine HRM as an integrated system rather than a collection of independent managerial practices.

One of the most influential approaches in this context is the Ability–Motivation–Opportunity (AMO) framework, which explains organizational performance through employee abilities, motivation, and opportunities for participation [4]. Simultaneously, contemporary studies highlight the importance of mediating organizational mechanisms, particularly organizational strategy, work engagement, and open innovation, in explaining the relationship between HRMP and organizational outcomes [5, 6, 7].

The aim of this paper is to conceptualize and empirically validate a comprehensive model of relationships between AMO-based HR practices, mediating organizational mechanisms, and sustainable organizational performance. The study uses data collected from organizations operating in Slovakia, the Czech Republic, and Poland (N = 450). The proposed model is verified using fuzzy-set Qualitative Comparative Analysis (fsQCA) and Spearman correlation analysis to identify configurations of HRMP and mediating variables associated with higher sustainable organizational performance.

The theoretical contribution of this study is threefold. First, it advances the configurational perspective in strategic HRM by conceptualizing HRM as an integrated system rather than a collection of isolated practices. Second, it extends the AMO framework by incorporating organizational strategy, work engagement, and open innovation into a single conceptual model explaining sustainable organizational performance. Third, it provides an empirically supported foundation for future causal testing of this integrated model using PLS-SEM and other structural approaches.

2 Literature review

Strategic human resource management research increasingly emphasizes that human resource management practices (HRMP) should be understood as integrated organizational systems rather than isolated managerial activities. Existing studies indicate that effective HRMP positively influence employee satisfaction, productivity, organizational commitment, and overall organizational performance [1]. At the same time, organizations increasingly perceive human capital as a strategic source of competitive advantage, long-term adaptability, and organizational sustainability [2]. However, despite extensive empirical research, findings regarding the HRM–performance relationship remain fragmented and inconsistent because many studies examine individual HR practices separately and use different conceptualizations of organizational performance [8].

Contemporary literature therefore highlights the need to examine HRM from a systemic and configurational perspective. According to [9], HRMP influence organizational outcomes primarily through implementation processes that shape employee attitudes and behavior, rather than through formal HR policies alone. Similarly, [10] emphasize that the effectiveness of HR systems depends not only on the existence of HR practices but also on how employees perceive and interpret them within organizational environments. These findings support the argument that HRMP should be examined as interconnected systems operating through multiple organizational mechanisms.

One of the most influential frameworks explaining these mechanisms is the Ability–Motivation–Opportunity (AMO) model. The AMO framework assumes that organizational performance is enhanced when employees possess the required abilities, sufficient motivation, and opportunities to participate in organizational processes [4]. Ability-enhancing HR practices are associated primarily with recruitment, training, and employee development, while motivation-enhancing practices include compensation systems, performance appraisal, and recognition mechanisms. Opportunity-enhancing practices focus on employee participation, communication, autonomy, and knowledge sharing. Previous studies indicate that AMO-oriented HR systems positively influence organizational effectiveness, employee well-being, and innovative work behavior [11,12].

Research further suggests that AMO-oriented HR practices contribute to organizational outcomes through several mediating organizational mechanisms. One of the most significant mechanisms is organizational strategy. [13] argue that HR systems become strategically effective when they are aligned with organizational goals and long-term priorities. Strategic alignment enables organizations to transform employee competencies and motivation into sustainable organizational outcomes. In this context, previous studies suggest positive relationships between AMO-oriented HR practices and organizational strategy, as well as between organizational strategy and organizational performance.

Another important mediating mechanism is work engagement. [5] identifies work engagement as a key behavioral mechanism explaining how HR systems influence employee and organizational outcomes. HR practices focused on employee development, recognition, and participation create conditions that increase employees' psychological involvement in work processes. [14] further demonstrate that sustainable HRMP positively affect employee resilience and engagement, which subsequently contribute to stronger organizational performance outcomes. Consequently, work engagement represents an important explanatory mechanism within the HRM–performance relationship.

The literature also increasingly highlights the importance of open innovation in explaining organizational performance. Open innovation refers to organizational processes supporting knowledge sharing, collaboration, and the integration of internal and external innovation resources. [15] argue that collaborative HRMP strengthen knowledge-sharing processes and innovation-oriented organizational climates. Similarly, [7] emphasize that HR systems supporting collaboration and employee participation positively influence organizational innovation capability and adaptability. Therefore, open innovation may represent another important mechanism connecting AMO-oriented HR systems and sustainable organizational performance.

Existing strategic human resource management research extensively examines the relationship between human resource management practices (HRMP) and organizational performance [16,17,18,1]. Previous studies either focus on individual HR practices or examine HRM systems as interconnected organizational mechanisms. At the same time, organizational performance is increasingly conceptualized as a multidimensional construct that includes financial, sustainable, and innovation-oriented dimensions [19,7,20,11].

Recent literature also highlights the importance of mediating organizational mechanisms, particularly organizational strategy, work engagement, and open innovation, in explaining the HRM–performance relationship [22,23,5,24]. However, despite extensive empirical evidence, existing research remains fragmented because most studies examine these mechanisms separately and rarely capture the synergistic effects of integrated HRM systems. Therefore, a research gap can be identified in the absence of an integrated configurational approach examining the relationships between AMO-based HR practices, organizational strategy, work engagement, open innovation, and sustainable organizational performance simultaneously. This study addresses this gap by proposing and empirically validating a comprehensive configurational model of these relationships.

Based on the identified research gap, this study adopts a configurational perspective and assumes that sustainable organizational performance results from combinations of AMO-oriented HR practices, organizational strategy, work engagement, and open innovation. This assumption is consistent with previous studies emphasizing

the importance of integrated HR systems and mediating organizational mechanisms in explaining organizational outcomes [9,25].

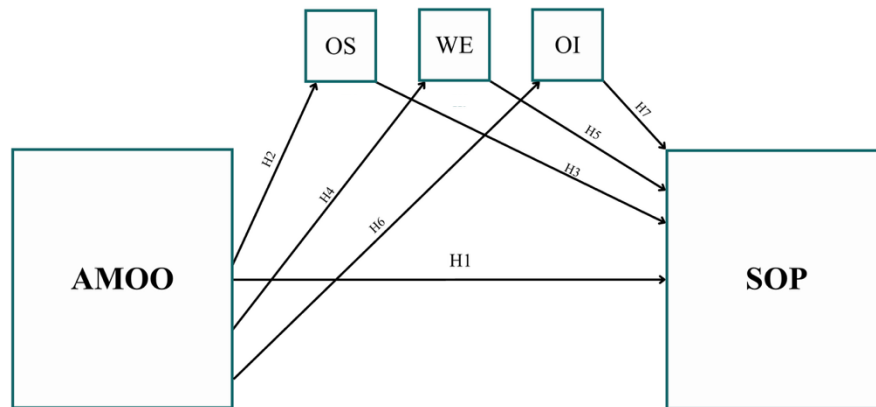


Figure 1
Hypothesis model

Accordingly, the following hypotheses are proposed:

H1: AMO-oriented HR practices are positively related to sustainable organizational performance.

H2: AMO-oriented HR practices are positively related to organizational strategy.

H3: Organizational strategy is positively related to sustainable organizational performance.

H4: AMO-oriented HR practices are positively related to work engagement.

H5: Work engagement is positively related to sustainable organizational performance.

H6: AMO-oriented HR practices are positively related to open innovation.

H7: Open innovation is positively related to sustainable organizational performance.

3 Methodology

The study employed a quantitative research design focused on examining the relationships between AMO-based human resource management practices, mediating organizational mechanisms, and sustainable organizational performance.

The proposed conceptual model was developed based on the configurational perspective and the assumptions of the Ability–Motivation–Opportunity (AMO) framework. The model integrates AMO-oriented HR practices with organizational strategy, work engagement, and open innovation as mediating variables influencing sustainable organizational performance.

Data collection was conducted using a questionnaire survey administered to medium-sized and large organizations operating in Slovakia, the Czech Republic, and Poland. The final research sample consisted of 450 respondents representing organizations from different sectors and industries. The selection of the examined countries was based on their comparable economic and organizational environments within the Central European context. The questionnaire structure and operationalization of variables were derived from previous strategic human resource management research and adapted to the objectives of the study. Individual constructs within the model included AMO-oriented HR practices, organizational strategy, work engagement, open innovation, and sustainable organizational performance. The variables were measured using standardized Likert-scale items reflecting employees' and managers' perceptions of organizational HR systems and organizational outcomes.

Spearman correlation analysis was conducted to examine the strength and direction of relationships among the individual constructs of the proposed model. Correlation heatmaps were additionally used to visualize the relationships between AMO-oriented HR practices, organizational strategy, work engagement, open innovation, and sustainable organizational performance across the examined countries. The use of Spearman correlation analysis was appropriate due to the non-parametric character of the data and the exploratory nature of the study [26]. To verify the conceptual coherence of the proposed model, the study applied a combined analytical approach. First, fuzzy-set Qualitative Comparative Analysis (fsQCA) was used to identify configurations of AMO-oriented HR practices and mediating organizational mechanisms associated with higher sustainable organizational performance. The configurational approach was selected because it enables the identification of multiple causal pathways leading to similar organizational outcomes and is consistent with the assumption that organizational performance results from combinations of interconnected organizational conditions rather than isolated variables [27].

The proposed conceptual model and the analytical procedure were intended to provide empirical support for the configurational relationships between HRMP and sustainable organizational performance and to establish a foundation for future advanced model testing using structural equation modeling approaches, particularly PLS-SEM.

4 Results and discussion

4.1 Correlation Analysis

The first part of the analysis focused on examining the relationships between AMO-oriented HR practices, organizational strategy, work engagement, open innovation, and sustainable organizational performance using Spearman correlation analysis. Due to the non-parametric character of the data, Spearman correlation coefficients were considered appropriate for identifying the strength and direction of relationships among the examined constructs. The results revealed statistically significant positive relationships between all variables included in the conceptual model. The findings indicate that organizations implementing stronger AMO-oriented HR systems also demonstrate higher levels of organizational strategy alignment, work engagement, open innovation, and sustainable organizational performance.

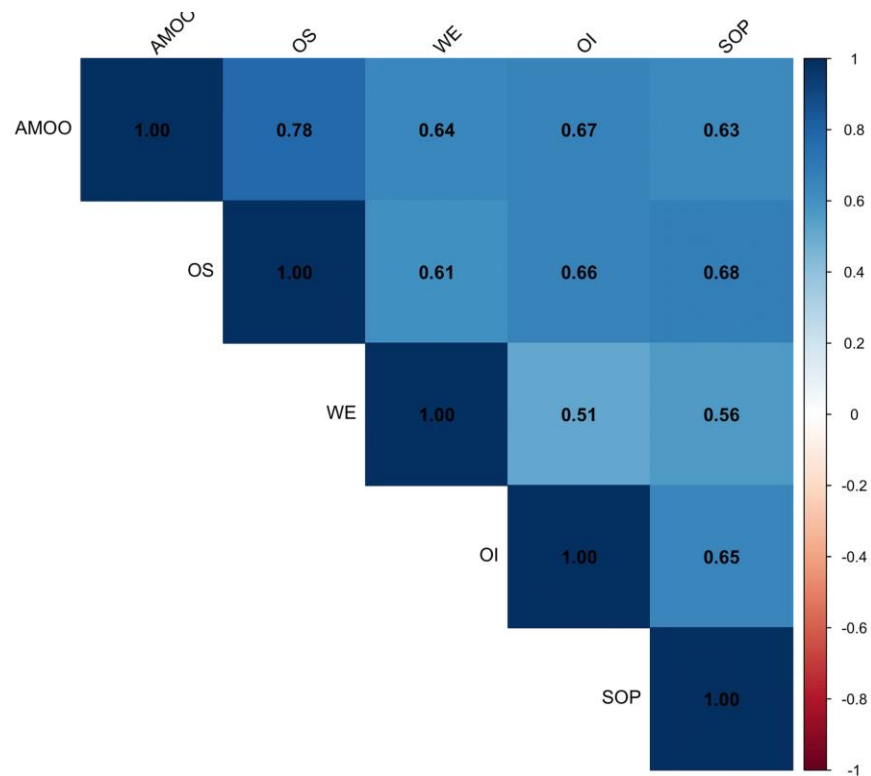


Figure 2
Correlation analysis - heatmap

Figure 2 presents the correlation heatmaps visualizing the relationships among the examined constructs across Slovakia, the Czech Republic, and Poland.

The strongest relationship was identified between AMO-oriented HR practices and organizational strategy ($r = 0.777$), indicating that organizations with stronger AMO-based HR systems also demonstrate stronger strategic alignment. Strong positive relationships were also identified between organizational strategy and sustainable organizational performance ($r = 0.682$), as well as between open innovation and sustainable organizational performance ($r = 0.651$).

Hypothesis	Relationship	Correlation (r)	Status
H1	AMO $\rightarrow$ SOP	0.631	✓ Supported
H2	AMO $\rightarrow$ OS	0.777	✓ Supported
H3	OS $\rightarrow$ SOP	0.682	✓ Supported
H4	AMO $\rightarrow$ WE	0.643	✓ Supported
H5	WE $\rightarrow$ SOP	0.565	✓ Supported
H6	AMO $\rightarrow$ OI	0.665	✓ Supported
H7	OI $\rightarrow$ SOP	0.651	✓ Supported

Table 1
Correlation analysis and hypothesis testing results

The results confirm that all proposed hypotheses were supported. The identified relationships suggest that AMO-oriented HR practices significantly contribute to sustainable organizational performance both directly and indirectly through organizational strategy, work engagement, and open innovation.

4.2 fsQCA Results

To further examine the configurational nature of the proposed model, fuzzy-set Qualitative Comparative Analysis (fsQCA) was conducted. The fsQCA approach enabled the identification of multiple causal configurations leading to high sustainable organizational performance. Unlike traditional linear approaches, fsQCA assumes that organizational outcomes may result from different combinations of organizational conditions.

The analysis demonstrated that sustainable organizational performance is not generated by isolated HR practices alone, but rather through synergistic combinations of AMO-oriented HR systems, organizational strategy, work engagement, and open innovation. The findings therefore support the configurational perspective adopted in this study.

AMOO	OS	WE	OI	Outcome (SOP)	Consistency	Cases (n)
1	1	1	1	1	0,953	197
0	1	1	1	1	0,985	9
1	1	0	1	1	0,985	7
1	0	1	1	1	0,977	9

Table 2
fsQCA truth table

Configuration (Path)	Consistency	PRI	Coverage
AMOO * OS * WE * OI → SOP	0,783	0,619	0,989

Table 3
Configurations leading to high sustainable organizational performance

The identified configurations indicate that several alternative pathways may lead to high sustainable organizational performance. In most identified configurations, AMO-oriented HR practices appeared as a core condition associated with organizational strategy and open innovation. Work engagement also emerged as an important complementary condition contributing to stronger organizational outcomes.

The fsQCA findings therefore confirm that sustainable organizational performance should be understood as the result of interconnected organizational mechanisms rather than independent managerial variables. These findings are consistent with previous configurational HRM research emphasizing the importance of internally aligned HR systems and synergistic organizational processes.

4.3 Discussion of Results

The empirical findings support the assumptions of the Ability–Motivation–Opportunity framework and confirm the importance of integrated HR systems for sustainable organizational performance. The significant relationship between AMO-oriented HR practices and sustainable organizational performance supports previous studies emphasizing the strategic role of HR systems in organizational effectiveness [1,4].

The strongest relationship identified between AMO-oriented HR practices and organizational strategy suggests that HR systems become more effective when aligned with long-term organizational objectives. This finding corresponds with previous research highlighting the strategic integration of HRM as a prerequisite for sustainable organizational outcomes [13].

The results also confirm the importance of work engagement as a behavioral mechanism linking HR systems and organizational performance. Organizations implementing developmental, motivational, and participatory HR practices appear

to create stronger employee engagement, which subsequently contributes to higher organizational effectiveness. This finding is consistent with [5,14], who emphasize the role of engagement in explaining the HRM–performance relationship.

Similarly, the positive relationship between AMO-oriented HR practices and open innovation indicates that HR systems supporting collaboration, participation, and knowledge sharing contribute to organizational innovation capability and adaptability. These findings correspond with previous studies emphasizing the importance of collaborative HR systems for innovation-oriented organizational climates [15,7].

Finally, the fsQCA results provide important support for the configurational perspective adopted in this study. The existence of multiple causal pathways leading to sustainable organizational performance suggests that organizations may achieve high performance through different combinations of HR systems and mediating organizational mechanisms. Consequently, sustainable organizational performance should not be interpreted as the result of isolated managerial practices but rather as the outcome of interconnected organizational configurations.

Conclusions

The aim of this paper was to conceptualize and empirically validate a comprehensive model of relationships between AMO-based human resource management practices, mediating organizational mechanisms, and sustainable organizational performance. The study integrated organizational strategy, work engagement, and open innovation into a configurational framework explaining the relationship between HRMP and sustainable organizational outcomes.

The empirical findings confirmed statistically significant positive relationships between AMO-oriented HR practices and sustainable organizational performance, as well as between the individual mediating variables included in the model. The results additionally demonstrated that organizational strategy, work engagement, and open innovation represent important organizational mechanisms through which HR systems influence organizational outcomes. The fsQCA analysis further confirmed the configurational nature of the proposed model by identifying multiple causal pathways leading to high sustainable organizational performance.

The study contributes to strategic human resource management literature in several ways. First, it extends the configurational perspective by conceptualizing HRM practices as integrated organizational systems rather than isolated managerial practices. Second, it contributes to explaining the HRM “black box” by theoretically integrating organizational strategy, work engagement, and open innovation as interconnected mediating mechanisms within a single configurational framework explaining sustainable organizational performance. Unlike previous studies, which have predominantly examined these mechanisms separately, the proposed framework provides a coherent theoretical basis for understanding their combined

effects and offers a foundation for future theory development and structural model testing. Third, the paper provides empirical evidence from the Central European organizational context, which remains relatively underrepresented in contemporary SHRM research.

From a managerial perspective, the findings suggest that organizations should focus on developing coherent AMO-oriented HR systems supporting employee development, motivation, participation, and collaboration. At the same time, organizations should align HR systems with organizational strategy and create conditions supporting work engagement and open innovation in order to strengthen long-term organizational sustainability and adaptability.

Despite its contributions, the study has several limitations. The research was based on cross-sectional questionnaire data collected within three Central European countries, which may limit the generalizability of the findings. Additionally, the study focused primarily on selected mediating mechanisms and did not include other contextual organizational variables that may influence sustainable organizational performance.

Future research should therefore focus on longitudinal research designs and advanced structural modeling approaches, particularly PLS-SEM, to further examine the causal relationships between AMO-based HR systems and organizational performance. Additional studies may also investigate the role of organizational culture, leadership styles, and sector-specific conditions within configurational HRM models.

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Generative AI as an Enabler of Sustainable Innovation in Hospitality Organizations: A Case Study of a Resort Hotel in Türkiye

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Abstract: The growing pressure on tourism organizations to combine economic performance with environmental responsibility has increased interest in innovation-driven solutions. Among emerging technologies, Generative Artificial Intelligence (AI) is gaining attention for its potential to support sustainable innovation in service-oriented industries. This study explores the role of Generative AI in enabling sustainability-related innovation in hospitality organizations, drawing on a case study of a resort hotel in Türkiye. Using a mixed-method approach that combines secondary research with an employee survey, the study examines how sustainability initiatives and AI-supported practices are perceived and implemented at the organizational level. The findings suggest that Generative AI contributes to sustainable innovation by supporting more efficient resource use, improving operational coordination, and enhancing data-driven decision-making. Employees demonstrate strong awareness of sustainability goals and generally view AI as a supportive and complementary innovation rather than a disruptive technology, although differences in usage and skill levels remain. The study highlights that the innovation potential of Generative AI depends not only on technological availability but also on organizational readiness, employee learning, and managerial commitment. By linking Generative AI with sustainability and innovation outcomes, this research contributes to the growing literature on digital innovation in hospitality and offers practical insights for organizations seeking to integrate AI into long-term sustainability and innovation strategies.

Keywords: Generative Artificial Intelligence; Sustainable Innovation; Hospitality Innovation; Smart Tourism

1 Introduction

Tourism is one of the most important sectors contributing to economic growth worldwide and plays a vital role in national development and financial stability. It supports balance of payments, creates employment opportunities across multiple industries such as hospitality and transportation, and contributes to income

generation and overall production growth [1]. For many destinations, tourism remains a key driver of economic resilience and social development.

At the same time, the rapid growth of tourism presents serious sustainability challenges. Increasing visitor numbers place significant pressure on natural resources, contribute to pollution, and intensify overcrowding in popular destinations. These impacts highlight the need for new approaches that allow tourism organizations to remain competitive while reducing their environmental footprint [2].

In parallel with these challenges, organizations across industries are accelerating investments in Generative Artificial Intelligence, recognizing its potential as a driver of innovation rather than only a tool for automation [3]. Generative AI enables organizations to analyze large volumes of data, automate routine tasks, and support more informed decision making, making daily operations more efficient and adaptive [4]. Within the tourism sector, such capabilities open new opportunities for process innovation, service improvement, and sustainability-oriented solutions.

Recent research suggests that Artificial Intelligence can support sustainable tourism by improving resource efficiency, reducing waste, and promoting environmentally responsible practices [5]. However, while AI adoption in tourism is increasing, there is limited empirical research focusing specifically on Generative AI as an enabler of sustainable innovation at the organizational level. This study addresses this gap by examining how Generative AI supports sustainability-driven innovation through a case study of a resort hotel in Alanya, Türkiye.

2 Literature Review

Sustainable tourism is widely defined as an approach that aims to balance economic growth with social well being and environmental protection, ensuring that tourism activities today do not compromise opportunities for future generations [6]. As global tourism continues to expand, concerns related to environmental degradation, resource depletion, and overcrowding have become more pronounced. These challenges have increased pressure on tourism organizations to rethink traditional business models and adopt innovative solutions that support long term sustainability while maintaining competitiveness.

In response to these challenges, innovation has become a central topic in tourism and hospitality research. Technological innovation, in particular, is increasingly viewed as a key enabler of more sustainable operational practices. Among emerging technologies, Artificial Intelligence has received growing attention for its ability to support efficiency, adaptability, and value creation across tourism and hospitality organizations. AI driven systems are now commonly used in areas such as

marketing, pricing, demand forecasting, and customer relationship management. Applications including chatbots, recommendation engines, and automated decision support systems help reduce operational costs, improve service speed, and enhance guest satisfaction [7]. Over time, research focus has shifted from basic automation toward more advanced AI solutions that support learning, innovation, and strategic decision making.

Recent reviews indicate that AI research in hospitality has expanded significantly, with growing emphasis on personalization, intelligent service systems, operational optimization, and data-driven decision-making. AI has become one of the most influential technological developments shaping contemporary hospitality management [8].

Generative Artificial Intelligence represents a significant development within this broader AI landscape. Unlike earlier AI applications that primarily analyze or classify data, Generative AI is capable of producing new content such as text, reports, recommendations, simulations, and analytical insights. In hospitality organizations, these capabilities create new opportunities for innovation in service delivery, internal communication, training, and performance management. Generative AI can support guest engagement through personalized communication, assist employees with real time information access, and enable managers to make more informed decisions based on continuously generated insights.

Generative AI applications such as ChatGPT are increasingly being adopted to support customer interactions, content generation, service delivery, and managerial decision-making within tourism and hospitality organizations [9]. When integrated with complementary technologies such as the Internet of Things, cloud computing, and big data analytics, Generative AI enables more responsive, data driven, and sustainable operational models [10]. From an innovation perspective, this positions Generative AI not merely as a support tool but as a catalyst for process and organizational innovation.

Empirical studies and international case examples further illustrate how AI contributes to sustainability related innovation in tourism. Crowd monitoring systems implemented in cities such as Amsterdam help manage visitor flows and reduce pressure on urban infrastructure. Robot operated hotels in Japan demonstrate how automation and AI can address labor shortages while maintaining service consistency. Scandinavian hotels increasingly rely on AI enabled energy management systems to optimize consumption, while AI supported food waste monitoring solutions help hospitality organizations reduce environmental impacts and improve efficiency [11] [12]. These examples highlight the diverse ways AI supports innovation in sustainability practices, while also showing that adoption levels vary significantly across countries and organizational contexts. Similarly, AI contributes not only to operational efficiency but also to sustainability performance through enhanced resource management, personalized services, and improved marketing effectiveness [13].

Despite this growing body of applications, the literature consistently identifies several barriers that limit effective AI adoption in tourism and hospitality organizations. High investment costs, insufficient digital infrastructure, and limited availability of skilled employees are commonly cited challenges, particularly for small and medium sized enterprises [14]. In addition, concerns related to data privacy, ethical use of AI, transparency, and algorithmic bias create uncertainty for both managers and employees. These issues are especially critical in service industries, where trust, human interaction, and perceived fairness play a central role in customer experience and organizational reputation [15].

Beyond technical limitations, researchers increasingly emphasize the organizational and managerial dimensions of AI driven innovation. Successful implementation depends not only on technological capability but also on employee awareness, acceptance, and learning. In hospitality organizations, where operations are highly labor intensive and service oriented, staff engagement is particularly important. Studies highlight that structured training programs, clear internal communication, and gradual implementation strategies help reduce resistance to change and enable employees to view AI as a support mechanism rather than a threat. These organizational factors strongly influence whether AI becomes a driver of innovation or remains an underutilized resource. Similarly, the successful implementation of Generative AI depends on balancing technological capabilities with employee readiness, organizational support, and responsible management practices [16].

Policy and institutional support also play an important role in enabling responsible and innovation oriented AI adoption. National strategies provide guidance on ethical standards, governance principles, and long term development priorities. Türkiye's National Artificial Intelligence Strategy 2021–2025 emphasizes AI as a means of improving productivity, supporting digital transformation, and promoting sustainability across sectors [17]. Such frameworks encourage organizations to align AI adoption with broader innovation and sustainability goals while reducing uncertainty and implementation risks.

Overall, the literature suggests that Generative Artificial Intelligence holds significant potential to act as an enabler of sustainable innovation in hospitality organizations. However, its contribution depends on organizational readiness, employee capabilities, managerial commitment, and supportive policy environments. These insights provide the conceptual foundation for examining how Generative AI is applied in practice through the case study presented in this research.

Recent bibliometric evidence demonstrates a rapid increase in AI-related tourism and hospitality research, particularly studies examining Generative AI applications and their implications for service innovation. However, most studies focus on technology adoption, customer interactions, or marketing applications, leaving organizational-level sustainability and innovation outcomes comparatively underexplored [18].

Despite the growing body of research on AI in tourism and hospitality, limited empirical studies have specifically examined Generative AI as an enabler of sustainable innovation at the organizational level. This study seeks to address this gap through a case study of a resort hotel in Türkiye.

3 Material and Method

This study adopts a mixed research approach combining qualitative and quantitative methods to examine how Generative Artificial Intelligence supports sustainable innovation in hospitality organizations. A case study design was selected to allow an in depth exploration of AI adoption within its real organizational context, focusing on Quattro Beach Spa & Resort Hotel in Alanya, Türkiye.

Secondary data were collected through a review of academic literature, industry reports, government publications, and international case studies related to Artificial Intelligence, innovation, and sustainability in tourism. These sources provided a broader conceptual and strategic perspective, helping to identify key trends, best practices, and innovation related challenges across different hospitality contexts.

The literature reviewed in this study was identified through searches in Google Scholar, Scopus, and Web of Science using combinations of keywords such as "Generative AI", "Artificial Intelligence", "hospitality", "tourism", "innovation", and "sustainability". Priority was given to peer-reviewed journal articles, international reports, and policy documents that specifically addressed AI applications in tourism and hospitality contexts. This approach ensured that the selected sources were directly relevant to the study's focus on sustainable innovation and AI adoption in hospitality organizations.

Primary data were gathered through a printed survey administered to 44 hotel employees in April 2025. Employees from different departments participated voluntarily, providing perspectives on sustainability practices, AI usage, and innovation readiness.

The collected data were analyzed using descriptive statistical methods to identify patterns, relationships, and general trends. Tables and figures were used to present the findings in a clear and accessible manner. Ethical research principles were strictly followed, with participation being voluntary and all responses remaining anonymous. The survey results are summarized using descriptive tables to support the interpretation of innovation-related findings. This methodological approach supports a structured evaluation of how Generative AI contributes to sustainability driven innovation at the organizational level.

4 Results

This section presents the results of the employee survey conducted at Quattro Beach Spa & Resort Hotel Alanya. The findings focus on three main areas: employee awareness of sustainability practices, current use and understanding of Artificial Intelligence, and perceptions regarding the role of Generative AI in supporting operational improvement and innovation. Together, these results provide empirical insight into how sustainability and AI supported initiatives are experienced at the organizational level and how they contribute to innovation related outcomes. The findings presented in this section are based on responses from 44 employees working in different departments of the hotel.

4.1 Sustainability awareness and daily practices

The survey results reveal a high level of awareness regarding sustainability initiatives among hotel employees. Approximately 95% of respondents indicated that they are familiar with the hotel's sustainability practices and believe these initiatives have a positive impact on the environment. This suggests that sustainability is not limited to managerial strategy but is well understood and recognized across operational levels. Employees most frequently identified energy saving, water conservation, and waste reduction as the key sustainability practices implemented in the hotel.

Survey Dimension	Summary of Findings
Awareness of sustainability initiatives	Very high; approximately 95% of respondents reported familiarity.
Perceived environmental impact	Largely positive across departments.
Most recognized sustainability practices	Energy saving, water conservation, waste reduction.
Familiarity with Artificial Intelligence	Mostly medium level; few respondents reported no familiarity.
Perceived impact of AI on operational efficiency	Positive; over 60% agreed that AI improves efficiency and reduces workload.
Perceived impact of AI on employee roles	AI viewed as supportive and complementary rather than threatening.

Table 1.
Employee awareness of sustainability initiatives and perceptions of AI
Source: Author's own survey data

Importantly, respondents described these practices as part of their everyday routines rather than as isolated or symbolic activities. Examples included conscious energy usage, responsible waste handling, and efforts to minimize unnecessary resource consumption. This indicates that sustainability principles are embedded in daily operational behavior and reflect a shared commitment across departments. All respondents reported having received training related to sustainability, highlighting a strong institutional emphasis on environmental responsibility and supporting consistency in implementation.

Employee responses further suggest that sustainability considerations are integrated into routine decision making processes. Many participants associated sustainability with everyday operational choices, such as adjusting energy use, monitoring consumption, and following environmentally responsible procedures. This alignment between sustainability goals and day to day work practices demonstrates that environmental responsibility has become part of the hotel's organizational culture rather than being treated as a standalone initiative. From an innovation perspective, this cultural embedding creates a favorable foundation for introducing sustainability oriented technological and process innovations.

4.2 Familiarity with Artificial Intelligence and current usage

When examining familiarity with Artificial Intelligence, the findings indicate that most employees report a moderate level of awareness and understanding. While a smaller group described themselves as highly familiar with AI technologies, very few respondents indicated no familiarity at all. This distribution suggests that AI applications are present within the organization but are not uniformly visible or actively used across all departments.

Differences in familiarity appear closely linked to job roles and functional responsibilities. Employees working in guest facing, administrative, or coordination focused positions reported more frequent interaction with AI supported systems. In contrast, staff in operational roles with limited digital interaction reported lower exposure. This uneven distribution highlights that AI adoption within the hotel is still evolving and that innovation diffusion across departments remains partial rather than fully organizational.

Despite these differences, employee perceptions of AI were largely positive. More than 60% of respondents agreed that AI technologies contribute to improved operational efficiency and cost reduction. Employees frequently associated AI usage with faster processes, improved coordination, reduced manual workload, and easier access to information. These responses indicate that AI is primarily perceived as a supporting mechanism that enables smoother operations rather than as a disruptive force.

Notably, employees did not express strong concerns about AI replacing human labor. Instead, AI was viewed as complementing human work by reducing repetitive tasks, improving accuracy, and supporting staff performance. This perception is particularly important in the hospitality context, where service quality relies heavily on human interaction. From an innovation standpoint, this positive framing suggests a readiness to accept AI as part of broader process and service innovation efforts.

4.3 Variation in AI use and opportunities for innovation

Daily interaction with AI tools varied noticeably across departments. Some employees reported frequent use of AI supported systems in their daily work, while others engaged with such tools only occasionally. This variation indicates that AI implementation remains selective and that certain operational areas have yet to fully benefit from available technologies.

The uneven use of AI highlights clear opportunities for innovation through broader integration and more consistent application across departments. Employees acknowledged that existing AI tools could be used more effectively if accessibility and training were improved. These findings suggest that current limitations are not related to resistance but rather to uneven exposure and capability development. From an innovation management perspective, this points to the importance of internal alignment and inclusive implementation strategies.

4.4 Employee Perceptions of AI's Potential Impact on Guest Experience

In addition to operational efficiency, employees were asked about their perceptions regarding the potential of AI to improve guest experiences. Therefore, the findings

reflect employee opinions and expectations rather than direct measurements of guest satisfaction or actual guest experiences.

However, perceptions related to guest experience were more mixed compared to efficiency related outcomes. Some employees noted that while AI has clear potential, its impact is not yet fully visible across all services. This suggests that guest facing AI applications are still in an early stage of implementation or require further refinement to deliver consistently noticeable benefits. These findings underline that technological innovation alone is not sufficient; effective design and integration into service processes are equally important.

4.5 Training, learning, and organizational readiness

Training emerged as a recurring and critical theme in the findings. Although all respondents reported receiving sustainability related training, a smaller proportion indicated that they had received structured training specifically focused on AI technologies. This gap helps explain why some employees expressed uncertainty or limited confidence in using AI tools, despite recognizing their benefits.

Employees who reported higher familiarity with AI were generally more comfortable with innovation related changes and more likely to identify AI's contribution to both efficiency and sustainability goals. This suggests that training and learning play a central role in enabling AI driven innovation. The findings highlight the importance of targeted AI specific training programs to build skills, reduce uncertainty, and support more effective integration of Generative AI into daily operations.

Innovation Theme	Description
Sustainability embedded in daily operations	Environmental practices integrated into routine work processes.
AI as an efficiency enabler	AI supports faster processes, better coordination, and reduced manual tasks.
Uneven adoption of AI	Differences in AI usage across departments and job roles.
Training and learning needs	Limited AI-specific training identified as a key gap.
Employee innovation readiness	Generally positive attitudes toward AI-enabled changes.
Sustainability-driven innovation	AI contributes to measurable improvements in energy and resource management.

Table 2.
Innovation-related themes emerging from employee responses
Source: Author's own survey data

4.6 AI, sustainability, and innovation outcomes

From a sustainability perspective, the results demonstrate a clear link between AI usage and environmental objectives. Employees with higher AI familiarity were more likely to associate AI supported systems with improved energy management, waste reduction, and enhanced operational monitoring. This indicates that AI helps make environmental impacts more visible and measurable, supporting informed decision making at multiple operational levels.

As a result, AI is perceived not only as a tool for improving efficiency but also as an enabler of sustainability driven innovation. By supporting data based insights and process improvements, Generative AI reinforces sustainability goals while contributing to organizational learning and continuous improvement.

The tables and figures associated with this section further support these findings. Table 1 summarizes survey results related to sustainability awareness, perceived environmental impact, AI familiarity, and perceived efficiency outcomes. Table 2 presents key themes from employee feedback concerning AI adoption, training needs, and sustainability integration. Visual figures illustrate levels of sustainability awareness, perceived operational impact of AI, and employee comfort with AI technologies. Together, these visual elements strengthen the empirical evidence and complement the narrative analysis.

4.7 Summary of key findings

Overall, the results show that hotel employees are open to the adoption of Generative AI and generally recognize its value for both sustainability and operational improvement. At the same time, the findings underline the importance of structured training, effective internal communication, and inclusive implementation strategies in realizing the full innovation potential of AI. These results provide empirical support for the argument that Generative AI can function as an enabler of sustainable innovation in hospitality organizations when guided by appropriate managerial and organizational conditions.

Conclusion & Summary

This study examined how Generative Artificial Intelligence can support sustainable tourism development by acting as an enabler of organizational and process innovation, using Quattro Beach Spa & Resort Hotel Alanya as a case study. The findings indicate that Generative AI contributes to sustainability-oriented innovation by supporting energy saving, waste reduction, operational efficiency, and improved coordination across hotel functions. In addition, AI-supported tools show potential to enhance guest experience through faster service delivery and more effective communication.

The results also reveal that the successful use of Generative AI is not without challenges. High implementation costs, gaps in digital skills, and concerns related to data privacy and fairness continue to influence adoption levels. Although employees generally express positive attitudes toward AI and recognize its benefits, the findings highlight the need for more structured AI-focused training and clearer internal communication. Addressing these factors is essential to ensure that AI supports innovation rather than remaining underutilized.

From an innovation perspective, the study shows that Generative AI is most effective when integrated into existing sustainability strategies and supported by organizational learning and employee engagement. AI should be viewed as a complementary innovation that enhances human capabilities rather than replacing them. When combined with appropriate governance, training programs, and supportive policy frameworks, Generative AI can strengthen sustainability performance while fostering continuous innovation.

Overall, this research demonstrates that Generative AI offers practical and strategic value for hospitality organizations seeking to innovate sustainably. The findings provide insights for managers and policymakers in Türkiye and beyond on how AI can support long-term competitiveness through responsible and innovation-driven implementation.

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Entrepreneurial Leadership and Innovation for Hungary: A Scoping Review

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Abstract: This study conducts a scoping review of Entrepreneurial Leadership (EL) in the context of Hungarian Small and Medium-Sized Enterprises (SMEs), complemented by a web-based review of global entrepreneurial firms. The topic focuses on how EL enables innovation, dynamic capability development, and effective collaboration between SMEs, universities. The study aims to build a conceptual foundation for forthcoming empirical research examining how Hungarian SMEs sense and seize value within collaborative innovation ecosystems. Key learnings show that EL mediates the relationship between human capital and innovation, founder characteristics shape open innovation pathways, and managerial discretion affects entrepreneurial outcomes. Additional insights reveal that Hungary's innovation performance and SME structure make EL particularly crucial for strengthening university–industry partnerships.

Keywords: entrepreneurial leadership; SMEs; Hungary; innovation capability; dynamic capabilities; university–industry collaboration.

1 Introduction

1.1 Context and motivation

Small and medium-sized enterprises (SMEs) are central to Hungary's economic dynamism and innovation outcomes, yet they operate under resource and capability constraints [1, 2]. The lack of proper internal resource requires firms to develop collaborative innovation with external partners [3], strategic entrepreneurship [4] and entrepreneurial leadership (EL) are the core of competition. The capacity of founders and top managers to craft vision, mobilize people, and orchestrate boundary-spanning innovation – has been repeatedly shown to translate human capital into firm-level innovativeness in such contexts [5, 6]. This paper develops a concise, conference-length synthesis to ground an empirical research follow-up.

1.2 Hungary's innovation capacity and SME profile

According to the Global Innovation Index (GII) 2025, Hungary ranks 36th out of 139 economies overall (23rd in Europe), performing stronger in innovation outputs than inputs, while market sophistication and institutions were ranked merely at 49th and 63rd position [7]. The Hungarian Central Statistical Office (KSH) reports a business landscape dominated by SMEs – almost 900.000 micro, small and medium units registered in 2024 – underlining their pivotal role in employment and value creation [8]. Recent analyses also note uneven SME performance by sector and region [9], their inappropriate organisational and cooperation culture [10] implying that leadership-driven capability development is increasingly consequential for innovation contribution [11].

1.3 Why SME – university – science park collaboration matters

Science parks are contemporary policy instruments designed to enhance national innovation capacity by fostering linkages among firms, universities, and research actors; they reduce search and coordination costs for SMEs and facilitate access to shared infrastructure and talent [12, 13]. As partners of universities, SMEs can diversify innovation outputs (e.g. prototypes, joint intellectual property (IP), demonstrators) while capturing commercial value via joint projects and market-oriented translational research [14]. For Hungary – where institutional disadvantage hampers innovation – well-structured collaboration platforms can help convert academic knowledge into business resources, then scalable opportunities [15].

Alongside firm-internal leadership capabilities, the organizational environments in which firms operate condition how entrepreneurial leadership translates into innovation and collaboration outcomes. Science parks represent one such environment, particularly relevant in contexts where firms face resource constraints, coordination challenges, and uncertainty in university–industry interaction. Rather than acting as direct innovation drivers, science parks provide structured settings that shape the range of feasible open innovation options available to entrepreneurial leaders.

From an entrepreneurial leadership perspective, science parks can be understood as discretionary environments that reduce search and coordination costs, standardize interfaces with universities, and offer access to shared infrastructure and boundary-spanning support functions. These features do not determine firms' innovation strategies, but they influence how founders and top managers enact opportunity recognition, partner selection, and resource commitment decisions. In this sense, science parks are analytically relevant not as homogeneous actors, but as enabling conditions that interact with leadership characteristics at the firm-level.

This positioning is particularly pertinent in economies where innovation performance depends less on the scale of internal resources and more on leadership-enabled collaboration. Through situating entrepreneurial leadership within science park environments, the paper connects micro-level leadership mechanisms with meso-level collaboration structures, without assuming uniform effects across firms. Science parks are therefore treated as contextual settings that may amplify or constrain the expression of founder-specific entrepreneurial leadership orientations, a linkage that becomes relevant when discussing open innovation mode fit and collaboration patterns later in the paper.

1.4 Entrepreneurial leadership: definition and relevance

Drawing on the Upper-Echelons perspective by Hambrick and Mason [16] – organisational outcomes can be predicted by the characteristics of top executives – and innovation leadership research, we define EL as the leadership configuration that combines opportunity recognition, future orientation, risk management, and mobilization of internal and external stakeholders to achieve innovation outcomes.

We position the work at the intersection of the Resource-Based View (RBV) and the Dynamic Capabilities View (DCV). Under RBV, human and social capital (e.g. employees' skills, founder's networks, leadership routines) constitute strategic resources; EL enhances their value creation by aligning them with a compelling vision [17]. While in DCV, EL fosters the routines to sense opportunities (market/technology scanning with universities), seize them (resource commitment and alliance governance in science parks), and transform assets (reconfiguring processes and roles for commercialization) [18].

1.5 Problem statement and research aim

Despite Hungary's stable mid-table GII position and comparatively better output performance, persistent input-side constraints (e.g. financing frictions, uneven absorptive capacity) and institutional boundaries (eg. lack of entrepreneurial and cooperative culture) limit the innovation productivity of SMEs. Consequently, leadership-enabled transformation, also collaboration with universities, is especially salient. This paper therefore synthesizes the state of knowledge on EL as a driver of SME innovation and collaboration readiness.

Methodologically, we employ a scoping review of academic studies retrieved with Scopus strings that combine leadership, entrepreneurship, innovation, and the "human" dimension, complemented by a web-based review of archetypal entrepreneurial firms (e.g., Tesla, Apple, Uber, PayPal) to illustrate how EL orchestrates dynamic capabilities at scale. The scoping approach is appropriate to map a fragmented field, identify consensus mechanisms (e.g. EL mediation), and spotlight contextual moderators (e.g. managerial discretion) [19] before hypothesis testing in Hungary.

2 Literature Review

2.1 Conceptual foundations

Research on the human side of innovation consistently roots firm-level innovativeness in intangible assets and leadership routines. The Resource-Based View (RBV) argues that valuable, rare, inimitable and non-substitutable (VRIN) resources – particularly human and social capital – underpin sustainable advantage, positioning leadership as a capability that orchestrates these resources toward innovation [17]. The Dynamic Capabilities View (DCV) extends this logic, emphasizing routines to sense opportunities, seize them through timely commitments, and transform assets for continued renewal [18]. The Upper-Echelons Theory (UET) adds a micro-foundational lens: strategic outcomes reflect top managers' experiences, values and cognition, implying that EL – as enacted by founders/CEOs and top management teams (TMTs) – channels attention and shapes the firm's innovation trajectory [16].

2.2 Entrepreneurial leadership as mediator between human capital and innovativeness

Across efficiency-driven and emerging contexts, EL is repeatedly shown to convert employee intellectual agility into firm-level innovativeness. In a study of 110 Serbian micro and small firms, the direct effect of intellectual agility on innovativeness disappears once EL is introduced as a mediator; future orientation—the leader’s capability to articulate a compelling direction and reduce uncertainty—emerges as the strongest path, while community building remains a positive, though weaker, channel [6]. This mediation pattern aligns with RBV/DCV: EL activates VRIN human capital and builds dynamic routines that transform cognition into outcomes under resource constraints typical of emerging economies.

Positive leadership appeared as an emerging trend, potentially supporting EL with a better workplace culture, introducing techniques like strength-based seminars and job crafting, emphasizing the role of managers and managers’ tasks in achieving the engagement and better performance of employees [20].

2.3 Founder/CEO characteristics and Open Innovation (OI) mode fit

Founder-level attributes strongly shape Open Innovation (OI) adoption and maturity in SMEs. OI paradigm describes the company’s outward-facing strategy, actively collaborating with business partners, to capture and create value [21]. Case evidence from seven Irish high-tech SMEs shows that OI is project-based and often followed by a “switchback” to more closed approaches once the immediate need is met; functional (technical) background enhances absorptive capacity, career and industry experience broaden networks and negotiation efficacy, legacy linkages ease partner access, and entrepreneurial orientation sustains boundary-spanning and selective revealing [11]. Complementary survey research on Korean SMEs finds that CEOs’ positive attitude, patience (crucial for longer-cycle inbound R&D), and technology education are associated with specific OI modes and with overcoming internal resistance such as NIH/NSH syndromes [22]. Together, these studies reinforce the UET view that who the leader is conditions how openness is practiced, with direct implications for crafting university–SME collaboration architectures.

Founder and CEO characteristics shape not only whether SMEs engage in open innovation but also how openness is enacted. Prior research shows that technical background, industry experience, entrepreneurial orientation and temporal preferences influence the selection and execution of different open innovation modes such as inbound, coupled or project-based collaboration [22, 11]. In this context, science parks can be understood as organizational settings that condition the enactment of founder-specific leadership preferences rather than as uniform innovation drivers.

Technically trained founders with strong absorptive capacity tend to align with inbound open innovation modes, emphasizing access to scientific knowledge, laboratories and skilled human capital. Science park settings reduce coordination frictions and facilitate structured interaction with universities, supporting leadership practices centered on opportunity sensing and selective knowledge acquisition. Conversely, founders with extensive industry experience and network capital are more likely to engage in coupled open innovation modes, using science parks as coordination spaces for joint development projects and collaborative governance arrangements. Here, entrepreneurial leadership is expressed through alliance orchestration and the alignment of heterogeneous partner expectations.

For more entrepreneurially oriented founders with limited internal R&D depth, science parks may initially enable exploratory and time-limited collaboration modes, such as pilot projects, demonstrators or publicly funded consortia. These arrangements allow learning and experimentation with reduced commitment, while leadership practices focus on flexibility and opportunity testing. Across these configurations, science parks expand the range of feasible open innovation modes without determining outcomes. Seen through this lens, science parks function as discretionary environments that amplify or constrain the expression of founder-specific entrepreneurial leadership. This perspective integrates founder fit and open innovation mode selection within a coherent analytical framework and supports treating science parks as enabling conditions in studies of SME collaboration rather than as actors with uniform effects.

2.4 Team-level leadership, market orientation and innovation capability

At the TMT level, shared leadership and market-oriented culture have significant positive effects on innovation capability, which in turn drives performance – evidence based on 336 SMEs (UAE) using structural-equation modeling [23]. Framed by RBV/DCV, shared leadership and market orientation function as strategic resources that operationalize sensing, seizing and transforming – thereby linking leadership behaviors to scalable innovation routines rather than isolated projects.

2.5 National context and managerial discretion

A meta-analysis integrating UET with the managerial discretion perspective shows that the effects of TMT attributes on corporate entrepreneurship are context-contingent: in environments with tighter constraints on managerial discretion (e.g., regulatory rigidity), the strength and direction of leadership effects vary, cautioning against “one-size-fits-all” prescriptions [24]. This is salient for emerging economy SMEs, where institutional frictions can dampen otherwise

positive leadership–innovation links; it elevates the role of collaboration platforms that expand leaders’ discretion via shared infrastructure and more flexible contracting.

2.6 Sustainability-oriented leadership (“innovability”)

Recent synthesis work extends EL toward innovability – the integration of sustainability with innovation – identifying leadership competencies in strategic framing, collaboration culture, sustainability commitment, continuous learning, and sensitivity to global megatrends [25]. Embedding these competencies at university–industry interfaces aligns innovation portfolios with EU policy priorities and can increase the legitimacy and funding prospects of SME projects.

The literature underscores a coherent mechanism chain: EL (future orientation; community building) mediates the conversion of human capital into innovativeness; founder attributes shape OI mode fit and collaboration behavior; shared leadership and market orientation form the bridge from leadership behaviors to innovation capability and, ultimately, performance; and national discretion moderates all of the above. For Hungary, where SMEs dominate the economy and innovation outputs exceed inputs, the greatest marginal gains likely lie in leadership-enabled collaboration—precisely where sensing, seizing and transforming can be institutionalized at manageable cost for SMEs.

3 Methodology

Given the breadth and conceptual heterogeneity of EL and its intersections with OI, RBV/DCV, and university–industry collaboration, we adopted a scoping review to map key constructs, mechanisms, and contextual moderators prior to an empirical Hungarian study. A scoping approach is appropriate for orientation in an evolving field [19] and to surface research gaps and practical implications for the SME–university–science park nexus in Hungary (see Norman et al. [26] for scope review in the field of innovation). The Hungarian context indicators used later in interpretation were drawn directly from WIPO’s Global GII 2025 and KSH statistical pages.

3.1 Academic review

Database: Scopus was selected for coverage depth in management, entrepreneurship, innovation, and engineering management journals.

Search strings: We reused the course-provided strings to ensure replicability:

TITLE-ABS-KEY (leader*) AND TITLE-ABS-KEY (innov*) AND TITLE-ABS-KEY (human*) AND TITLE-ABS-KEY (entrepreneur*)

with data filter PUBYEAR > 2009

case-enhanced variants to capture systemic entrepreneurship exemplars:

TITLE-ABS-KEY (leader* AND innov* AND human* AND entrepreneur* AND tesla) and

TITLE-ABS-KEY (leader* AND innov* AND human* AND entrepreneur* AND musk)

Time window: Publications from 2010–2025 (inclusive) to reflect contemporary EL/OI theorizing and empirical work in SMEs.

Eligibility criteria:

Inclusion: peer-reviewed journal articles; conceptual, quantitative, qualitative or mixed-methods studies; explicit focus on EL (or closely allied constructs: founder/CEO attributes, TMT shared leadership) and outcomes related to innovation capability, corporate entrepreneurship, OI, or dynamic capabilities; SME samples or general firm samples with interpretable SME implications.

Exclusion: conference abstracts only; dissertations; non-English articles; studies without leadership content; purely macro policy reports without firm-level mechanisms.

Screening and selection: Titles/abstracts were screened against eligibility criteria; full texts were then reviewed to extract constructs (e.g. EL components, OI modes), contexts (economy type, industry), mechanisms (e.g. mediation of intellectual agility by EL), and outcomes (innovation capability, performance). The strings above returned core studies later analyzed in Chapter 2.

Synthesis approach. We applied thematic coding to group evidence into mechanism clusters (EL mediation; founder/OI fit; TMT shared leadership–market orientation–innovation capability; managerial discretion as moderator; sustainability/innovability leadership), which structure Chapter 4 (Results).

3.2 Web-based review of non-academic sources

To triangulate leadership mechanisms with practice-proximate narratives, we carried out a targeted review of authoritative non-academic sources on firms widely used as entrepreneurial leadership exemplars. These sources were used only to illustrate mechanisms already identified in peer-reviewed studies (e.g. visionary framing; absorptive capacity; ecosystem orchestration) and not as primary empirical evidence for Hungary.

3.3 National indicators for contextualization

To anchor findings in Hungary, we referenced WIPO's GII 2025 (rank 36th overall; outputs > inputs) and KSH SME demography and performance snapshots (dominance of SMEs; sectoral heterogeneity) for brief contextual statistics used in Chapters 1–2 and for result links in Chapters 4–5.

Nevertheless, the scoping review privileges breadth over critical appraisal; we did not conduct formal risk-of-bias assessments or meta-analytic weighting. The inclusion of illustrative non-academic corporate histories is for conceptual triangulation only; interpretations rely primarily on peer-reviewed evidence. Finally, while GII/KSH data strengthen contextual relevance, country-specific causal claims require the planned empirical follow-up within Hungarian SME–university–science park triads.

4 Results

4.1 Theme 1. EL as the Activation Mechanism of Human Capital

Building directly on the evidence summarized in Chapter 2, the findings confirm that entrepreneurial leadership is the mediating mechanism that activates employees' intellectual agility into measurable innovativeness [6]. In the Serbian SME study, intellectual agility alone had no significant direct effect on innovativeness after incorporating EL; future orientation emerged as the strongest mediator, followed by community building.

SMEs in emerging economies require *leadership-driven capability activation* rather than relying solely on human capital availability. This supports applying the same mechanism to Hungary, where SMEs dominate the economic landscape and innovation performance is shaped more by leadership and collaboration patterns than by resource abundance (as indicated by WIPO GII and KSH data).

4.2 Theme 2. Founder/OI Mode Fit as a Determinant of Collaboration Success

Results reinforce that founder/CEO characteristics determine how SMEs select and execute OI modes. Studies show that OI is typically project-based, often reverting to closed practices once a need is met [11]. Technically trained founders demonstrate greater absorptive capacity, while founders with broader industry or

career experience enable richer networks and negotiation capacity; those with strong entrepreneurial orientation (EO) facilitate boundary-spanning behavior needed for collaboration with universities or science parks. For Hungary, tailoring collaboration structures (e.g. inbound vs. coupled OI modes) to specific founder profiles is likely essential. This is pertinent given the heterogeneous SME composition reported by KSH and EU SME Fact Sheets, showing significant variation in sectoral maturity and absorptive capacity among Hungarian SMEs [8, 27].

4.3 Theme 3. Shared Leadership and Market Orientation as Drivers of Innovation Capability

The TMT-level findings illustrate that shared leadership, together with a market-oriented culture, exerts indirect but powerful influence on innovation capability and overall performance via dynamic capability development [24]. These effects were validated in the large-scale study of 336 SMEs (UAE), demonstrating high external validity across non-Western, efficiency-driven contexts.

For Hungarian SMEs within university collaborations, embedding shared leadership structures (e.g. joint academic–SME decision boards, co-led project teams) can significantly enhance innovation capability formation, improving the likelihood of commercialization – a national priority indicated by Hungary’s stronger GII outputs than inputs.

4.4 Theme 4. Institutional Moderators: Managerial Discretion and Collaboration Platforms

A major outcome of the meta-analysis reviewed in Chapter 2 concerns managerial discretion. Where national contexts restrict leaders’ discretion (regulatory rigidity, weak institutional support), leadership attributes have attenuated effects on corporate entrepreneurship [24]. Conversely, environments that expand discretion amplify EL’s positive impact on innovation. Science parks and university partnership frameworks – by offering shared infrastructure, clearer IP protocols, and standardized contracting – can act as discretion-enhancing environments for Hungarian SMEs. This is critical because GII 2025 data show that Hungary’s innovation inputs lag behind outputs [7], implying structural constraints that collaboration platforms can help mitigate.

4.5 Theme 5. Innovability Competencies as Emerging Requirements

The literature reveals that beyond classical EL behaviors, innovability competencies – including sustainability orientation, collaboration culture, and megatrend awareness—are increasingly necessary for innovation leadership. These competencies are especially relevant for SMEs embedded in EU policy landscapes emphasizing climate, digital, and societal missions [25]. Hungarian SMEs operating in science parks (which are policy tools for mission-oriented innovation) are well-positioned to benefit from acquiring such competencies, especially as Hungary seeks to improve its GII outputs in sectors like high-tech manufacturing and R&D linkage performance [28].

4.6 Theme 6. Systemic Entrepreneurship as a Benchmark for Leadership Patterns

Although global exemplars – Tesla, Apple, Uber, PayPal [29]-[34] – are not directly comparable to SMEs, they illuminate recurring leadership patterns also reflected in SME-level evidence: (1) Visionary future framing (Tesla under Elon Musk), (2) Design- and culture-driven transformation (Apple under Steve Jobs), (3) Aggressive scaling with ecosystem orchestration (Uber under Travis Kalanick), (4) Complementary founder skills enabling OI (PayPal founders: Max Levchin, Peter Thiel, Luke Nosek, later Elon Musk).

These cases validate mechanisms identified in peer-reviewed SME studies: absorptive capacity, boundary spanning, and leadership-enabled sensing/seizing. They support using EL-focused frameworks when analyzing Hungarian SME collaboration readiness.

4.7 Theme 7. Learning-by-Doing and Proximity Effects in Collaboration Maturity

Studies reviewed in Chapter 2 consistently show that SME innovation processes mature through iterative learning, not static planning [11]. Moreover, spatial and cognitive proximities strongly moderate collaboration outcomes, influencing absorptive capacity and EL effectiveness [6].

Hungarian SMEs – many concentrated in Budapest/Pest County clusters (per KSH data) yet diverse across regions [9] – will experience differing collaboration frictions. Science parks thus offer an important function by reducing cognitive distance (through boundary-spanning professionals, joint labs) and supporting cumulative capability building.

Conclusions & Implications

This conference manuscript synthesized how EL operates as the pivotal integrator of human and social capital, open-innovation behavior, and dynamic capability building in SMEs – mechanisms that are especially salient for Hungary’s innovation context. Hungary’s GII 2025 profile [7] indicates that firms convert available inputs relatively efficiently but face input-side constraints (e.g. financing, linkages, skills) that limit the scale and pace of innovation investment. In such circumstances, *leadership-enabled collaboration* becomes a high-leverage pathway for improving national innovation outcomes.

Across studies reviewed in Chapter 2 and structured in Chapter 4, EL – particularly future orientation and community building – mediates the relationship between employees’ intellectual agility and firm innovativeness in micro and small firms; without EL, human-capital advantages underperform. This consolidates RBV/DCV insights: EL activates VRIN resources and establishes sensing–seizing–transforming routines that convert cognition into outcomes under resource constraints typical of emerging economies. For Hungary’s SME-dominated economy, these leadership mechanisms are not peripheral but central to innovation productivity.

Results also show that founder/CEO attributes (technical background, experience, network legacy, entrepreneurial orientation) shape OI mode fit – for example, technically-educated and patient founders align with inbound R&D, while network-strong founders favor coupled modes. In practice, this implies tailoring university–SME collaboration architectures (timelines, IP and milestone design, partner composition) to *specific* founder profiles - crucial given the heterogeneity observed across Hungarian SME ecosystems.

At the team level, shared leadership and market orientation reliably enhance innovation capability and performance, offering a design cue for collaboration governance (e.g. mixed academic–SME steering groups, joint product councils) inside science parks. Because managerial discretion moderates the effect of leadership attributes on corporate entrepreneurship, science park frameworks that standardize contracting, IP options, and access to shared infrastructure can act as discretion-enhancing environments – amplifying EL’s positive impact and helping Hungary address input-side frictions flagged by the GII.

Finally, aligning EL with innovability competencies (sustainability commitment, collaboration culture, megatrend sensitivity) positions SME–university projects for EU-relevant funding and legitimacy while enlarging the scope of innovation outcomes beyond short-term commercialization. In short, the strongest near-term gains for Hungary likely lie where entrepreneurial leadership meets structured collaboration platforms (universities and science parks), enabling founder-fit OI, shared-leadership routines, and accelerated capability maturation. This conclusion provides a practical map for the next study phase: testing EL-mediated value

creation in Hungarian SME–university–science park dyads through carefully specified, context-sensitive designs.

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Ethical Pricing from the Consumer Perspective: An Exploratory Study

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Abstract: Consumers often criticize businesses, claiming that the prices charged for their products or services are unjustified, that companies overprice their offerings relative to the costs incurred, and that such pricing practices are therefore unfair. Similar concerns can also arise in business-to-business relationships. The ethical aspects of pricing have been discussed since Thomas Aquinas introduced the concept of the just price, while contemporary literature has expanded the discussion to include price fairness, transparency, and corporate social responsibility. Although ethical pricing has received increasing scholarly attention, relatively little empirical research has examined how consumers perceive ethical pricing and which factors most strongly influence these perceptions. This study aims to address this gap by combining a review of the literature on business ethics, pricing strategies, and ethical pricing with an exploratory empirical investigation. I collected the primary data through an online questionnaire survey involving 58 respondents, in which I used seven-point Likert-scale questions to measure perceptions of price fairness, transparency, willingness to pay, and attitudes toward dynamic and personalized pricing. The results indicate that consumers attach considerable importance to fair and transparent pricing practices and generally reject unjustified price increases. At the same time, their willingness to pay a premium for ethically priced products remains only moderate, confirming the existence of an attitude–behavior gap. The findings contribute to a better understanding of consumer expectations regarding ethical pricing and provide practical implications for companies seeking to develop responsible and trust-building pricing strategies.

Keywords: Ethical pricing, fair pricing, ethical economy, pricing methods

1 The Concept of Business Ethics

I would like to approach the concept of ethical pricing from the perspective of business ethics; therefore, I will first provide a brief review of the literature in this field.

Business ethics is a key area of applied ethics that examines the moral dimensions of economic and business activities. The central question of this field is what norms and values economic actors should adhere to, and how these principles manifest in

practice. Economic ethics is thus a discipline that is both normative and descriptive, serving to provide a moral foundation for economic decisions [1].

In the international literature, the concept of business ethics can be approached from several angles. According to one fundamental approach, business ethics involves the application of ethical principles to economic decisions and the functioning of economic institutions. According to Velasquez [2], business ethics examines the moral standards that guide the behavior of business organizations and the individuals working within them. Similarly, Ferrell et al. [3] emphasize that business ethics is aimed at analyzing and resolving ethical dilemmas that arise in the decision-making process, with particular regard to the corporate environment.

Stakeholder theory is of particular significance in the international literature, as it has fundamentally transformed the approach to business ethics. According to Freeman [4], a company does not merely serve the interests of its owners but must also take into account the interests of all stakeholders—such as employees, consumers, suppliers, and society. This approach has become one of the cornerstones of business ethics, as it highlights that corporate decisions have broader societal consequences.

The concept of corporate social responsibility (CSR) has also played an important role in the development of business ethics. According to Carroll's [5] classic model, corporate responsibility consists of four dimensions: economic, legal, ethical, and philanthropic responsibility. This approach highlights that economic success cannot be separated from ethical conduct, and that companies must actively contribute to social well-being.

Another important strand in the international literature is the institutional and systemic approach, which examines the ethical foundations of economic systems. Sen's [6] capability approach emphasizes that economic development cannot be measured solely by income indicators; rather, it must also take into account people's actual opportunities and quality of life. This approach strengthens the link between economic ethics and development policy.

Donaldson and Dunfee's [7] integrative social contract theory also represents a significant contribution to the theory of economic ethics. According to the authors, the behavior of economic actors is determined simultaneously by universal moral norms and local social rules. This duality is particularly important in a globalized economy, where companies operate in diverse cultural and institutional environments.

In Hungarian academic literature, the interpretation of business ethics is closely linked to the issues of social responsibility and sustainability. Zsolnai [1] emphasizes that economic activities are not value-neutral but always entail moral consequences; therefore, economic actors bear a responsibility toward society and the environment. According to Kindler & Zsolnai [8], the task of business ethics is to examine how economic decisions contribute to social well-being and within what

moral boundaries they must operate. Csutora and Kerekes [9], meanwhile, emphasize that integrating sustainability into corporate operations is essential for ensuring long-term competitiveness.

The importance of business ethics is constantly growing today, as globalization, digitalization, and changing social expectations give rise to increasingly complex ethical dilemmas. Corporate operations are increasingly shaped by expectations regarding transparency, accountability, and sustainability. Consequently, business ethics is not merely a theoretical issue but also has practical significance from the perspectives of corporate management and financial control. Business ethics is an interdisciplinary field of study that examines the moral foundations of economic activities and contributes to the development of responsible, sustainable, and socially acceptable business practices.

2 A Literature Review of Pricing Strategies

In this chapter of my thesis, I provide a brief review of the literature on several pricing strategies used in practice.

Price is one of the most important elements of the marketing mix (4Ps), as it is the only marketing tool that directly generates revenue for the company. Pricing is not merely a matter of determining the value of a product or service; it is also a strategic decision that significantly influences a company's competitiveness, profitability, market position, and long-term viability. When developing an appropriate pricing strategy, companies must take into account their costs, the value perceived by consumers, competitors' prices, as well as market demand and the external economic environment [10]. The strategic importance of pricing is further heightened by the fact that price often serves as an indicator of quality for consumers, thus playing not only an economic but also a psychological role [11].

Marketing and management literature distinguishes three classic pricing approaches: cost-based, value-based, and competitor-based pricing. Although these can be applied as standalone strategies, in practice companies often combine them to simultaneously ensure profitability, market competitiveness, and consumer satisfaction [12].

Cost-based pricing is the oldest and, at the same time, the most widely used pricing strategy. Its basic principle is that the company determines the total cost of producing a product or service and then adds a predetermined profit margin to that cost. Due to the simplicity of this method, it is particularly widespread among manufacturing companies, small and medium-sized enterprises, and public utilities [10]. One of the most important advantages of cost-based pricing is that it ensures cost recovery and the achievement of the desired profit, while being relatively easy to apply and plan. This is particularly advantageous in markets where demand is

relatively stable or where the company's primary goal is to maintain financial stability [13]. At the same time, the literature also raises numerous criticisms of this method. Cost-based pricing focuses primarily on a company's internal processes, while paying little attention to consumer needs, perceived value, or competitors' pricing decisions. As a result, the resulting price may be too high for consumers or, conversely, lower than what the market would be willing to pay. According to Nagle and Müller [12], costs alone do not determine a product's market value; therefore, exclusively cost-based pricing can result in a competitive disadvantage in the long run. Monroe [11] also emphasizes that consumers do not purchase a company's costs, but rather the utility they perceive.

In contrast, value-based pricing is based on the premise that the price is determined not by production costs, but by the value perceived by the consumer. The essence of this strategy is that the company assesses the benefits, utility, and experience its product or service provides to the consumer and then sets the price accordingly [10]. This approach is becoming increasingly important today, particularly in the case of services, premium products, innovative technologies, and brand-oriented markets. A prerequisite for the successful application of value-based pricing is a thorough understanding of consumer value. The company must be able to identify which features consumers consider important, what problems they expect the product to solve, and how much they are willing to pay for the perceived added value [14]. Therefore, value-based pricing is closely linked to market research, the analysis of consumer behavior, and segmentation. According to the literature, one of the most important advantages of value-based pricing is that it enables a company to achieve higher profit margins, provided it succeeds in clearly communicating the unique value of the product or service to consumers [15]. In addition, it promotes long-term consumer satisfaction and fosters brand loyalty. At the same time, applying this method is a complex task, as consumer value is constantly changing, and measuring it requires significant research effort. Hinterhuber [14] also points out that while many companies claim to use value-based pricing, in reality they continue to make their decisions based on cost.

The third classic strategy is competition-based pricing, in which a company primarily aligns its own prices with those of its competitors. This is particularly common in markets where products or services are difficult to differentiate from one another, or where price competition is intense [10]. The company may decide to set prices lower, equal to, or higher than those of its competitors, depending on the market position it wishes to occupy.

One of the most important advantages of competitor-based pricing is that it helps the company maintain its market competitiveness while reducing the risk of deviating significantly from the prevailing market price level. Particularly in oligopolistic markets, companies constantly monitor each other's pricing policies and react quickly to price changes when necessary [12]. Advances in digital technologies have further reinforced this trend, as prices can now be compared in real time. However, there are also significant limitations to applying this strategy.

If a company focuses exclusively on tracking competitors' prices, it runs the risk of ignoring its own cost structure or the value perceived by consumers. In the long run, this can lead to a price war, declining profits, and a weakening of market differentiation [11]. According to Porter's [16] approach to competitive strategy, a sustainable competitive advantage is achieved not solely through low prices, but through unique value creation and differentiation.

Penetration pricing is a strategy in which a company offers a new product or service at a relatively low price upon market launch in order to quickly gain a large market share and encourage consumers to try it. The strategy is based on the premise that a low price reduces the risk of purchase, increases demand, and makes it more difficult for competitors to enter the market [12]. Penetration pricing is particularly effective in markets where price sensitivity is high, significant economies of scale can be achieved, and the company aims to establish a long-term competitive advantage. According to Kotler et al. [10], the success of this strategy depends on the company's ability to operate profitably even with a low profit margin initially, as well as having sufficient production capacity to meet increased demand. At the same time, an introductory price that is too low can, in the long run, damage consumers' perception of the product's quality and make it difficult to raise prices later on.

In contrast, the goal of price skimming is for the company to set a high price when introducing an innovative or unique product and to gradually lower it as the product's life cycle progresses. This strategy is most successfully applied to products that represent significant innovation, have a strong brand, or face few direct competitors initially [10].

A high introductory price allows for a faster return on research and development costs and enables companies to target consumer segments with a high willingness to pay. Nagle and Müller [12] emphasize that the skimming strategy is particularly common in technology industries, where, due to the rapid pace of innovation, early adopters are willing to pay a premium price for novelty. However, this strategy remains effective only as long as competitors do not enter the market with similar products and consumers continue to perceive the product's uniqueness.

Psychological pricing is based on the premise that consumers' perception of price is not entirely rational; therefore, when setting prices, companies consciously draw on the findings of behavioral economics. According to Monroe [11], consumers often compare prices to mental reference points; therefore, the same price can elicit different consumer reactions depending on how it is presented. The best-known form of this is the use of prices ending in 9 (for example, 9,990 Ft), which shoppers typically perceive as lower than the next round number. Other tools of psychological pricing include displaying reference prices, using prestige prices, and effectively communicating prices visually. According to Schiffman and Wisenblit [17], these techniques can significantly influence purchasing decisions, particularly in the case

of impulse purchases. At the same time, excessive manipulation or misleading price communication can erode consumer trust in the long run.

The purpose of promotional pricing is to stimulate short-term demand through various price discounts and promotions. In such cases, companies temporarily lower the prices of their products in order to increase sales volume, attract new customers, or reduce inventory [10]. Promotional pricing can take many forms, such as temporary price reductions, coupons, volume discounts, seasonal promotions, or loyalty programs. Although these tools can significantly increase sales in the short term, the literature points out that overly frequent promotions can lower consumers' price expectations and weaken brand value in the long run [11]. Companies should therefore use price promotions as a strategic tool rather than as an ongoing sales method.

Product line and product mix pricing refers to the coordinated pricing of a company's entire product offering. In this approach, rather than optimizing the prices of individual products separately, the profitability of the entire product portfolio is taken into account. According to Kotler et al. [10], the basis of this strategy is that the cross-demand between individual products must also be taken into account. In product line pricing, for example, different prices are assigned to different quality or feature levels, while product mix pricing also includes the pricing of complementary products, optional services, accessories, and consumables. Typical examples of this are the pricing policies for printers and ink cartridges, as well as game consoles and video games.

In bundling, a company offers multiple products or services together at a lower price than they would cost individually. The goal of this strategy is to increase the average basket size, encourage sales of less popular products, and provide consumers with higher perceived value [18]. Bundling is particularly widespread in telecommunications, the software industry, tourism, and retail. The literature distinguishes between pure bundling, where products can be purchased exclusively as a bundle, and mixed bundling, where consumers can purchase products either separately or as a bundle. According to Stremersch and Tellis [18], mixed bundling generally provides greater flexibility for the firm and is more favorably received by consumers.

3 Ethical Pricing

Ethical pricing can be understood as lying at the intersection of marketing, consumer behavior, and business ethics. Its essence lies not merely in whether a price is lawful, but also in whether consumers perceive the pricing practice as fair, justifiable, and honest. In the literature, this is most often linked to the concept of “price fairness,” that is, the perception of whether a price is fair. According to Xia et al. [19], price fairness is a consumer value judgment in which the buyer compares the current price to a reference price, past experience, a competitor’s offer, or the company’s presumed costs.

The classic starting point is the work of Kahneman et al. [20], which states that consumers consider a price increase acceptable if it is linked to rising costs or the company’s survival, but perceive it as unethical if the company is merely taking advantage of increased demand. This is particularly important during a crisis, when consumers’ vulnerability increases and pricing can easily give the impression of “price gouging,” that is, exploitative overpricing.

Campbell [21] further clarified this by noting that the perception of price unfairness depends not only on the price increase itself but also on the motives consumers attribute to the company. If consumers feel that the price increase is driven by greed or an excessive desire to increase profits, they will consider the pricing to be unfair. If, on the other hand, the price increase can be attributed to external factors—such as rising supplier costs—then the price becomes more acceptable.

According to research by Bolton et al. [22], consumers often overestimate companies’ profit margins and underestimate costs, so they easily conclude that the price is unreasonably high. This means that ethical pricing is not only a matter of pricing policy but also of communication: the company must make it clear what costs, value, and services the price reflects.

Maxwell [23] emphasizes the concept of rule-based price fairness. According to this concept, consumers evaluate not only the price level but also the fairness of the pricing process. A price appears more ethical if it is determined based on clear, consistent, and predictable rules. This is particularly important in situations where consumers encounter different prices for the same product or service.

The spread of dynamic pricing has raised new ethical issues. According to Haws and Bearden [24], consumers may react negatively if they perceive that others are paying different prices for the same product, especially when the reason for the price difference is not transparent. This is particularly important in the digital environment, as algorithmic and personalized pricing can create information asymmetry between the company and the consumer.

Transparency is therefore a central element of ethical pricing. Ferguson and Ellen [25] demonstrated that transparent communication of price increases can improve the perception of price fairness. Similarly, Rothenberger [26] concluded that the

more clear information consumers have about the components of a price, the more positively they are likely to assess the fairness of that price.

Research on cost transparency also supports this. According to Mohan et al. [27], disclosing cost components can reduce consumers' assumption that a company is making excessive profits. This is particularly important for ethical or sustainable products, where a higher price often reflects higher wages, sustainable raw materials, or a more responsible supply chain.

At the same time, ethical pricing does not mean that the price must be low. Based on the strategic pricing approach of Nagle et al. [28], a company must align the price with the value created. From an ethical standpoint, the problem is not the high price itself, but rather when the price is not commensurate with the value provided to the consumer, or when the company misrepresents the reasons for the price.

The issue of willingness to pay often arises in the context of ethical products and services. According to research by Trudel and Cotte [29], consumers are willing to pay a premium for ethically produced products, but they may also penalize unethical companies by showing a lower willingness to pay. Auger et al. [30], however, caution that the impact of ethical attributes is not the same across all markets and consumer groups, as buyers weigh social and environmental characteristics alongside other product attributes, such as price, brand, and country of origin.

According to Carrigan and Attalla [31], there is a significant attitude–behavior gap in ethical consumption: consumers often claim that ethical corporate behavior is important to them, but price, convenience, and quality are frequently stronger factors in their purchasing decisions. From the perspective of ethical pricing, this means that an ethical price can only be marketable if the consumer understands and appreciates the rationale behind it.

Therefore, based on the above, ethical pricing rests on four main pillars: fairness, transparency, value for money, and the avoidance of exploiting vulnerable situations. According to the literature, consumers do not necessarily consider a low price to be ethical, but rather a price that is justifiable, consistent, not misleading, and does not exploit consumers' lack of information or a state of need. Therefore, ethical pricing is not merely a moral expectation, but also a factor that builds trust and ensures long-term competitiveness.

4 Evaluation of the Results of the Empirical Research

The research was based on primary quantitative data collection, which involved conducting an online questionnaire survey to examine consumers' attitudes toward ethical pricing. Data collection was carried out using a convenience sampling method, with a total of 58 valid questionnaires analyzed. The questionnaire included demographic questions as well as statements measuring various dimensions of ethical pricing—such as price fairness, price transparency, attitudes toward ethical pricing, willingness to pay a higher price, and perceptions of dynamic and personalized pricing. Attitudes were rated on a seven-point Likert scale, where a score of 1 indicated complete disagreement and a score of 7 indicated complete agreement.

I analyzed the data using IBM SPSS Statistics 25 software. During the analysis, I applied descriptive statistical methods to calculate the frequency distributions, means, and standard deviations of each variable. The results primarily allow for exploratory conclusions, as the relatively small sample size and the non-representative sample limit their generalizability to the entire Hungarian consumer population. Nevertheless, the research provides valuable information on the main characteristics and correlations of consumer perceptions of ethical pricing.

The gender distribution in the sample was relatively balanced: 55.2% of the respondents were men, while 44.8% were women. In terms of age distribution, the sample consisted primarily of young adults, as 53.4% of respondents were born between 1997 and 2010. Those born between 1981 and 1996 accounted for 29.3%, while the age group born between 1965 and 1980 made up 13.8%. Those born between 1946 and 1964 represented only 3.4%. Based on distribution by place of residence, the vast majority of respondents, 77.6%, live in Budapest. The proportion of those living in small towns and rural cities was 8.6% each, while those living in villages or small towns accounted for 5.2%. In terms of employment status, nearly half of the sample were employees (48.3%), while 25.9% were students. The proportion of respondents in managerial positions was 12.1%, that of entrepreneurs was 10.3%, while retirees accounted for 3.4%. Based on educational attainment, the sample demonstrated a high level of education. 63.8% of respondents had a college degree, 22.4% had a high school diploma, 12.1% had a vocational school or trade school diploma, and 1.7% had only a primary school education. In terms of marital status, more than half of the respondents—53.4% —were single, 29.3% were married, 10.3% were in a registered domestic partnership, 5.2% were divorced, and 1.7% were widowed. In terms of the number of children, 72.4% of respondents had no children. 8.6% each had one, two, or three children, while 1.7% of the sample had four or more children. Based on net monthly income, the largest group consisted of those earning over 600,000 Ft (25.9%). This was followed by respondents with incomes between 300,001 and 400,000 Ft (19.0%), as well as the category earning between 500,001 and 600,000 Ft (17.2%). The proportion of those earning between 0 and 200,000 Ft and between 400,001 and 500,000 Ft was 13.8%, while 10.3%

reported an income between 200,001 and 300,000 Ft. Based on the above, it can be said that the sample consisted primarily of young, Budapest-based respondents with a college degree, who were employed and had no children.

The aim of the research was to explore how consumers view ethical pricing, how they evaluate companies' current pricing practices, and to what extent they are willing to pay a higher price for products from ethically operating companies. Based on the results, respondents tend to view current corporate pricing practices as moderately fair. The average scores for statements assessing price fairness fell within the middle range, suggesting that consumers do not consider the pricing observed in the market to be unequivocally fair. This suggests that there is a certain degree of distrust or skepticism among consumers regarding companies' pricing decisions. Respondents therefore do not categorically reject corporate pricing, but neither do they consider it entirely fair. This is consistent with findings in the literature on price fairness, which indicate that consumers evaluate prices not only on the basis of economic rationality but also in terms of moral and fairness considerations [19].

The survey of attitudes toward ethical pricing yielded much more striking results. The majority of respondents clearly consider it important for companies to set their prices ethically and strongly reject unjustified or excessive price increases. A particularly striking finding is that respondents explicitly view price-hiking practices not backed by actual cost increases or objective economic reasons as unethical. This suggests that consumers associate pricing not solely with corporate decision-making but also with moral responsibility. The results confirm the classic finding by Kahneman et al. [20] that the social acceptability of profit maximization is constrained by norms of fairness.

One of the study's strongest findings relates to the importance of price transparency. Respondents clearly consider it important that the factors determining a product's price be clear and understandable, and they view it positively when companies justify their prices. This suggests that, for consumers, ethical pricing depends not only on the price itself but also on how transparent and traceable the pricing process is. Price transparency can therefore be considered an important factor in consumer trust. This finding aligns well with the theory of procedural fairness, according to which consumers evaluate not only the final price but also the pricing process itself.

The results regarding willingness to pay paint a more nuanced picture. Although respondents generally have a positive attitude toward ethical companies, their willingness to pay a higher price was only moderately positive. This indicates that while consumers support ethical business practices at the level of their values, price sensitivity continues to play a significant role in their actual purchasing decisions. In other words, there is a certain discrepancy between stated ethical attitudes and actual economic behavior. This can be explained by the so-called "attitude-behavior gap," a phenomenon widely recognized in consumer behavior research.

The findings related to dynamic and personalized pricing also offer interesting insights. Respondents consider pricing practices that adapt to changes in supply and demand to be moderately acceptable, suggesting a certain level of acceptance of market-economy logic. At the same time, they view personalized pricing—that is, situations where different consumers pay different prices for the same product—in a significantly more negative light. This suggests that consumers distinguish between market-based price adjustments and price discrimination, which they perceive as unfair. Consumers therefore do not reject price changes per se, but rather those practices that violate the norms of equal treatment or fairness.

The results of the study suggest that consumers are highly ethically sensitive when it comes to pricing. They consider fairness, justification, and transparency to be important, yet they adopt a more pragmatic approach when it comes to their actual willingness to pay. One of the central conclusions of the study is therefore that ethical pricing can positively influence consumer perceptions and trust in the company, but this does not necessarily automatically result in a higher willingness to pay. It is important to emphasize, however, that the study has limitations. The sample size of 58 is relatively small, which limits the generalizability of the results. Furthermore, because the questionnaire-based data collection method relies on self-reporting, there may be a bias toward socially desirable responses, particularly when it comes to ethical issues. Nevertheless, the study provides useful insights into consumer attitudes toward ethical pricing.

Conclusions

This study examined consumers' perceptions of ethical pricing by combining a review of the relevant literature with an empirical survey. The findings demonstrate that consumers evaluate pricing not only according to economic criteria but also based on ethical considerations such as fairness, transparency, and the justification of price changes. Respondents expressed strong support for transparent and fair pricing practices while rejecting unjustified price increases and personalized pricing perceived as discriminatory. Although ethical pricing positively influenced consumer attitudes, the willingness to pay a higher price for ethically priced products proved to be only moderate, indicating that ethical preferences are often constrained by price sensitivity.

From a managerial perspective, the results suggest that transparent communication, fair pricing policies, and responsible pricing decisions can strengthen consumer trust and corporate reputation, thereby contributing to long-term customer relationships. However, companies should recognize that ethical pricing alone may not be sufficient to influence purchasing behaviour without delivering clear customer value.

The study is subject to certain limitations, primarily the relatively small convenience sample of 58 respondents, which restricts the generalizability of the findings. Future research should involve larger and more representative samples and

examine the influence of demographic, cultural, and socioeconomic factors on ethical pricing perceptions. In addition, comparative international studies could provide a broader understanding of consumer expectations regarding ethical pricing in different market environments.

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Changes in consumer behavior in the context of the digital economy and applied marketing approaches

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Abstract: The era of digital transformation has led to fundamental changes in consumer behavior, just as in many other fields. The widespread use of social media and social networks, e-commerce, and e-marketing has significantly altered consumers' decisionmaking mechanisms, purchasing habits, and forms of interaction with brands, making them more dynamic, interactive, and information-driven. These changes necessitate a reconsideration of traditional marketing approaches and highlight the role of digital transformation in applied marketing strategies. The article analyzes the main directions of consumer behavior transformation in the context of the digital economy. In particular, it explores the impact of personalized marketing, big data analytics, AI-based recommendation systems, and social media marketing on consumer behavior. It also emphasizes the increasing use of digital channels by consumers for information gathering, product comparison, and purchasing decisions. The research results show that, under the conditions of the digital economy, marketing approaches are evolving towards data-driven decision-making, real-time interaction, and optimization of customer experience. This plays a crucial role in shaping competitive advantage for enterprises. In conclusion, the digital economy not only transforms consumer behavior but also requires marketing strategies to be more flexible, innovative, and technology-oriented.

Keywords: Digital economy Consumer behavior Digital transformation E-commerce Social media

1 Introduction

Marketing science has a long tradition of embracing new challenges, new methods, and new disciplines. The field today is built upon the diverse efforts of researchers who, for almost 50 years, have synthesized solutions from a variety of disciplines to provide new insight to marketing problems. More often than not, the crucible of marketing science has given back to other disciplines, models, and methods that are better and more robust. For example, in the early 1980s, consumer packaged goods firms experienced a data revolution. No longer dependent upon aggregate, time-

delayed data such as warehouse withdrawals, the advent of scanner data enabled marketing scientists to observe the behavior of individual consumers making purchases over many shopping trips and for many product categories [1].

Expansion of e-commerce, growth of digital platforms, application of artificial intelligence-based algorithms, and processing of big data — as the main driving forces of the digital economy — have fundamentally transformed the content of relationships between producers and consumers. By integrating technologies such as artificial intelligence and mobile access, e-commerce enables online transactions, expands market access, and transforms traditional trade to meet the demands of the digital era. As a result, global-scale, information-driven, personalized, and efficient virtual markets are emerging, creating broad opportunities for business entities (especially micro, small, and medium enterprises) as well as consumers, and fundamentally changing the ways goods and services are purchased, sold, and delivered. As noted, e-commerce is no longer limited to online sales; it also encompasses digital services, data flows, and intellectual ecosystems. This affects all areas — from supply chains to consumer behavior — expands the application of innovation, and stimulates economic growth.

The impact of the digital economy on trade has significantly transformed consumer decision-making mechanisms, turning consumers not only into passive buyers of products and services but also into active subjects who generate, share information, and influence market behavior. Unlike traditional markets, the abundance of choices in the digital environment, accessibility of information, public opinion formed on social networks, and personalized advertising mechanisms have enriched consumer behavior beyond rational models, incorporating elements of behavioral economics. In this regard, revisiting classical consumer behavior models such as Engel–Kollat–Blackwell and Stimulus–Response within the context of the digital economy emerges as a relevant scientific problem.

The main purpose of the article is to analyze the transformation of consumer behavior in the digital economy based on theoretical approaches and to identify the real manifestations of these changes through empirical research. Within the framework of the study, the following tasks are set: to explain the essence of the concept of the digital economy; to systematize the main theoretical models of consumer behavior; to analyze the mechanisms of the digital environment's influence on consumer decisions; to identify key trends based on empirical data; and to propose practical recommendations.

While existing literature extensively covers the macroeconomic benefits of the digital economy and general e-commerce trends, there is a notable research gap regarding how classical consumer behavior models (e.g., the Engel–Kollat–Blackwell and Stimulus–Response frameworks) interact with modern socio-psychological anomalies like the digital Veblen and Snob effects under algorithmic personalization. Most studies treat these models in isolation. This paper addresses this gap by synthesizing classical consumer behavior theories with data-driven

marketing realities, exploring how AI-driven recommendation landscapes alter the traditional linear customer journey into a dynamic, non-linear loop.

In the Internet of Things (IoT) consumer products like coffee machines and smoke detectors are connected with the Internet, which effectively expands the Internet to the physical world. Such products have the ability to collect and share data from the user's environment and, thus, their broad emergence will affect well-established concepts presented in the extant marketing literature [5].

2 Methodology

This study adopts a secondary data analysis and synthesis methodology. To evaluate the empirical shift in consumer behavior, we examine secondary empirical datasets from Eurostat (2023) tracking e-commerce penetration within the European Union over a ten-year horizon (2013–2023). Additionally, to analyze the impact of electronic Word-of-Mouth (eWOM), we utilize comparative meta-synthesis based on causal models (specifically the Information Adoption Model - IAM) from recent empirical literature, analyzing regression metrics to weight the influence of anonymous reviews versus social media recommendations.

3 The Concept of the Digital Economy and Theoretical Foundations of Consumer Behavior

The digital economy, in scientific literature, is characterized as an economic system based on information and communication technologies, where digital data plays a decisive role in the processes of production, distribution, exchange, and consumption. As a global network of economic activities grounded in digital technologies, it encompasses online connections, transactions, and data flows, covering sectors such as retail trade, finance, and healthcare. The digital economy includes a wide spectrum ranging from e-commerce, online banking, electronic taxation, digital customs, and digital marketing to the core infrastructure of the internet, mobile technologies, cloud computing, artificial intelligence, and the Internet of Things (IoT). All of these enable producers and consumers to interact within the digital environment and create new value. In essence, the digital economy significantly strengthens the economic activity of digital resources, fundamentally transforming the ways goods, services, and information are produced, exchanged, and consumed.

The advent of the digital transformation era signifies more than just adopting digital technologies; it represents a profound shift in how organizations operate and

innovate in the digital age. Beyond mere digitalization, this era heralds a holistic reimagining of business models, processes, and customer interactions [9].

Among the classical models of consumer behavior, the “Engel–Kollat–Blackwell” model, Kotler’s “stimulus–response” model, and other behavioral frameworks hold an important place. According to the Engel–Kollat–Blackwell model, the consumer’s decision-making process consists of the stages of problem recognition, information search, evaluation of alternatives, purchase, and post-purchase behavior. The digital environment influences each of these stages, particularly accelerating and expanding the phases of information search and comparison of alternatives.

In the “stimulus–response” model, alongside marketing stimuli, social, cultural, and personal factors are presented as the main determinants of consumer behavior. Under the conditions of the digital economy, these stimuli have taken new forms such as algorithmic advertising, personalized content, influencer marketing, and user experience (UX). Thus, theoretical analysis shows that although classical consumer behavior models remain relevant in the digital economy, their content must be integrated with new technological and social realities. This makes it necessary to study the transformation of consumer behavior models both in theoretical and empirical dimensions.

4 Transformation of Consumer Behavior in the Digital Environment

As noted, the formation of the digital economy has created systemic changes in the structure and content of consumer behavior. In traditional market conditions, consumers relied mainly on information flows limited to mass media and physical sales spaces, whereas in the digital environment, the volume of information is vast and increasingly personalized. For this reason, the essence of the consumer decision-making process has changed at all stages — recognition of need, information search, evaluation of alternatives, purchase, and post-purchase behavior — making it necessary to adapt the aforementioned behavioral models to the digital economy.

Digital platforms have significantly reduced consumers’ information costs, simplified product and service comparisons, enabled price monitoring and access to user reviews, and made decision-making faster, while at the same time more directed through algorithmic recommendations and social proof mechanisms. As we know, artificial intelligence-based recommendation systems applied by Amazon, Google, Meta, and other platforms shape the choice environment based on consumers’ previous behavior, thereby placing consumer economic behavior under the influence of technological architecture.

Consumer purchasing behavior has been shaped by artificial intelligence-based recommendation systems and providing customer satisfaction has been relatively more important for companies. Businesses should also focus on ensuring that these systems operate on a transparent, secure and ethical basis. Only in this case can it be said that the systems work successfully and effectively. The fact that the consumer acts with the recommendations of these systems in all stages before, during and after the purchase is an important determinant in the purchasing decision process. From this perspective, businesses operating in the electronic environment in particular need to be sensitive in the functionality of artificial intelligence-based recommendations and have a futuristic structure [6].

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The Fourth Industrial Revolution and the development of digital technologies have led to social transformation in human history, changing many areas — from communication styles to work practices, from concepts of entertainment to

socialization and shopping habits. Customer–brand/company interactions have been transformed, giving rise to new trends. Overall, the modern digital world plays a special role in the transformation of consumer behavior, as user reviews, ratings, and influencer content formed in digital networks enjoy higher levels of trust compared to traditional advertising tools. As a result, consumers possess extensive information and make decisions not only based on firms’ provided data but also on the experiences of other users and the norms formed by digital communities. This demonstrates that the “subjective norms” factor highlighted in Ajzen’s Theory of Planned Behavior has stronger influence in the digital economy environment.

Digitalization has also transformed relationships among producers, consumers, and brands. Whereas in the traditional model interaction was mainly limited to the act of sale, in the digital environment these relationships acquire a continuous character through ongoing communication, personalized offers, online services, and post-purchase support. This increases the importance of factors such as user experience (UX), digital trust, and data security in shaping consumer satisfaction and brand loyalty.

The Snob Effect, which explains consumer behavior, in the digital economy is characterized by consumers rejecting mass-produced products and preferring rare, exclusive, and status-oriented digital goods and services. In this context, the snob effect manifests itself in consumers choosing products and services to differentiate from mass use and to demonstrate social status. Platforms reinforce this behavior through artificial exclusivity, premium memberships, and limited access mechanisms. The reasons that further strengthen the snob effect in the digital economy include:

- Status visibility (likes, followers, badges, blue ticks)
- Ease of comparison
- Artificial creation of exclusivity

Among the socio-psychological effects explaining consumer behavior, the Veblen Effect in the digital economy is characterized by high prices creating social status and symbolic capital rather than functional value of digital goods and services. This leads to increased demand through premium subscriptions, expensive NFTs, and elite platform models.

As we know, the Bandwagon Effect refers to the behavior of people choosing a product, service, or idea simply because others do. In this case, demand is driven not by individual need but by the tendency to join the crowd.

In the digital economy, this effect is stronger because:

- User numbers are publicly visible
- Social proof is constantly presented visually
- Decisions are often made emotionally and quickly

Thus, in the digital economic environment, consumer behavior is transformed not only technically but also socio-psychologically, turning the consumer from a passive market

5 The Impact of Data on Consumer Behavior

In the era of digital transformation, big data has become a critical tool for all economic actors. Through analytical instruments, businesses gain opportunities to better understand consumer needs, design personalized offers, and optimize decision-making processes. Research results show that big data enhances the effectiveness of marketing strategies and influences consumer behavior.

As we know, the main components of big data technology include several key stages: data collection, data storage, data processing, and data analysis. The initial stage involves gathering information from multiple sources such as social media, online transactions, sensor data, and customer interactions. The volume of collected data is enormous, and effective collection, integration, and analysis often require automated tools and technologies. Traditional data storage solutions may struggle with the size and complexity of large-scale information, which is why cloud-based storage systems are increasingly applied.

Advanced analytics — including machine learning, predictive analysis, and data mining — can be used to inform business strategies, improve customer experience, and foster innovation. By analyzing consumer behavior and preferences, companies can personalize marketing campaigns more effectively, increase engagement and sales, and thereby accelerate the growth rate of the global economy.

Research shows that year after year, consumer behavior in the digital economy is characterized by high online activity (more than 85% of internet users engage in online shopping). The digitalization of trade influences consumer behavior in the following ways:

- **Influence of social media:** Especially in developing markets, social media plays a major role in product and service research.
- **Attention to brand values:** Focus on social and environmental aspects has increased, while traditional brand loyalty has declined.
- **Mobile shopping and digital payments:** These have become standard practices.
- **Trust in digital reviews:** Consumers rely heavily on digital reviews and information before purchasing, driven by convenience and the tendency to make informed decisions.
- **Demand for personalized experiences:** Consumers prefer individual and customized offers.

- **Convenience and informed decision-making:** Shoppers aim to make easier and more informed choices.

The digital economy can therefore be seen as a broad range of economic activities which use digitized information and knowledge as key factors of production. The internet, big data, cloud computing, financial technology (fintech) and other new digital technologies are used to collect, store, analyze, share information digitally, transform social interactions and create a globalized market place. The digitization of the economy brings about benefits and efficiencies as digital technologies facilitate innovation create job opportunities and foster economic growth. The digital economy also spreads through all facets of society. It is therefore influencing agent in consumer behaviour, other levels of interactions and bringing about great sociological changes [7].

6 Empirical Analysis of the Impact of the Digital Economy on Consumer Behavior

Various analyses have shown that approximately 81% of retail shoppers conduct initial online research before making a purchase decision. This once again demonstrates that online information search has become an essential part of the purchasing process for modern consumers.

In recent years, online shopping has gained significant popularity across the European Union, reflecting a profound structural shift in retail logistics and buyer habits. According to longitudinal data compiled by Eurostat (2023), 75% of surveyed individuals in the EU reported purchasing or ordering goods and services online for personal use within the preceding 12 months. This represents a substantial increase from 2013, where the e-commerce penetration rate stood at 57% (Eurostat, 2013). This macro-level growth highlights not only an increase in transaction volumes but also a qualitative evolution in consumer motivations. While the digital landscape in 2013 was primarily driven by basic functional conveniences such as online product browsing and home delivery options, the contemporary digital consumer in 2023 prioritizes advanced interactive values. These include 24/7 continuous platform availability, instant cross-platform price comparison mechanisms, and highly tailored, AI-driven personalized product recommendations that streamline the dynamic decision-making process.

Globally, the development of the digital economy is systematically transforming consumer online shopping behavior — more people are making purchases via the internet, prioritizing different product categories, and businesses are adapting their sales strategies to online platforms. These trends empirically support the impact of the digital economy on consumer purchasing decisions.

Erkan and Evans carried out a study on the influence of electronic word of mouth (EWOM) on consumers' online purchase intentions. Multiple linear regression analysis was employed to test each hypothesis. The study empirically tested and compared the influence of friends' recommendations on social media and anonymous reviews on shopping websites in the context of online purchase intention. The researchers analyzed the impacts of these two platforms based on the components of information adoption model (IAM) which were borrowed as information quality, information credibility, information usefulness and information adoption. Survey was conducted and the results revealed that anonymous reviews were more influential on consumer' online purchase intentions than friends' recommendations on social media [2].

Conclusion

The development of the digital economy has led to fundamental changes in consumer behavior. Analysis and empirical data show that digital platforms, social media, artificial intelligence-based recommendation systems, and big data technologies have accelerated, personalized, and made consumer decision-making more interactive. Classical consumer behavior models remain relevant in the digital environment, but their adaptation to technological and social realities is necessary.

In the digital environment, consumers are no longer passive buyers but have become active actors who generate information and influence market behavior. Socio-psychological effects such as the Snob, Veblen, and Bandwagon effects have intensified under the conditions of the digital economy, increasing the social and status motivations behind consumer choices of goods and services. Big Data and analytical tools expand opportunities for personalized offers and informed decision-making, thereby enhancing the effectiveness of marketing strategies.

Empirical findings confirm that the growth of online shopping, the influence of social media, and reliance on digital reviews validate the transformation of consumer behavior. This holds practical significance for business entities in terms of optimizing marketing strategies, strengthening consumer trust, and building sustainable business models.

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Development of a Self-Assessment-Based Fertility Estimation System

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Abstract: Infertility is a complex reproductive health issue shaped by biological, psychological, lifestyle-related, and social factors. This research presents the development of a self-assessment-based fertility scoring system that supports fertility awareness without relying on laboratory hormone testing. The system uses questionnaire data on menstrual cycle characteristics, reported symptoms, lifestyle-related and exogenous factors, and timing-related variables to generate structured, non-diagnostic feedback. The methodology is based on a rule-based evaluation framework implemented as a web-based prototype in a Python–Flask environment with modular JSON-based configuration layers. User responses are processed into item-level, domain-level, and overall scores, supported by missing-value handling, category labels, visual feedback, and explanatory notes. The contribution of the system lies in its transparent and reproducible scoring architecture rather than clinical diagnosis. Future work will focus on score calibration, consent-based data collection, clinical validation, and possible machine learning integration after suitable datasets become available.

Keywords: fertility scoring system; self-assessment; reproductive health; fertility awareness

1 Introduction

Infertility is one of the most complex reproductive health challenges today, as it affects not only biological functioning but also psychological well-being, social quality of life, and economic stability [1] [2]. Female fertility is shaped by the interaction of hormonal, lifestyle-related, environmental, psychological, and socio-economic factors. For this reason, fertility preservation cannot be reduced to clinical treatment alone. Early awareness, prevention, and lifestyle-related self-reflection also play an important role in supporting reproductive health [3] [4].

According to the WHO, approximately one in six couples of reproductive age experience some form of fertility difficulty [5]. Although assisted reproductive technologies have developed significantly, treatment is often expensive, physically demanding, and emotionally burdensome, while success is not guaranteed [6] [7].

This highlights the need for accessible tools that can support early recognition and help users understand which personal, behavioural, or health-related factors may be relevant before clinical intervention becomes necessary. Several factors that influence fertility are modifiable, including nutrition, sleep, physical activity, smoking, alcohol consumption, and stress [8]. Digital self-assessment systems can therefore create value by translating these factors into structured feedback. Such systems can improve reproductive awareness, support informed decision-making, and encourage timely consultation with specialists when relevant patterns appear.

At the same time, the current fertility application market shows important limitations. Many widely used menstruation and fertility tracking applications mainly focus on cycle tracking, ovulation prediction, reminders, and user engagement, while their clinical relevance and integration into care remain variable [9] [10]. Sensor-based systems, such as Ava or similar wearable fertility technologies, provide more advanced physiological measurements, but they often require external devices, paid access, or closed algorithmic processing [11]. Educational and awareness-oriented tools can support fertility knowledge and early self-reflection, but their feedback is often static, general, or limited in personalization [12] [13]. In addition, reproductive health applications raise important concerns regarding transparency, data protection, and user privacy [14]. As a result, there is still a gap for a transparent, modular, and scientifically grounded system that gives immediate, interpretable feedback without requiring laboratory hormone testing, external sensors, or paid access.

The present research addresses this gap through the development of a self-assessment-based fertility scoring system. The aim is to create a transparent, rule-based, and non-diagnostic assessment framework that uses structured questionnaire data to support reproductive self-awareness. The system is positioned as an engineering-oriented educational prototype: it applies modular processing logic and interpretable output to help users recognize fertility-related patterns and identify areas where professional consultation may be useful.

2 Methodological framework

The developed fertility scoring system was designed as a self-assessment-based framework that translates user-reported information into structured fertility-related indicators. The methodological starting point was a previous conceptual model that organized female fertility determinants into endogenous and exogenous factors [15]. That earlier model included several hormonal, biochemical and clinical indicators, such as AMH, FSH, TSH, ovarian reserve, ovulatory function and uterine health. These variables are clinically relevant, but they are not suitable for a general self-assessment tool, because most users do not have access to laboratory

values or specialist diagnostic results [16]. For this reason, the present system shifts the focus from hormone-based modelling to questionnaire-based assessment.

The aim of this methodological shift was to create an accessible educational screening logic based on observable or reportable indicators. In the absence of laboratory data, the system uses variables that may indirectly reflect underlying reproductive processes, such as menstrual cycle length, cycle variability, bleeding patterns, pain, diagnosed conditions, lifestyle habits, sleep, stress, body mass index and intercourse timing. These factors cannot provide diagnostic certainty, but they can support early awareness and self-reflection, especially when several less visible risk patterns appear together [4]. In this sense, the system follows the broader logic of fertility-awareness-based approaches, where self-observation is used as a tool for reproductive education and early recognition rather than as a substitute for clinical diagnosis [17].

The questionnaire was built around five assessment domains: cycle and ovulation, lifestyle and exogenous factors, pain and symptoms, demographics and medical history, and timing/partner-related factors. These domains were not created as arbitrary categories. They reflect the main functional areas through which fertility may be influenced in a self-assessment context. The cycle and ovulation domain represents the most direct observable proxy of hormonal and ovulatory function, because ovulation, cycle regularity and luteal phase adequacy are central biological conditions of conception [18]. The lifestyle and exogenous domain captures modifiable behavioural and environmental factors, such as BMI, sleep, stress, smoking, alcohol consumption and environmental exposures, which may influence hormonal balance, metabolic function and reproductive outcomes [8] [19]. The pain and symptoms domain collects signs that may indicate reproductive or endocrine disorders, including endometriosis, PCOS, thyroid dysfunction and hyperprolactinaemia [20] [21]. The demographics and medical history domain covers background factors, such as age, previous pregnancy, trying time and family history, which strongly shape reproductive probability but are only partly modifiable [22] [23]. Finally, the timing and partner-related domain reflects behavioural and relational conditions that may affect the chance of conception, especially intercourse frequency and timing during the fertile window [24] [25].

The questionnaire items were selected from the literature according to three practical criteria. First, the factor had to be relevant to female fertility or fertility-related awareness. Second, it had to be answerable by a non-clinical user without laboratory testing. Third, the answer had to be transformable into a transparent scoring rule. This means that the system does not ask for every possible medical detail, but focuses on variables that can be interpreted in a structured and reproducible way. For example, cycle length, luteal phase length, BMI, sleep duration and age can be handled as scale variables, while smoking status, diet type, diagnosed conditions and ovulation tracking can be handled as categorical variables. This design supports both usability and methodological clarity. The five-domain structure also serves an engineering purpose. It separates heterogeneous

information into smaller, interpretable modules. Instead of producing only one overall score, the system first evaluates each domain separately. This makes it possible to show which area contributes most strongly to the result. It also avoids the main weakness of a single undifferentiated score: the loss of information. For example, a low score caused by irregular cycles has a different meaning from a low score caused by smoking and sleep deprivation, even if the numerical value is similar. Domain-level evaluation therefore improves interpretability and supports more targeted educational feedback.

Overall, the methodological framework should be understood as a non-diagnostic, literature-based decision-support structure. Its purpose is to organize self-reported information and highlight potentially relevant patterns, not to replace gynecological, endocrinological or reproductive medical evaluation.

3 Scoring and evaluation logic

The scoring logic was developed to convert heterogeneous questionnaire answers into comparable, interpretable indicators. Since primary clinical data were not available, the scoring rules were derived from published literature and from the relative biological relevance of each factor. The aim was not to define exact medical probabilities, but to create a transparent relative ordering of responses within each question or smaller question group, while using domain weights and cap rules to reduce the limitations of simple numerical averaging. In this logic, an answer receives a higher score when it is closer to the fertility-related optimum described in the literature, and a lower score when it represents a less favourable or more concerning pattern.

Each item was evaluated on a 0–100 scale. The maximum value indicates the most favourable category within the given question, while lower values indicate increasing deviation from the expected optimum. The size of the reduction depends on the reported importance of the factor, the seriousness of the deviation and the likely reversibility of the condition. For example, a mild lifestyle deviation receives a smaller reduction than a diagnosed reproductive disorder, because its biological effect is usually less direct and more modifiable. By contrast, a very short luteal phase receives a stronger reduction because luteal phase insufficiency may affect endometrial preparation and implantation [26] [27]. Severe BMI deviation is also scored more strictly, because both underweight and obesity are linked to impaired reproductive function [28]. Similarly, diagnosed endometriosis receives a strong reduction because it may affect fertility through inflammatory, anatomical and endometrial mechanisms [29].

The system uses different scoring patterns depending on the nature of the variable. Some items are scored as nominal categories, such as diet type or smoking status.

Others are ordinal, such as perceived stress level or pain severity. Scale variables, such as age, BMI, cycle length, sleep duration and luteal phase length, are scored according to biologically meaningful ranges. In several cases, the relationship is not linear. BMI requires a U-shaped interpretation, because both very low and very high BMI values may be unfavourable for reproductive function [28]. Age also requires non-linear interpretation, because fertility decline becomes stronger after specific reproductive age thresholds [22] [30]. This approach makes the model more flexible than a simple linear point system.

Domain scores are calculated from the item scores belonging to the same domain. The result expresses how close the user's responses are to the favourable range within that area. The final score is then calculated from weighted domain scores. The weights reflect the relative importance of each domain in fertility-related assessment. The cycle and ovulation domain received the highest weight, 0.30, because ovulation, cycle regularity and luteal phase adequacy are among the most direct functional indicators of female fertility [18]. The lifestyle and exogenous domain received a weight of 0.25, because modifiable factors such as BMI, sleep, stress, smoking, alcohol consumption and environmental exposures can affect hormonal balance, metabolic function and reproductive outcomes [8] [19]. The pain and symptoms domain received a weight of 0.20, because symptoms and diagnosed conditions may indicate clinically relevant disorders, although their effect depends on severity, diagnosis and individual context [20] [21]. The demographics and medical history domain received a weight of 0.15, because age, previous pregnancy and family history are important but partly static factors [22] [23]. The timing and partner-related domain received a weight of 0.10, because it mainly represents behavioural and relational conditions rather than female biological function, but it can still modify the probability of conception [24] [31].

The weighting scheme was designed as a transparent compromise between biological relevance and educational usefulness. An equal distribution of weights would not have reflected the stronger reproductive role of ovulation and cycle function. At the same time, giving excessive weight to pain and symptoms could have distorted the overall result, because some symptoms are important warning signs but do not affect every user in the same way. The final distribution therefore preserves the dominant role of cycle and ovulation indicators, while still giving meaningful weight to lifestyle, symptoms, background factors and timing behaviour.

Missing values are handled separately from unfavourable answers. If a user does not know an answer, or if a question is not applicable, the system does not automatically treat this as a negative fertility indicator. Instead, missing items are excluded from the relevant score calculation and reflected in a completeness indicator. This prevents the final result from being distorted by unavailable information. At the same time, the completeness value tells the user how much of the model could actually be evaluated. This is important because a high score with low completeness is less informative than a high score based on a more complete

response profile. The domain and overall scores are interpreted through broad score bands. Scores of 80 or above indicate a high category, scores between 65 and 79 indicate a medium category, and scores below 65 indicate a low category. These categories should not be read as diagnostic labels. They are interpretive bands that help users understand the result more easily. Their main function is to support communication and visualization, not to define strict medical thresholds.

In addition to ordinary scoring, the system applies override and cap rules. These rules are necessary because some fertility-related situations cannot be represented accurately by simple averaging. In a purely additive model, several favourable answers could compensate for a clinically important warning sign. This would be misleading in cases where the biological limitation is strong or threshold-like. For example, hysterectomy requires a strict cap because the anatomical basis of natural gestation is absent [32]. Very long cycles or very few menstrual periods require strong limitation because they may indicate amenorrhoea or severe ovulatory dysfunction. Advanced reproductive age and extreme BMI values also require cap logic, because they are linked to sharp declines or disruptions in reproductive function [22] [25] [33] [34]. Diagnosed endocrine or inflammatory conditions may also limit the maximum score when they indicate specific reproductive risk patterns [35] [36] [37] [29].

The purpose of the cap logic is to preserve biological plausibility. If a factor indicates a strong functional limitation, the score should not remain high simply because other domains are favourable. Similarly, some combined patterns may be stronger than the sum of their individual components, such as high stress with very short sleep [38], smoking with frequent alcohol consumption [39] [40], or irregular cycles with androgenic symptoms. These rules reduce the risk of misleading compensation effects. The override system also supports educational feedback. Some rules do not only reduce or cap the score, but also trigger explanatory notes. These notes help the user understand why a specific pattern may be relevant and when medical consultation may be reasonable. In this way, the scoring logic is not a black-box prediction mechanism. It is a transparent evaluation framework in which each score, cap and comment can be traced back to a predefined rule and a fertility-related rationale.

4 System architecture and implementation

To make the scoring logic operational, the fertility scoring system was implemented as a modular web-based prototype using a Python–Flask backend and a lightweight HTML–JavaScript frontend. The architecture follows a layered logic in which the questionnaire interface, configuration files, validation layer, scoring engine, and result presentation are separated. This structure was selected because the system functions both as a user-facing tool and as a research prototype. Therefore, the

technical design had to remain simple, auditable, and easy to modify. A more complex cloud-based or microservice architecture would have introduced unnecessary dependencies at this development stage.

A central design decision was the use of JSON-based configuration files for both the questionnaire structure and the scoring rules. The questionnaire schema defines the questions, answer types, response options, domains, and input constraints, while the scoring configuration stores score ranges, domain weights, and override rules. This separates the model logic from the application code. As a result, new questions, modified score ranges, or updated override rules can be introduced at the configuration level without rewriting the backend or frontend logic. From an engineering perspective, this supports maintainability and version control; from a methodological perspective, it makes the rule set inspectable.

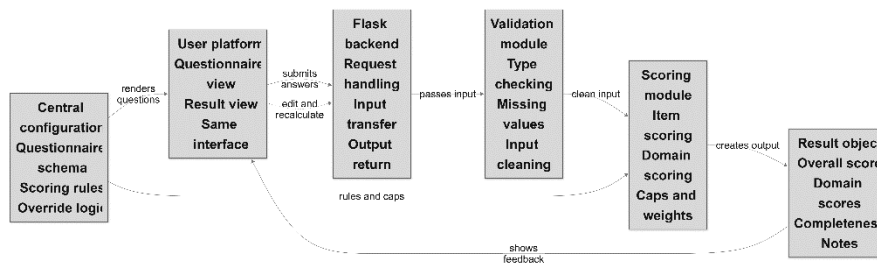


Figure 1
System architecture – data flow

The questionnaire is automatically rendered from the central configuration layer. The user interface is therefore not manually hard-coded question by question, but generated from the same structured source that defines the assessment logic. This reduces the risk of inconsistency between the displayed questionnaire and the variables used by the scoring model. It also supports later extension, because changes in the questionnaire schema can be reflected in the interface without restructuring the whole application. The data flow of the system is shown in Figure 1.

The backend was implemented in Python with Flask because this combination is lightweight, readable, and appropriate for a research-oriented prototype. Python supports the implementation of validation, scoring, and data-processing logic, while Flask provides simple endpoints for loading the questionnaire and calculating the score. In the current version, the backend acts as a controlled communication layer between the frontend, the validation process, and the scoring engine, rather than as a large-scale commercial application framework. After submission, the validation layer checks type compatibility, expected input ranges, and missing-value markers before passing a cleaned response object to the scoring engine. This step ensures that the scoring engine receives structured and processable input. It also separates input validation from score calculation, which makes the system easier to test and maintain.

The scoring engine is the computational core of the system. It reads the scoring configuration, calculates item-level values, aggregates them into domain scores, applies domain weights, and executes the predefined override and cap rules. The calculation is deterministic: identical input under the same configuration version produces identical output. This was chosen deliberately, because the current research phase does not yet include a clinically validated dataset that would justify machine learning-based prediction. A rule-based engine is therefore more appropriate at this stage, as it remains explainable and controllable. The result is returned as a structured output object containing the overall score, domain scores, completeness values, category labels, and explanatory notes. This output is displayed on the same user platform where the questionnaire was completed. The circular data flow supports usability, because the user does not leave the interface after submission. It also supports the educational function of the system, since answers can be modified and recalculated, allowing the user to observe how changes in selected variables influence the output.

The current implementation operates as a local and stateless prototype. Submitted answers are processed only for score calculation and are not stored by default. This design was selected because fertility-related data are sensitive and because the primary aim of the prototype is to test the model logic rather than to collect user data. Future versions may introduce online deployment and data storage, but this would require a separate consent and data-protection framework.

5 User feedback and interpretability

The user feedback layer was designed to make the fertility scoring logic understandable, not only visible. Since the system has an educational purpose, the interface cannot simply display a numerical result. It must help the user understand what the result means, which domain influenced it, and why certain answers may be relevant. For this reason, the output combines an overall score, domain-level scores, category labels, completeness information, visual representation, and explanatory notes.

The system presents domain-level scores in addition to the overall score. This design allows the user to see whether the result is mainly influenced by cycle and ovulation patterns, lifestyle-related factors, pain and symptoms, demographic or medical background, or timing-related behaviour. This is important because two users may receive similar overall scores for very different reasons. By showing the domain profile, the system makes the output more specific and prevents the interpretation of fertility-related status as one homogeneous number. Each domain score is assigned to a broad category: high, medium, or low. These categories are not diagnostic labels, but communication tools. Their role is to reduce cognitive load and make the numerical output easier to interpret. In a self-assessment context,

users may not know whether a score such as 72 or 84 is meaningful. Category labels provide a first layer of interpretation, while the detailed numerical scores preserve transparency. The completeness indicator shows how much of the questionnaire could be evaluated based on the submitted answers. This helps users interpret the reliability of the output. A high score based on nearly complete information is more informative than a high score based on many missing answers. By displaying completeness separately, the system makes the limits of the result visible without treating unknown information as an unfavourable fertility-related factor.

The radar chart was selected as the main visual output because it represents the five-domain profile in a compact form. This is useful in a short educational report, where the goal is not to present complex statistical results, but to show balance or imbalance between functional areas. The chart allows users to see whether the profile is evenly strong or whether one domain is clearly weaker than the others. In this way, the visual output seen in Figure 2. connects the numerical score to concrete areas of reproductive health.

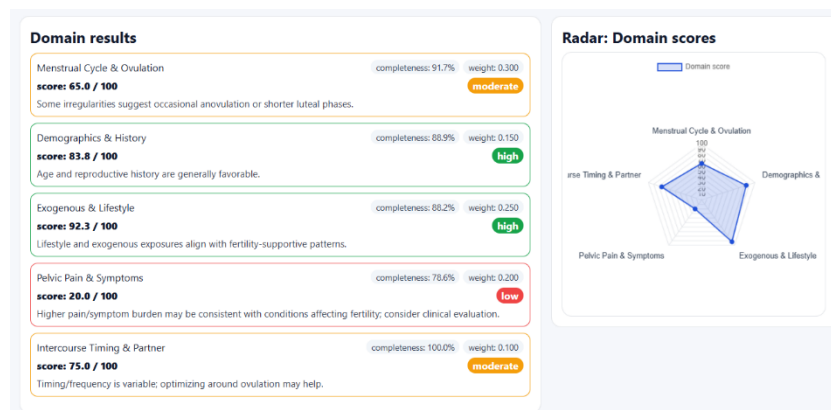


Figure 2
Visualisation of the domain results

The interface was also designed to keep the questionnaire and the result on the same platform. This is important because the system is not only a calculator, but a learning environment. If the result appeared in a separate document or disconnected report, the user would be less able to connect the output to the original answers. By keeping the questionnaire, result cards, chart, and explanatory notes in one interface, the system supports immediate comparison between input and output. This also enables recalculation: the user can change an answer and observe how the result changes. This interactive mechanism strengthens self-reflection and makes the scoring model more understandable.

Explanatory notes connect the score to the scientific logic behind it. When a response or response combination activates a relevant rule, the system can display a short explanation of why the factor matters. For example, notes may be triggered

by very short or long cycles, low or high BMI, short sleep, high stress, severe menstrual pain, diagnosed PCOS, endometriosis, or prolonged trying time. Their purpose is to make the scoring logic traceable and to help users recognize when professional consultation may be reasonable.

Overall, the feedback layer turns the scoring result into an interpretable educational output. The user can see the domain structure, the numerical values, the completeness of the input, the visual profile, and the explanatory comments. This makes the system more suitable for educational, research, and awareness-raising use than a single unexplained fertility score.

6 Discussion and limitations

The developed fertility scoring system occupies a specific position among existing fertility-related digital tools. Many commercial applications focus mainly on cycle tracking, ovulation prediction, reminders, community functions, or user engagement. Sensor-based systems can provide more advanced physiological input, but they often require additional hardware, paid access, or closed algorithmic processing. Educational tools support fertility awareness, but their feedback is often static or only weakly personalized [12] [13]. In contrast, the developed system combines an educational purpose with an interactive and rule-based scoring architecture. Its main contribution is not clinical prediction accuracy, but the creation of a transparent framework that converts self-reported fertility-related information into structured and interpretable feedback.

The system creates value through accessibility, transparency, and modularity. It does not require laboratory hormone values, wearable sensors, registration, or paid access, which makes it suitable for early-awareness and educational contexts. Its logic is also explicitly documented: the questionnaire items, domain structure, scoring rules, domain weights, missing-value handling, and override rules are stored in a modular configuration layer. This means that the assumptions behind the output are visible and can be reviewed, updated, or tested. From an engineering perspective, this supports maintainability and reproducibility. From an educational perspective, it helps users understand that the output is not a hidden prediction, but the result of predefined, interpretable evaluation logic.

A central methodological issue is that the current scoring model is based on literature-supported relative ordering rather than clinically calibrated probability estimation. The score assigned to an answer indicates that one response category is more or less favourable than another within a given question or domain. However, the exact numerical distance between two scores should not be interpreted as a precise biomedical measurement. For example, the difference between 80 and 65 does not necessarily have the same meaning in cycle length, BMI, sleep duration,

pain severity, or diagnosed endometriosis. The system can justify why one category is placed below another, but it cannot yet fully justify whether a specific deduction should be 5, 10, or 15 points. This is an important limitation of the current prototype.

This limitation is especially relevant because the model operates in a heterogeneous factor space. The questionnaire combines biological, behavioural, demographic, symptomatic, medical-history, and timing-related variables. These variables differ in measurability, reversibility, clinical seriousness, and causal proximity to fertility. A lifestyle factor such as moderate caffeine intake is not methodologically equivalent to a diagnosed condition such as endometriosis, even if both are represented numerically. Similarly, a missing ovulation-tracking answer has a different meaning from a missing diagnosis-related answer. For this reason, the system cannot rely on simple averaging alone.

The use of domain weights, completeness indicators, and override rules is an attempt to manage this heterogeneity. Domain weights ensure that more direct biological indicators, especially cycle and ovulation variables, have a stronger influence on the overall score. Completeness values prevent missing information from being treated as an unfavourable answer. Override and cap rules protect the result from biologically implausible compensation effects, where favourable answers in one area would otherwise hide a clinically important warning pattern in another. For example, healthy lifestyle responses should not fully compensate for amenorrhoea, premature ovarian insufficiency, hysterectomy, or strong symptom combinations suggesting a reproductive disorder. In this sense, the system already moves beyond a simple relative scoring table and applies a more structured evaluation logic. Nevertheless, the current system should be interpreted as a first-stage educational prototype. It has not yet been clinically validated, and its scoring rules are based on literature review and logical modelling rather than empirical calibration. The output should therefore not be read as a medically confirmed probability of infertility. It is more appropriate to interpret the result as a structured awareness profile that highlights potentially relevant fertility-related patterns. This distinction is essential, because self-reported questionnaire data can be incomplete, uncertain, or misunderstood. The completeness indicator helps communicate this uncertainty, but it cannot fully eliminate the limitations of self-reporting. Future development should therefore focus on strengthening the scoring structure and testing the model's behaviour. Sensitivity analysis could show how strongly each question, domain, and override rule influences the final output. Synthetic scenario testing could help identify whether the system behaves plausibly in typical, borderline, and extreme cases. The current relative scoring logic should also be complemented by clearer impact categories, such as low-impact, moderate-impact, high-impact, and critical factors. This would make the model less dependent on small numerical differences and easier to defend scientifically.

A further development direction is consent-based data collection. The current prototype does not store user responses, which is appropriate for privacy protection during the initial phase, especially because fertility-related data are sensitive.

However, empirical validation requires structured data collection, ethical approval, a clear consent form, and GDPR-compliant data handling. Online deployment would also require secure hosting, database design, anonymization procedures, and user-rights management. Only after such data are available would machine learning integration become methodologically justified. Even then, data-driven models should not replace the current interpretability logic, but should support score refinement, calibration, and comparison between rule-based and empirical patterns.

Conclusions

This research presented the development of a self-assessment-based fertility scoring system designed to support reproductive awareness through structured and interpretable feedback. The system translates questionnaire data on cycle patterns, lifestyle and exogenous factors, pain and symptoms, demographic and medical history, and timing-related behaviour into domain-level and overall scores. Its contribution lies in the transparent architecture of the scoring framework: questionnaire items, scoring rules, domain weights, missing-value handling, and override logic are organized in a modular and reproducible way. The system should be understood as an educational prototype rather than a clinical diagnostic tool. Its current scoring logic provides literature-supported relative ordering, while future work should focus on score calibration, validation, and consent-based data collection.

Overall, the fertility scoring system offers a scalable and transparent approach to digital fertility awareness. By combining accessibility, modularity, and interpretability, it can support users in recognizing relevant reproductive patterns and can serve as a basis for future research-oriented and clinically validated reproductive health tools.

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Assessing Green Mindset Institutionalization in Azerbaijan's Higher Education: Evidence from UI GreenMetric and THE Impact Rankings

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Abstract: The purpose of this article is to evaluate the institutionalization of the green mindset in Azerbaijan's higher education by analyzing long-term sustainability performance trends using UI GreenMetric World University Rankings and the Times Higher Education Impact University Rankings (THE Impact Rankings) data from 2021 to 2025. The study focused on selected universities in Baku, Azerbaijan. Data collected for this study were quantitatively examined using a longitudinal comparative approach that utilized an unbalanced panel dataset and applied descriptive trend analysis and Spearman's Rank Correlation Coefficient. The results of the article showed modest increases in UI GreenMetric rankings over the past five years, variability in THE Impact Rankings, and weak or no statistically significant correlations between universities' internal sustainability practices and their external SDG performance. The findings show that increases in internal sustainable practices do not translate into greater international awareness of universities' SDG impacts. Further, the study presents preliminary evidence of a developing yet incomplete sustainability institutionalization process in Azerbaijan's higher education system. The study contributes to exploratory evidence for the institutionalization of sustainability in higher education in Azerbaijan, indicating both progress, and persistent issues in aligning campus-based environmental management to broader sustainable development goals. Given the small sample size and methodological limitations, results are interpreted cautiously as emerging patterns rather than definitive conclusions.

Keywords: Sustainability, sustainable development goals (SDGs), The impact rankings, UI (Universitas of Indonesia) GreenMetric, higher education, Azerbaijani universities

1 Introduction

Universities across the world are widely recognized as key players in promoting sustainable development through their core functions of education, research, campus operations, and community engagement. Beyond supporting individual environment-related initiatives, universities are expected to establish an integrated institutional commitment to sustainability, known as the institutionalization of a

"green mindset". This concept includes the incorporation of environmental awareness, sustainability values and responsible behavior into organizational structures, governing documents and educational environments [5, 15].

A sustainable "green" mindset in higher education goes beyond infrastructure improvements and operational efficiencies. It reflects institutional commitment to sustainability that shapes decision-making processes, curriculum design, research priorities, and public engagement strategies [12]. In this regard, sustainability benchmarking rankings such as the UI GreenMetric World University Ranking and the Times Higher Education (THE) Impact Ranking allow institutions to measure their progress toward achieving goals related to environmental management and the United Nations Sustainable Development Goals (SDGs). The UI GreenMetric focuses on campus-based environmental performance metrics - including energy efficiency, waste management, water usage and sustainability education- while the THE Impact Rankings examines institutional contributions towards achievement of each of the 17 SDGs, including climate action, quality education, and responsible consumption [5, 7].

Universities around the world are being pressed by a variety of stakeholders including, students, faculty, funders and governments to have tangible commitments to sustainability and to showcase their contributions to addressing complex environmental and social challenges [11]. This demand has also increased competition amongst universities to improve their position within various types of sustainability-related rankings, which can enhance institutional reputation, attract resources, and recruit high-quality students and faculty [9]. As a result, universities are increasingly investing in sustainability initiatives, research programs, and partnerships to differentiate themselves and fulfill their social and environmental responsibilities.

In the emerging sustainability context, including Azerbaijan, limited empirical evidence is available on how universities align their internal sustainability practices with external recognition of the SDGs. Azerbaijan's higher education sector is witnessing growing participation in international sustainability rankings, with the number of institutions represented in THE Impact Rankings growing from 18 to 28 between 2024 and 2025, representing 60% of all higher education institutions in the country. This participation rate is higher than the regional average of 5-35% in the South Caucasus and Central Asia, suggesting an emerging institutional commitment to sustainability reporting and assessment.

Despite greater involvement from Azerbaijan's universities in improving their sustainability, there have been few studies that examine the overall trend of sustainability performance at these institutions or the relationship between the environmental practices implemented on campuses, and their contribution to the SDGs. Therefore, it will be important to determine if improvements in institutional environmental management shown through UI GreenMetric, reflect improvements in how the institutions position themselves related to the SDGs through THE Impact

Rankings. This analysis can provide an indirect, however quantifiable measure to assess the degree of institutionalization of the green mindset in higher education.

Hence, this paper studies selected Azerbaijani universities using longitudinal data from UI GreenMetric and THE Impact Rankings from 2021 to 2025. The research focuses on seven institutions: Baku State University (BSU), Azerbaijan State Economic University (UNEC), Western Caspian University (WCU), Azerbaijan University of Architecture and Construction (AUAC), Azerbaijan State Oil and Industry University (ASIOU), Azerbaijan Technical University (ATU) and Baku Higher Oil School (BHOS). The study does not attempt to determine causal relationships instead, it examines descriptive trends and statistical associations between sustainability performance indicators and SDG positioning. This contributes exploratory evidence to thoughts surrounding sustainability institutionalization in Azerbaijani higher education and provides insights into the current stage of green mindset development within the sector.

2 Literature Review

2.1 University Sustainability and Green Campus Initiatives

Universities and their role in supporting sustainable development have gained academic attention in the last two decades. Higher education is now often seen not just as an educational institution but as a key agent of social transformation that can prepare future leaders, create new knowledge through research and promote sustainability [2, 12]. This expanded role is also consistent with the United Nations 2030 Agenda for Sustainable Development, which emphasizes the necessity of climate action and sustainable practices by all sectors of society.

The concept of "green campus" has emerged as a comprehensive framework for integrating sustainability into higher education operations and culture. Green campus initiatives encompass sustainable infrastructure, energy efficiency, waste management, sustainable transportation, water conservation, and environmental education [4, 5]. Research by Fachrudin et al. (2019) identified three critical factors for realizing green campuses: education, practical, and seminar activities; green campus campaigns through various media; and green applications including paperless initiatives and environmentally friendly practices. These factors demonstrated strong correlations, indicating their collective importance in raising awareness and promoting sustainability concepts within university communities.

Universities implementing green campus programs have reported significant progress in students' perception and adoption of sustainable habits, increased implementation of green infrastructures, and improved waste and resource

management [13]. Environmental education emerges as crucial for fostering ecological awareness, reducing institutions' ecological footprints, and preparing students for future environmental challenges. However, research also reveals persistent challenges in translating sustainability initiatives into systemic transformations and achieving genuine institutional commitment beyond public relations efforts [7].

The literature emphasizes that sustainable universities must integrate sustainability principles into their institutional structures, campus operations, and education-research activities across various disciplines [14]. This holistic approach requires universities to rethink their missions, restructure curricula, and integrate sustainability into all aspects of education and learning [10]. Universities are increasingly establishing sustainability centers to coordinate efforts, reduce environmental footprints, and contribute to developing green professions.

Despite growing attention to campus sustainability, studies reveal mixed results regarding the effectiveness of green campus initiatives in changing student behavior and awareness. Research by Hutcherson et al. (2013) found that community college students generally showed low awareness of campus sustainability efforts, though institutions with higher implementation levels and active promotion tended to have students with greater awareness and stronger pro-environmental attitudes. Similarly, Al-Nuaimi et al. (2022) found that while over 80% of surveyed higher education students grasped sustainability knowledge, this understanding decreased for attitudes and behaviors, with external factors such as social media and peer influence proving more impactful than traditional educational settings.

The concept of institutionalizing a "green mindset" extends beyond physical infrastructure to encompass the development of environmental consciousness, ethical awareness, and sustainable behavioral patterns among students and staff [17]. Research suggests that embedding sustainability in core courses, even in disciplines not traditionally associated with environmental studies, can effectively improve students' environmental awareness and sustainable mindset, influencing their behavior and encouraging green business ideas [17]. This finding underscores the importance of curriculum integration rather than relying solely on extracurricular initiatives or campus infrastructure improvements.

2.2 UI GreenMetric and THE Impact Rankings as Assessment Tools

The spread of sustainability assessment tools and ranking systems reflects the growing demand for transparent, comparable measures of university sustainability performance. Although several methods exist to assess or rank institutional sustainability activities globally, the UI GreenMetric World University Ranking and THE Impact Rankings are currently among the most prominent global assessment models. Launched by Universitas Indonesia in 2010, the UI GreenMetric

Sustainability Assessment Tool uses six key categories to measure the level of sustainability at each participating institution: setting & infrastructure, energy & climate change, waste management, water conservation, transportation, and education. The internationally accepted benchmark provided by this ranking model is designed to encourage institutions to continually enhance their sustainability performance and share successful strategies. By 2020, more than 900 institutions from 94 countries were ranked under the UI GreenMetric program. The metrics used within the UI GreenMetric framework include physical characteristics such as campus green space ratios, energy efficient building technologies, recycling programs, water-saving initiatives, alternative modes of transportation and the integration of sustainability principles into academic curricula and research [5]. However, UI GreenMetric has faced criticism for its relative simplicity compared to other assessment systems and for requiring data types that are generally less empirical and demanding than those used in alternative frameworks. Despite these critiques, the ranking has proven valuable in promoting sustainability awareness and facilitating international comparisons of university environmental performance [17].

THE Impact Rankings, launched in 2019, provide a global assessment of universities' contributions to the SDGs using a range of indicators including research output, teaching quality, knowledge transfer, and societal engagement [7]. The rankings evaluate performance across all seventeen SDGs, with universities required to submit data on SDG 17 (Partnerships for the Goals) and at least three additional SDGs of their choice. The methodology employs a weightage system to calculate overall scores, which are then used to create global rankings and SDG-specific rankings. This approach allows universities to showcase their strengths in particular sustainability domains while providing a comprehensive view of their overall SDG contributions. THE Impact Rankings are very different from other types of rankings of academia because they rank universities based on how well those universities can positively affect society and contribute to a more sustainable world, versus being ranked primarily based on the quality of research produced by that institution and its academic reputation. The changing focus is indicative of the change in the way we view higher education, where the social missions of institutions are becoming equally important as the historic roles of teaching and research [16]. THE Impact Rankings have become increasingly recognized as useful tools for measuring universities' impacts in terms of improving the environment; economically; and socially, and measuring them against SDGs.

Both ranking systems provide complementary assessments of university sustainability. UI GreenMetric focuses primarily on campus-level environmental management and operational sustainability. It provides quantifiable measures of the physical aspects of campuses and resources used by an institution. In contrast, THE Impact Rankings assesses the broader societal contributions and commitments of universities towards achieving SDGs through research outputs, educational programs, and community engagements focused on contributing to sustainable

development. The relationship between performance in these two systems offers insights into whether universities' internal sustainability practices align with their external SDGs contributions and visibility. Research examining the effectiveness of these ranking systems reveals mixed findings. While participation in rankings can motivate institutions to implement sustainability initiatives and track progress over time, rankings alone do not guarantee increased awareness or behavioral change among students and staff [17]. Furthermore, ranking methodologies may reflect participation patterns, reporting practices, and methodological changes across years, necessitating careful interpretation of results.

2.3 University Social Responsibility and Sustainable Development

The concept of University Social Responsibility (USR) has emerged as a framework for understanding higher education institutions' obligations to contribute to sustainable development and societal well-being. USR extends the principles of corporate social responsibility to the academic context, emphasizing universities' ethical responsibilities to minimize their ecological footprints, promote social equity, and contribute to economic development [3]. Universities' social responsibility encompasses their primary functions of research, teaching, and community service, through which they must increase their interdisciplinary focus and encourage critical thinking and effective citizenship [3]. As arguably the most important societal institution, universities play a crucial role in developing citizens capable of contributing politically, socially, culturally, and economically to just and progressive societies. Furthermore, universities are entrusted with molding global citizens who can contribute to achieving the SDGs. The integration of sustainability into university missions reflects a recognition that higher education institutions serve as centers of strategic rotation within educational systems and cornerstones of sustainable development, particularly in the globalized era [3]. This recognition stems from universities' multiple tasks and their continued importance in forming qualified human capital. Universities are expected to ensure dignified living conditions with regard to human rights by creating and maintaining the widest possible range of options for freely defining life plans, taking into account principles of fairness among and between present and future generations in the use of environmental, economic, and social resources.

The literature has shown that a university's responsibility is to serve as an agent of change for all sustainability-related issues, as well as be a place where students develop their awareness and skills to deal with future problems [10]. This role requires to establish sustainability through policy and practice, and train their graduates to become sustainability advocates. Programs and courses relating to environmental sustainability have experienced exponential growth along with growing interest in on-campus sustainability initiatives and incorporating sustainability across diverse disciplines. In addition to highlighting the importance

of stakeholder engagement, sustainable funding models, and the barriers to incorporating sustainability into existing academic processes [2], the literature also notes that operational changes, such as improving energy efficiency or reducing waste, are typically less difficult than changing curricula and research agendas. Developing a collaborative framework through alliances and networks will provide mechanisms for knowledge transfer, resource allocation and collective advocacy for sustainability in higher education.

In the context of Azerbaijan, the higher education sector's engagement with sustainability remains an emerging area of practice and research. As Azerbaijani Universities become increasingly involved in International Sustainability Rankings, it would appear that there is a greater awareness at the institutional level regarding sustainability as well as the desire to use these rankings as benchmarks of global standards. However, the extent to which Azerbaijani Universities are engaging in actual institutional transformation versus merely symbolic compliance with current international trends needs to be researched empirically. Understanding the alignment between universities' internal sustainability practices and their external SDG positioning can provide insights into the depth and authenticity of sustainability institutionalization in the Azerbaijani context.

3 Data and Methodology

3.1 Research Design

This study used a longitudinal comparative quantitative design using secondary data collected from two global sustainability ranking systems: the UI GreenMetric World University Ranking and THE Impact Ranking. The comparison was conducted with respect to Azerbaijani universities that had publicly available ranking data throughout the period from 2021 to 2025. The size of the dataset differs because there are variations in how many institutions participated in each year and ranking system; therefore, this is considered an unbalanced panel where different universities having data available for different time periods.

The study is exploratory in nature and does not aim to establish causal relationships between variables. Instead, it evaluates whether patterns of institutional sustainability performance, as measured by UI GreenMetric indicators, align with SDG-related impact positioning captured by THE Impact Rankings. This alignment is interpreted as an empirical proxy for universities' green mindset institutionalization—a systemic institutional commitment to sustainability that manifests in both internal environmental practices and external contributions to SDGs.

3.2 Data, Data Sources and Measures

3.2.1 Institutional Sustainability Performance

UI GreenMetric overall scores and category-level scores were used to measure campus-level environmental management and sustainability practices. The category scores include:

- **Energy and Climate Change:** Measures related to energy efficiency, renewable energy use, and climate action policies
- **Waste Management:** Indicators of waste reduction, recycling programs, and waste treatment practices
- **Water Conservation:** Metrics assessing water use efficiency and conservation initiatives
- **Education and Research:** Measures of sustainability integration in curricula, research output, and educational programs

Figure 1 represents the data obtained from the official website of the UI GreenMetric World University Rankings for seven Azerbaijani universities for a selected time period.

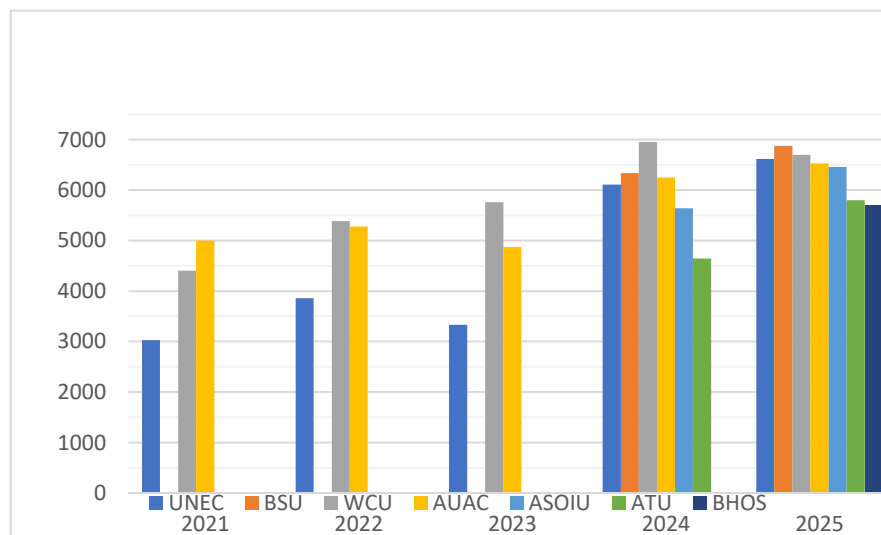


Figure 1

Trend in UI GreenMetric overall scores for selected Azerbaijani universities (2021–2025)

3.2.2 SDG and Impact Positioning

THE Impact Rankings overall bands and SDG-specific bands were used to capture universities' broader contributions to sustainable development. Because THE Impact results are reported as bands (e.g., 401-600, 801-1000, 1001+) rather than precise ranks, all bands were converted into ordinal numeric values using the lower bound of each band (e.g., 401-600 → 401; 1001+ → 1001). This conversion preserves the ordinal ranking structure without assuming interval-scale distances between positions. For interpretability in correlation analyses, an "impact performance" variable was defined as the negative of the rank value, such that higher values indicate better performance.

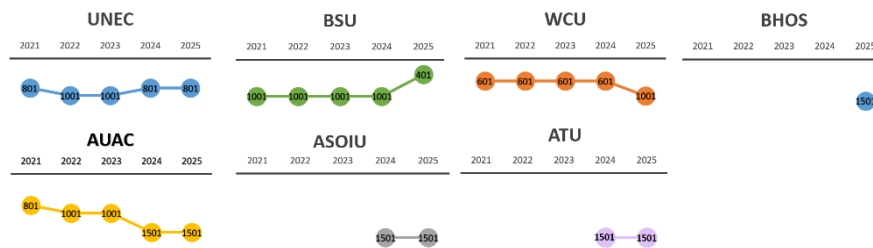


Figure 2

THE Impact Overall Band Trends for Selected Azerbaijani Universities (2021–2025)

Figure 2 demonstrates the overall impact ranking results of universities over a 5-year time frame collected from the official website of The Impact Rankings.

3.2.3 Sample and Data Availability

The sample comprises seven Azerbaijani universities. These are Azerbaijan State Economic University (UNEC), Baku State University (BSU), Western Caspian University (WCU), Azerbaijan University of Architecture and Construction (AUAC), Azerbaijan State Oil and Industry University (ASIOU), Azerbaijan Technical University (ATU) and Baku Higher Oil School (BHOS). The final dataset contains 35 university-year observations across the 2021-2025 period. Data availability varied by year and institution due to gaps in ranking participation and publication. Due to variation in ranking participation across institutions and years, the dataset constitutes an unbalanced panel. This unbalanced panel structure reflects the reality of participation patterns in rankings, where universities may enter or exit ranking systems based on institutional priorities, resource availability, and strategic decisions. All available observations were retained in the analysis to maximize the use of existing data. For correlational analyses, pairwise deletion was applied to ensure that only complete cases for the variables under examination were included in each specific analysis.

3.3 Methodology

Methodology designed with the objective of conducting an integrative evaluation that would provide a reasonable but cautious examination of patterns related to sustainability performance for each of the universities included in this study.

3.3.1 Descriptive Trend Analysis

Descriptive statistics and trends were created from the descriptive data to compare changes in the UI GreenMetric Overall Score, Category Scores, and THE Impact Positioning over time. The intention was to determine whether trends in specific sustainability performance indicators improved.

3.3.2 Spearman Rank Correlation Analysis

Spearman's Rank Correlation analysis was selected to measure the relationships among the various UI GreenMetric Indicators and the THE Impact Positioning because of the following reasons. First, the ranking data was ordinal. Secondly, a small sample size makes use of non-distributional properties advantageous. Thirdly, no assumptions of linearity or normality are required. Correlations were compared at two levels:

General Alignment - GreenMetric Overall Score compared to THE Impact Performance.

Category to SDG Alignment - Specific GreenMetric Categories (Energy, Water, Education, and Waste) in comparison with Correspondingly Ranked SDGs (SDG 7-Affordable and Clean Energy, SDG 6- Clean Water and Sanitation, SDG 4- Quality Education, and SDG 12- Responsible Consumption and Production).

$$\rho = 1 - 6 \sum d_i^2 / n(n^2 - 1) \quad (1)$$

In this equation (1), ρ represents the Spearman rank correlation coefficient, n is the number of paired observations and d_i^2 is the difference between the ranks of paired observations. Pairwise deletion was incorporated to maximize the number of valid observations used in each correlation due to the unbalanced panel structure of the data. Statistical correlation significance was applied at the 5% significance level ($\alpha = 0.05$), though results are interpreted cautiously given the exploratory nature of the study and the small sample size.

4 Findings

4.1 Ranking Participation Patterns

Participation by Azerbaijani universities within international sustainability ranking systems has shown a significant increase. According to the Ministry of Science and Education of the Republic of Azerbaijan, in terms of THE Impact Rankings, there was an increase in participation from 18 Azerbaijani Institutions in 2024 to 28 in 2025; that is about 60 % of all Higher Education Institutes in Azerbaijan. The relatively high level of participation among Azerbaijani Institutions far exceeded the regional average for the South Caucasus and Central Asia, which ranged from 5- 35%.

Among the seven universities surveyed by this research study, UNEC, BSU, WCU, and AUAC participated in THE Impact Rankings each year from 2021 to 2025. Therefore, they provided full data on their global ranking for a total of five years. The remaining three universities participated as follows: ASOIU and ATU first entered THE Impact Rankings in 2024, while BHOS first participated in 2025. Furthermore, the participation patterns of the seven universities in UI GreenMetric were variable. WCU, AUAC and UNEC remained consistently engaged in the reporting process during each of the five years studied, suggesting a strong commitment to developing an institutional-wide sustainability report. In contrast, BSU, ASOIU and ATU did not participate until 2024 and BHOS attended only in 2025. It remains to be seen if these universities will continue to emphasize environmental reporting at their institutions or make strategic decisions about when to submit reports.

The variation of university rankings for participant status represents a larger trend for sustainability at the university level, as universities can select to use varying assessment frameworks based upon what is most strategic for each institution, how many resources are available and whether or not there is an alignment with existing university strengths. As such, it appears that participating in THE Impact Ranking is viewed as either strategically more beneficial or easier to implement compared to collecting more specific data regarding environmental practices at the campus level for GreenMetric.

4.2 GreenMetric Performance Trends

Analysis of the trends in UI GreenMetric overall scores by institutions indicates that most of the trends are generally positive but do not follow a linear trend in institutional sustainability performance over time. These trends vary across universities, reflecting different paths taken on their journey toward sustainable development.

UNEC experienced an impressive rise throughout the five years under review. However, it is also subject to annual variations. Between 2021 and 2025, UNEC's total scores increased by 118.6%, increasing from 3025 points in 2021 to 6613 points in 2025. The sizeable and consistent improvement in UNEC's scores indicates that UNEC has made major investments in its sustainability infrastructure, policies, and practices over the course of this five-year study.

WCU exhibited strong and consistent results during this evaluation. The overall result for WCU improved dramatically, increasing from 4400 points in 2021 to its highest (6950) in 2024, then decreased slightly to 6700 points in 2025. This placement was second nationally and 546th internationally according to the data. As mentioned earlier, the small decrease in rankings from 2024 to 2025 could be due to the new methodological approach used by GreenMetric in evaluating each institution's sustainability; differences in the reporting methodologies among universities evaluated; or actual changes in the sustainability performance metrics used by these universities.

BSU, ASOIU and ATU have shown a significant development over the last two years in the GreenMetric rankings. From 2024 to 2025, the total number of points on the GreenMetric index increased by 540 points (approximately 8.5%) for BSU, 818 points (approximately 14.5%) for ASOIU and 1153 points (approximately 24.8%) for ATU. In 2025, BSU took 493rd position among all participants of the GreenMetric worldwide and was ranked in first place in the national ranking. The universities performed relatively well in some categories of the GreenMetric but also have potential for further development in other categories.

Overall, the descriptive trends indicate non-linear yet mostly positive improvements in institutional sustainability performance of those universities continuously participating in GreenMetric evaluations. There is significant variability in the degree of positive trend across each institution. For example, UNEC showed the greatest increases, which may have been related to their sustainability development efforts.

4.3 THE Impact Positioning Patterns

THE Impact Rankings positioning exhibited considerable year-to-year variability across universities, with patterns of both improvement and decline observed during the study period.

UNEC maintained relatively stable positioning in the middle-to-lower bands throughout most of the observation period. The institution's overall band fluctuated between 801-1000 and 1001+, with positioning at the 801-1000 level in 2025. This stability suggests consistent but moderate performance in SDG-related indicators, without the dramatic improvements observed in the institution's GreenMetric

scores. The institution ranked second nationally in the 2025 THE Impact Rankings alongside BHOS, both achieving the 801-1000 band.

Beginning with WCU, there was an indication that the university experienced a period of stability at first, then a decline. WCU positioned itself within the 601-800 band for the years of 2021 through 2024. The university positioned itself in this manner, indicating that it performed relatively well compared to other Azerbaijani universities. In contrast, however, the position of WCU dropped to the 1001+ band in 2025. A significant loss in relative position to others occurred when WCU's position changed. Although WCU had excellent results on the UI GreenMetric rankings as indicated previously.

In comparison to other universities, BSU showed significant positive movement upward in its overall impact position. In terms of bands in which an institution is ranked in the 2021 - 2024 time frame, BSU was consistently placed in the "1001+" band (the lowest reported band). For 2025, however, BSU moved to the "401-600" band. Thus, BSU has shown a significant increase in relative positioning. From being at the lower end of the spectrum for participating institutions, it has moved up to be in the higher middle range.

AUAC's THE Impact Rankings were positioned in a relatively low performance range from 2021 through to 2025. The rankings ranged from 801 to 1501. In 2021, AUAC achieved the highest ranking of 801. Then there was a downturn to 1001 for both 2022 and 2023. Finally, AUAC experienced an additional decline to 1501 for both 2024 and 2025. Therefore, it appears that the overall trends indicate decreased international visibility in sustainability-related performance over the observation period.

Both ASOIU and ATU had an identical THE Impact Rankings position of 1501 for both years (2024-2025). Therefore, it can be stated that while both universities are at a stable ranking, their overall rankings are relatively low. There was no identifiable upward or downward movement from the data collected.

The variability of the year-to-year SDG rankings and the variable degree of improvement or decline does not always correlate with GreenMetric university performance metrics. This could be due to a variety of factors such as, the change in the method used to determine the rankings, variations in the quality and accuracy of the information provided by each institution when submitting their data, an increase in competition from other institutions participating in the rankings and actual fluctuations in research output and campus SDG related efforts.

4.4 Alignment Between GreenMetric and THE Impact Rankings

Spearman Rank Correlation Coefficients were used to investigate whether there is a statistical relationship between each of the UI GreenMetric Performance

Indicators and THE Impact Ranking's Positioning, examining both overall alignment and category-to-SDG correspondences. Table 1 below demonstrates the results.

Variable Pair	ρ	p	n
Greenmetric Overall vs Impact Overall	0.197	0.539	23
Energy vs SDG 7	0.205	0.596	14
Water vs SDG 6	0.019	0.968	12
Education vs SDG 4	-0.330	0.332	21
Waste vs SDG 12	-0.645	0.239	7

Table 1.

Spearman Correlations Between GreenMetric Variables and SDG Performance

Overall Alignment: There was a weak non-statistically significant association between an institution's Overall GreenMetric Score and its THE Impact overall performance ($\rho = 0.197$; $p = 0.539$; $n = 22$). The result of this investigation implies that when examined across the available data set, institutions performing at a high level on campus-wide sustainability issues as assessed through GreenMetric do not generally have corresponding high positions in THE Impact Rankings. This result would indicate that the available rankings measure different types of institutional sustainable practices.

Category-to-SDG Alignment: The association between categories of campuses and their corresponding Sustainable Development Goals (SDGs) was found to be weak across the majority of analyses of theoretically matching category-SDG pairs:

Energy vs. SDG 7 (Affordable and Clean Energy) - The correlation was weak and was not statistically significant ($\rho = 0.205$, $p = 0.596$, $n = 14$). Although there is theoretical alignment between GreenMetric's energy and climate change categories and SDG 7, the sample showed that institutions do not statistically relate their performance on those aspects of sustainability.

Water vs. SDG 6 (Clean Water and Sanitation) - The correlation was negligible and non-significant. There were virtually no relationships between water related campus activities and the position of the institution regarding SDG 6 ($\rho = 0.019$, $p = 0.968$, $n = 12$).

Education vs. SDG 4 (Quality Education) - The relationship was weak-to-moderately negative and not statistically significant ($\rho = -0.330$, $p = 0.322$, $n = 21$). However, the negative trend could suggest that the higher a university scored for GreenMetric education categories they had poorer positions concerning SDG 4, suggesting an inverse relationship.

Waste vs SDG 12 (Responsible Consumption and Production) - The study found there is an overall moderate-to-very strong negative relationship ($\rho = -0.645$; $p =$

0.239; $n = 7$) between Waste Category and SDG 12 ranking performance. Therefore, it appears that for the data provided, high Waste Category scores are related to lower levels of SDG 12 ranking performance. However, the relationship did not reach statistical significance level. Due to the extremely low number of paired cases examined in this study, these results should be approached with extreme caution and viewed as exploratory only.

The data limitations (e.g., limited number of observations), the unbalanced nature of the panel, and the fact that multiple comparisons were made to evaluate relationships in a single study suggest that these correlational patterns can only be viewed as preliminary and require confirmation using larger and more robust datasets. Overall, the majority of non-significant correlations found in this analysis indicate that there does not appear to be an obvious relationship between campus sustainability practices and positioning relative to Sustainable Development Goals using these two metrics for this particular time frame.

5 Limitations

The results of this research have to be seen in conjunction with significant methodological restrictions in terms of the application of conclusions and their generality.

Sample Size and Statistical Power: With only seven universities examined over the course of five years, there were at most 35 different combinations of university year available for analysis and many fewer for specific analyses due to missing data. Therefore, given its very low number, the sample size restricts the statistical power of all analyses. As such, the likelihood of both Type II error (not detecting a true association), and Type I error (finding a false relationship) is increased. The low sample size makes it difficult to do advanced statistical model development that could control for confounding variables or examine complex interaction effects.

Unbalanced Panel Structure: Due to varying degrees of data availability for each university and each year of observation, the data is structured in an unbalanced panel format. An unbalanced panel complicates interpretations because some universities entered the GreenMetric rankings for the first time only in 2024. Thus, longitudinal comparisons can only be made on the basis of other remaining institutions. This imbalance may introduce bias if the universities with complete data differ systematically from those with partial data in ways that affect sustainability performance trajectories.

Ranking-Based Constructs: To estimate various sustainability concepts, this study uses ranking positions and scores. In addition to the actual performance of an institution regarding sustainability, rankings include aspects related to participant behavior (which institutions participate); reporting behavior; methodology changes

in ranking systems over time; and who is included within the comparison group. Changes in ranking position may result from factors other than genuine changes in institutional sustainability practices, including variations in which institutions participate, modifications to ranking methodologies, and differences in data quality and completeness across submission cycles.

Limited Generalizability: Although the study is limited to seven universities in Azerbaijan over a particular five-year period, the findings are not generalizable to other institutions, countries, or time periods without further research. There are many factors that distinguish the Azerbaijani higher education environment such as, structural elements of institutions, environmental regulations, resource constraints and cultural considerations, that may influence trends in sustainability performance differently than similar factors operating in other settings.

Correlational Study Design: The study's correlational and descriptive design precludes causal inferences about relationships between variables. While the analysis examines associations between GreenMetric performance and THE Impact positioning, it cannot determine whether improvements in campus-level sustainability cause changes in SDG positioning, whether both are driven by common underlying factors, or whether the relationship is spurious.

Time Period: The five-year observation period provides a useful longitudinal view; however, it is relatively short-term for assessing long-term transformational processes within an institution. Institutionalizing sustainability is a long-term process that can take decades to become fully established, and thus trends identified over a five-year period may not reflect long-term trends.

Measurement Validity: The extent to which UI GreenMetric and THE Impact Rankings validly measure the construct of "green mindset" remains an open question. These rankings capture observable indicators of sustainability practices and SDG contributions, but may not fully reflect the depth of institutional commitment, cultural transformation, or systemic integration of sustainability principles that constitute a genuine green mindset.

These limitations underscore the exploratory nature of the study and the need for caution in interpreting findings. The results should be viewed as preliminary evidence of emerging patterns rather than definitive conclusions about sustainability institutionalization in Azerbaijani higher education.

6 Recommendations for Universities of Azerbaijan

Despite the limitations noted above, it is possible to outline some concrete suggestions for Azerbaijan-based institutions of higher education to intensify the institutionalization of the green mindset across institutional dimensions.

Enhance Strategic Alignment Between Operational and Impact Dimensions:

The weak correlations between GreenMetric performance and THE Impact positioning suggest that universities have an opportunity to develop more inclusive and integrated sustainability plans connecting on-campus environmental actions with educational opportunities, research projects, and community outreach/engagement projects that address the SDGs. Sustainability offices should collaborate and coordinate amongst operational, academic, and research domains so that the investment in new facilities translates into educational opportunities, research projects and social impacts recognized within a more comprehensive sustainability review.

Strengthen Sustainability Data Infrastructure and Reporting Capacity:

To consistently participate in multiple ranking systems, universities need to have robust systems for collecting, documenting, storing, and disseminating data related to sustainability. Therefore, this type of data documentation system will allow universities to track their own progress towards becoming more sustainable and to communicate their progress to internal and external stakeholders regarding sustainability performance.

Integrate Sustainability Across Curricula and Research Programs:

Although improving campus operations (energy use, waste management, water conservation) is a critical component of enhancing sustainability performance at universities, findings suggest that universities should also focus on integrating sustainability into educational programs and research activities. This integration should extend beyond environmental science and engineering to encompass social sciences, humanities, business, and professional programs, ensuring that all graduates develop sustainability competencies relevant to their fields.

Development of Long-Term Sustainability Plans:

The non-linear nature of sustainability performance improvements observed in the data suggests that universities should develop comprehensive, long-term sustainability roadmaps with clear milestones, targets, and accountability mechanisms. These roadmaps should be reviewed and updated annually using available data to assess performance and changes in institutional priorities.

Inter-Institutional Cooperation and Learning:

The variability in sustainability performance among the universities provides many opportunities for inter-institutional cooperation and learning. Azerbaijani universities should consider establishing a national sustainability consortium or network to share best practices, coordinate data collection efforts, pool resources for sustainability initiatives, and collectively advocate for supportive policies and funding. Such collaboration could accelerate sustainability institutionalization across the sector while reducing duplication of effort.

Involvement of Stakeholders in Sustainability Decision-Making Processes:

Effective institutionalizing of sustainability at universities requires the involvement of diverse stakeholders, including students, faculty, staff, administrators, alumni

and community partners. Universities should establish participatory governance structures for sustainability, such as sustainability committees with broad representation, student sustainability councils, and mechanisms for incorporating stakeholder input into sustainability planning and decision-making.

Supporting Faculty Research in Sustainability Topics: The findings indicate that operational excellence in sustainability alone does not necessarily equate to high performance in research weighted SDG rankings. Universities should support building research capacity in topics related to sustainability and SDGs, encourage faculty members to conduct research in these areas, and create incentives for interdisciplinary research teams focused on addressing sustainability local and global challenges.

Communicate Sustainability Achievements Strategically: Universities should develop comprehensive communication strategies to promote and highlight their sustainability achievements both internally and externally. This includes not only reporting to ranking organizations but also communicating with prospective students, faculty, funding agencies, policymakers, and the broader public about sustainability initiatives, research contributions, and educational programs. Strategic communication can enhance institutional reputation, attract resources, and inspire broader societal engagement with sustainability.

Monitor and Evaluate Sustainability Initiatives: Universities should implement systematic monitoring and evaluation frameworks to assess the effectiveness of sustainability initiatives, identify areas for improvement, and demonstrate accountability to stakeholders. This should include both quantitative metrics aligned with international frameworks and qualitative assessments of cultural change, stakeholder engagement, and institutional transformation.

Conclusion

The longitudinal analysis of the sustainability performance of Azerbaijan universities from 2021 to 2025 demonstrates that the higher education sector in Azerbaijan is in the early stages of institutionalizing a green mindset. There are several trends that have been identified during this longitudinal research project.

First, participation in international sustainability ranking systems by Azerbaijani universities has increased significantly, showing an increase in awareness of sustainability at the institutional level and an increased level of engagement by institutions with global benchmarking frameworks for sustainability. Second, results of UI GreenMetric demonstrated generally positive, though non-linear progress in campus-level sustainability practices over time. These results suggest ongoing investments in environmental infrastructure, policies, and management at the university level. Third, The Impact Rankings demonstrated fluctuations across institutions and years, reflective of the dynamic nature of reporting quality and competitive benchmarking conditions related to SDGs.

Moreover, the research identified weak or statistically insignificant relationships between greenmetric performance and the impact positioning across most overall category comparisons. This suggests that improvements in campus sustainability practices are not consistently being translated into stronger external recognition of broader contributions to SDGs.

Overall, the findings indicate that Azerbaijani universities have made progress toward incorporating sustainable practices into their institutional structures, however, the incorporation of sustainable practices remains both partial and unequal. Although significant improvements have occurred with respect to operational sustainability and international participation, greater integration among different aspects of governance, academic programs, research and social impact will be required for institutions to develop as truly sustainable organizations. The study contributes initial empirical evidence on sustainability development in Azerbaijani higher education and highlights the importance of a more comprehensive and coordinated approach to embedding green mindset principles across institutional dimensions.

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Human capital resilience in the age of global transformations: the role of sustainable and digital human resource management in strengthening organizational competitiveness

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Abstract: This study examines how sustainable and digital human resource management jointly shape human capital resilience and, through this capability, organizational competitiveness under globalization, digitalization, and sustainability pressures. Rather than treating these themes as parallel developments, the study integrates them into a single explanatory framework. Human capital resilience is conceptualized as a dynamic organizational capability composed of four interrelated capacities: preserving employees' health, knowledge, motivation, and commitment; renewing skills and roles in response to change; enabling adaptation through ethically governed digital systems; and converting individual competencies into organizational learning, memory, innovation, and continuity. The study therefore asks how sustainable and digital HRM practices build these capacities, through which mechanisms they influence competitiveness, and under what ethical and contextual conditions their effects are strengthened or weakened.

Methodologically, the article employs a structured integrative literature review and conceptual synthesis of the 36 works included in its reference corpus, covering foundational and contemporary contributions to globalization, Sustainable HRM, digital HRM, human capital theory, employee engagement, and organizational agility. The sources were classified by theme, compared according to their explanatory mechanisms, and synthesized into the Human Capital Resilience Integration Framework (HCRIF) and five testable propositions. The framework constitutes the study's original theoretical contribution. It proposes that Sustainable HRM primarily protects and regenerates human resources, whereas digital HRM enhances organizational sensing, learning, coordination, and adaptive renewal. These effects become mutually reinforcing only when digitalization is human-centered, transparent, fair, and subject to human oversight. Employee engagement and organizational learning are identified as key transmission mechanisms, while global complexity and local institutional conditions function as boundary conditions. The framework transforms a descriptive review into a theory-building model and provides a basis for empirical validation and future research.

Keywords: Human Capital Resilience, Sustainable Human Resource Management, Digital Human Resources, Organizational Competitiveness, Global Transformation.

1 The Multidimensional Nature of Globalization and Its Impact on Human Resource Management

Although globalization is often perceived as a phenomenon unique to the modern era, it is in fact a historical process whose roots extend much further into the past. While its widespread use in the social sciences dates back to the late 1960s—particularly the 1980s and 1990s—the foundations of economic, political, and cultural integration on a global scale were established much earlier. Geographic discoveries, the Industrial Revolution, and the emergence of modern communication networks represent key turning points in this process. In this respect, globalization cannot be explained merely as a narrow economic phenomenon characterized by increased capital and trade flows; rather, it represents a multilayered transformation process in which knowledge, technology, labor, culture, and management practices circulate across the world [30, p. 148; 5, pp. 45–46].

When the historical trajectory of globalization is examined, it becomes evident that each period has accelerated this process through its own distinctive dynamics. Geographic discoveries reshaped global trade routes and spheres of political influence, while the Industrial Revolution introduced profound changes in production techniques, transportation, and communication systems, thereby transforming globalization into a more systematic and institutionalized structure. Although wars and economic crises in the twentieth century occasionally appeared to disrupt this process, globalization did not disappear; on the contrary, it continued to evolve by developing new actors, tools, and forms of interaction. Particularly after the Second World War, the revival of international trade, the strengthening of multinational corporations, and the increasing mobility of labor constituted the material foundations of contemporary global integration [19, pp. 27–28; 25, pp. 5, 7–9]. From the 1970s onward, the collapse of the Bretton Woods system, the relaxation of controls on capital movements, and the acceleration of financial liberalization further deepened this process. With the widespread diffusion of the internet in the 1990s, along with advancements in satellite technologies, optical cable infrastructures, and computer systems, global interaction became significantly faster, more simultaneous, and more comprehensive in scope [2, p. 157; 5, pp. 45–46].

From a theoretical perspective, globalization consists of economic, political, technological, and cultural dimensions that continuously reinforce one another. Economic globalization refers to the increasing interdependence of national economies and the reorganization of production processes in accordance with global market dynamics [12, p. 2; 29, p. 7]. The political dimension has led to the transformation of state-centered structures and increased the visibility of international organizations, non-governmental organizations, and multinational corporations [3, pp. 45–46; 20, p. 3]. The technological dimension has strengthened

the material foundations of globalization through the development of digital communication infrastructures and the acceleration of information flows [Dirlik, 2000, p. 9]. Meanwhile, the cultural dimension has created a new sphere of interaction that simultaneously generates both convergence and differentiation among societies [20, pp. 3–4; 29, pp. 8–9]. Marshall McLuhan’s concept of the “global village” and Anthony Giddens’ emphasis on the intensification of social relations on a global scale demonstrate that this era is defined not only by the transcendence of physical boundaries but also by the deepening of interdependent relationships [27, p. 10; 14, p. 64].

This multidimensional transformation has directly influenced the structure and functioning of human resource management. Today, processes such as recruitment, development, performance evaluation, and employee retention are no longer shaped solely by the conditions of local labor markets but are increasingly influenced by global dynamics. The intensification of global talent competition, the widespread emergence of cultural diversity, the growing importance of international labor standards, and the proliferation of cross-border digital collaboration models have significantly expanded both the scope and complexity of human resource management.

Despite this expansion, three limitations remain visible in the literature. First, Sustainable HRM and digital HRM are frequently examined as separate streams, which obscures how their combined effects shape the durability and adaptability of human capital. Second, human capital resilience is often used as a broad outcome label without specifying its internal dimensions or the mechanisms through which HR practices produce it. Third, the link between resilience and organizational competitiveness is commonly asserted rather than expressed through testable relationships. To address these gaps, this study develops an integrated conceptual explanation around three questions: how sustainable and digital HRM jointly build human capital resilience; through which mechanisms resilience is translated into organizational competitiveness; and which ethical, institutional, and global conditions shape these relationships.

2 Methodological Approach and Review Design

This study adopts a qualitative, theory-building design based on a structured integrative literature review. An integrative review is appropriate because the problem crosses several partially disconnected bodies of knowledge—globalization, sustainability, digital transformation, human capital theory, employee engagement, organizational learning, and competitiveness—and therefore requires conceptual comparison rather than the aggregation of a single type of empirical finding. The purpose is not to estimate effect sizes or claim exhaustive coverage of all publications, but to identify recurring constructs, causal mechanisms, tensions,

and boundary conditions that can be combined into a coherent theoretical framework.

The analytical corpus consists of the 36 works presented in the reference list, published between 1971 and 2023. The source base is purposive rather than exhaustive. For the purposes of the synthesis, sources were organized according to their direct conceptual contribution to six domains: the historical and multidimensional character of globalization; Sustainable HRM; digital HRM and technological transformation; human capital theory; employee engagement and organizational learning; and organizational agility and competitiveness. Foundational works were used to establish core concepts, while more recent studies were used to identify contemporary mechanisms such as data-driven decision-making, digital leadership, ethical digitalization, and continuous reskilling.

The review proceeded in four analytical stages. First, each source was coded descriptively according to its principal construct, level of analysis, and proposed organizational outcome. Second, relational coding was used to identify mechanisms linking HR practices to employee-level and organization-level outcomes, including well-being, commitment, learning, skill renewal, knowledge retention, agility, and innovation. Third, convergent claims and theoretical tensions were compared, particularly the tension between efficiency and employee well-being, between digital visibility and privacy, and between global standardization and local adaptation. Fourth, the recurring mechanisms were synthesized into the Human Capital Resilience Integration Framework, from which five propositions were derived. This staged process makes explicit how the article moves from literature description to theoretical integration.

Rigor was strengthened through conceptual traceability: literature-supported claims remain linked to the cited sources, whereas the dimensions, causal ordering, and propositions of the proposed framework are explicitly presented as the authors' synthesis. The review also distinguishes antecedents, mechanisms, outcomes, and boundary conditions, reducing the risk of treating all concepts as interchangeable. Nevertheless, the method has limitations. Because the corpus is purposive, the study does not provide database-level exhaustiveness, a formal quality score for each source, an assessment of publication bias, or meta-analytic effect estimates. Its conclusions should therefore be interpreted as theoretically grounded propositions that require empirical testing rather than as statistically verified causal effects.

3 Sustainable and Digital Human Resource Management

In the face of uncertainties created by global transformation processes, increasing competition, and deepening inequalities, the concept of sustainability has evolved

from being an optional consideration into a fundamental balancing element for contemporary organizations. In its simplest sense, sustainability refers not only to the continuation of a system's current functioning but also to its ability to adapt to changing conditions and maintain its existence in the future. In this respect, sustainability represents an approach that goes beyond continuity, encompassing resilience, renewal capacity, and long-term stability [9]. Within this framework, human resource management must be considered not merely as a function that meets existing workforce requirements, but as a strategic domain that prepares organizations to cope with future uncertainties.

The strengthening of sustainability thinking on a global scale was significantly influenced by the Brundtland Report, which represents an important turning point in the development of the concept. In this report, sustainable development was defined as a model of development that meets present needs without compromising the ability of future generations to meet their own needs [12, p. 14]. Consequently, sustainability has moved beyond being solely an environmental issue and has become an ethical and strategic principle encompassing economic continuity, social welfare, and intergenerational responsibility [9]. Historically, Hans Carl von Carlowitz's approach to the continuity of forests also demonstrates that the essence of sustainability lies in the preservation of resources and their capacity for regeneration [12, p. 14]. The meanings embedded in the origin of the concept—such as “to support,” “to protect,” “to maintain,” and “to sustain”—further indicate that sustainability is not only a technical matter but also one that carries a strong ethical dimension [32, p. 59; 15, p. 2].

From a business management perspective, one of the most widely recognized approaches to sustainability is Elkington's Triple Bottom Line model. According to this model, organizational success cannot be measured solely by economic performance indicators; social impacts and environmental responsibilities are also integral components of corporate success [10]. Therefore, environmental sensitivity, social contribution, and the quality of relationships established with employees have become as important as financial outcomes. A truly sustainable organizational structure requires the simultaneous consideration of economic prosperity, social justice, and environmental responsibility [35].

This perspective has also redefined the role of human resource management within organizations. Sustainable Human Resource Management (Sustainable HRM) views employees not merely as components of current performance, but as strategic assets that shape the future of the organization. Although it represents a continuation of the historical evolution from traditional personnel management to human resource management and subsequently to strategic human resource management, Sustainable HRM extends this trajectory by offering a more comprehensive understanding. This approach emphasizes not only the effective utilization of human resources but also their protection, development, and continuous renewal as fundamental objectives [26, p. 56; 36, p. 3]. Accordingly, employees are no longer regarded as easily replaceable elements; rather, they are considered key

stakeholders who embody knowledge, learning capability, innovation capacity, and organizational memory [28, pp. 86–87]. The intensification of global talent competition, the widespread emergence of cultural diversity, the growing importance of international labor standards, and the expansion of cross-border digital collaboration models have significantly increased both the scope and complexity of human resource management.

Although there is no single universally accepted definition of Sustainable Human Resource Management (Sustainable HRM) in the literature, the common point shared by different approaches is the necessity of designing human resource policies and practices in alignment with economic, social, and environmental objectives through a long-term perspective [13; 6]. Wagner defines this approach as a form of human resource management that meets the present needs of both organizations and society without jeopardizing future requirements [35, p. 443]. Similarly, Ehnert conceptualizes Sustainable HRM as a system that supports the achievement of organizational goals while enabling the long-term preservation and regeneration of human resources [8]. Thom and Zaugg define sustainability as a set of practices shaped by a sense of long-term responsibility throughout all processes, from recruitment to employee exit [32].

The macro–micro level distinction proposed by Ehnert and Harry provides an important framework for understanding the scope of Sustainable Human Resource Management. At the macro level, human resource management is positioned as a strategic instrument that contributes to the economic, environmental, and social sustainability goals of the organization; at the micro level, the focus shifts to preserving employees' health, well-being, motivation, work–life balance, and competencies [9, p. 223]. Contemporary challenges such as an aging workforce, increasing workloads, talent shortages, and burnout clearly demonstrate that human resources are not merely elements to be utilized, but values that must be protected and developed. The open systems approach also supports this perspective; since organizations continuously interact with their environments, they cannot simply utilize human resources but must develop and regenerate them [8, p. 172; 21, p. 1077].

Within this context, digital transformation has emerged as one of the most significant factors bringing both new opportunities and new risks to the preservation and development of human capital. This transformation does not merely involve the adoption of new technologies; it also fundamentally reshapes management philosophies, working methods, and organizational processes. Human resource management has been among the areas most affected by this transformation. Many processes—including recruitment, training and development, performance evaluation, personnel administration, and employee experience—are now conducted through digital platforms. As a result, human resource management has moved away from slow manual practices toward a faster, more systematic, and data-driven structure [34, p. 370].

The most significant driving force behind digital transformation in human resources has been the rapid advancement of information technologies. Developments in software infrastructures, hardware systems, and communication networks have compelled HR units to adapt to this new order. Consequently, HR departments have evolved from units primarily responsible for routine administrative tasks into more strategic structures that monitor technological developments, effectively utilize digital tools, and base their decisions on data [16, pp. 5–6]. The redesign of business processes, the growing demand for speed and agility, and the increasing importance of cost efficiency have further accelerated this transformation. The widespread adoption of digital systems in areas such as recruitment, performance evaluation, and data management has made processes more transparent, traceable, and measurable.

One of the most remarkable contributions of digital human resource management is the increased visibility and manageability of human capital. Applicant tracking systems, AI-supported screening tools, and data analytics applications enable faster evaluation of applications and the rapid identification of suitable candidates. Automation technologies reduce routine workloads such as payroll processing, leave management, and reporting, allowing HR professionals to focus more on strategic issues. Furthermore, digital platforms enable employees to easily access performance data, training content, and career development tools, thereby improving the overall employee experience. In this respect, digitalization is not merely a technical tool that enhances operational efficiency; it also functions as a managerial infrastructure that strengthens employee satisfaction and organizational commitment.

The development of data analytics has further increased the strategic value of digital human resource management. The systematic monitoring of data such as employee performance, absenteeism rates, workforce costs, and turnover trends provides managers not only with the ability to evaluate current conditions but also with the capacity to generate future-oriented projections. In this way, human resource management has evolved from an intuition-based and reactive structure into an analytical capacity capable of anticipating risks in advance. The replacement of traditional annual performance evaluations with digital systems that provide continuous feedback and support development is another important indicator of this transformation. Performance approaches such as OKRs (Objectives and Key Results) make it easier to clearly establish the connection between individual goals and organizational objectives.

In the field of training and development, digitalization has become one of the most effective tools for strengthening the resilience of human capital. E-learning platforms, online courses, and virtual classrooms enable employees to continue learning independently of time and location constraints. Learning Management Systems (LMS) facilitate the monitoring of this process, enabling a stronger connection between individual development and organizational goals. Particularly in today's business environment, where skill transformation is accelerating,

continuous reskilling and the development of digital competencies have become critically important.

4 Human Capital Theory and the Concept of Resilience

One of the theoretical foundations of sustainable and digital human resource management is based on human capital theory. Human capital is a broad concept that encompasses not only an individual's labor capacity but also the economic value of the knowledge, skills, expertise, experience, and all competencies developed over time [1, p. 162]. The most distinctive characteristic that differentiates this form of capital from others is its capacity to be developed and transformed. Educational opportunities, vocational training processes, healthcare services, and other investments aimed at improving quality of life constitute the fundamental elements that nourish human capital. Such investments not only enhance an individual's productivity but also increase their capacity to generate income and their value within the economic system [7, pp. 10–11]. Therefore, human capital should not be regarded as a fixed set of attributes, but rather as a dynamic accumulation that continuously develops and generates economic returns.

The works of Theodore W. Schultz played a decisive role in establishing a systematic framework for human capital theory. Schultz demonstrated that economic growth cannot be explained solely through the accumulation of physical capital; rather, a significant portion of growth stems from the knowledge, skills, and competencies acquired by individuals [31, pp. 24–36]. This perspective repositioned individuals from being passive elements of the production process to becoming strategic forms of capital that require investment, development, and protection. Educational activities, on-the-job learning processes, non-formal education programs, access to healthcare services, and mobility opportunities that enable better working conditions have been evaluated as investments in human capital within this context [31, pp. 24–36].

From the perspective of contemporary organizations, the value of human capital has become even more evident as it constitutes one of the fundamental components of intellectual capital. The knowledge base, experience, and cognitive competencies possessed by employees serve as primary sources of organizational value across various domains, including research and development activities, customer relations, innovation processes, and service quality [18, p. 33]. However, the fact that this knowledge accumulation is directly owned by individuals makes it increasingly important for organizations to invest in developing, motivating, and retaining employees [4]. At this point, the primary responsibility of organizations is to transform individual knowledge stocks into organizational value and to

institutionalize this knowledge within organizational processes, thereby embedding it into organizational memory [24, p. 119]. Otherwise, even if human capital exists within the organization, its potential may not be transformed into a competitive advantage.

Within this theoretical framework, the concept of **human capital resilience** emerges as one of the key analytical concepts that integrates human resource management shaped by sustainability and digitalization. Human capital resilience refers to an organization's ability to preserve, renew, and develop employees' knowledge, skills, experience, health, motivation, commitment, and learning capacity in the face of global uncertainties, pressures of digital transformation, and competitive market conditions. This concept encompasses not only the ability to survive during periods of crisis but also the capacity to rapidly adapt to changing conditions, restructure when necessary, and generate new value. Therefore, resilience should be understood not as the passive protection of human capital, but as an active process that involves continuously strengthening it, increasing its flexibility, and preparing it for future challenges.

5 Original Theoretical Contribution: The Human Capital Resilience Integration Framework

The review indicates that the existing literature explains important parts of the problem but does not fully specify how Sustainable HRM and digital HRM combine to produce a resilient form of human capital. The original contribution of this study is therefore the Human Capital Resilience Integration Framework (HCRIF). The framework defines human capital resilience not as a general capacity to endure disruption, but as a higher-order organizational capability formed through four interdependent capacities: preservation, adaptive renewal, ethical digital enablement, and organizational conversion. It also separates the practices that create resilience from the mechanisms that transmit its effects and the competitive outcomes that follow.

Preservation capacity refers to the organization's ability to sustain employees' health, well-being, motivation, commitment, employability, and critical knowledge during periods of pressure. Practices such as fair employment, safe work, work-life balance, participation, career continuity, and talent retention reduce the erosion of human resources and protect organizational memory [9, p. 223; 21, p. 1077]. Preservation is therefore more than retention: it keeps the human and relational foundations of future adaptation available.

Adaptive renewal capacity denotes the ability to update skills, redesign roles, mobilize talent, and learn rapidly as technological and market demands change. Training, reskilling, internal mobility, continuous feedback, and flexible workforce

planning transform human capital from a stock of existing competencies into a renewable resource. This dimension extends human capital theory by emphasizing not only investment in knowledge and skills but also their continuous reconfiguration under uncertainty [31, pp. 24–36; 34, p. 370].

Ethical digital enablement capacity concerns the use of analytics, automation, artificial intelligence, digital platforms, and learning systems to sense emerging risks, make capabilities visible, personalize development, and coordinate responses. Digital tools can strengthen resilience by revealing skill gaps, turnover risks, burnout indicators, and learning needs; however, their contribution is conditional. When data collection is opaque, surveillance-oriented, biased, or detached from human judgment, digitalization may weaken trust and engagement. Ethical governance—privacy protection, transparency, algorithmic fairness, proportionality, and human oversight—is therefore part of resilience itself rather than an external compliance issue.

Organizational conversion capacity is the ability to translate individual knowledge, experience, and learning into shared routines, institutional memory, collaborative problem-solving, innovation, and coordinated action. Human capital does not create lasting competitive advantage merely because competent employees are present; it must be embedded in processes and relationships that allow knowledge to circulate and remain within the organization [4; 24, p. 119]. This dimension explains how employee-level capabilities become organization-level resilience.

Taken together, the four capacities establish a causal chain. Sustainable HRM primarily strengthens preservation and regeneration; digital HRM primarily strengthens sensing, coordination, and adaptive renewal; and their integration supports organizational conversion. Employee engagement and organizational learning transmit these effects because employees are more likely to share knowledge, participate in change, and invest effort when they experience fair treatment, development opportunities, meaningful participation, and trustworthy digital systems [22, p. 3; 23, p. 17]. The resulting resilience enhances agility, innovation, continuity, talent retention, and employer attractiveness, which collectively strengthen organizational competitiveness. The framework is recursive because stronger competitive performance can provide additional resources for future investment in people, technology, and sustainable practices.

Proposition 1. Sustainable HRM practices are positively associated with human capital resilience because they strengthen preservation and adaptive renewal capacities.

Proposition 2. Digital HRM practices are positively associated with human capital resilience through improved sensing, learning, coordination, and skill renewal; this relationship is stronger when digital systems are governed by transparency, fairness, privacy protection, and human oversight.

Proposition 3. The joint implementation of Sustainable HRM and ethically governed digital HRM produces a greater increase in human capital resilience than either approach implemented in isolation.

Proposition 4. Employee engagement and organizational learning mediate the relationship between integrated sustainable-digital HRM practices and human capital resilience.

Proposition 5. Human capital resilience mediates the relationship between integrated sustainable-digital HRM and organizational competitiveness, while global complexity, sectoral conditions, and the balance between global standardization and local adaptation moderate the strength of this relationship.

6 Global Competition, Managerial Complexity, and the Strategic Role of Sustainable-Digital Human Resource Management

The transformation occurring along the axes of globalization, digitalization, and sustainability has significantly altered the scope and functioning of human resource management. This change has become particularly visible within the context of global human resource management. Human resource functions are no longer administrative processes confined to the borders of a single country; rather, they have evolved into a multilayered domain that must be managed simultaneously, coherently, and strategically across organizational structures dispersed across different geographical regions. The expansion of business activities into international markets, the geographical dispersion of employees across countries, and the increasing mobility of the workforce have made global human resource management an indispensable component for contemporary organizations.

One of the most significant contributions of global human resource management is the expansion of the talent pool on a global scale. Organizations are no longer limited to the opportunities provided by local labor markets; instead, they can access employees with diverse educational backgrounds, areas of expertise, and cultural experiences. This situation enhances organizational learning capacity, diversifies problem-solving approaches, and supports the ability to generate innovation. The convergence of employees from diverse cultural and professional backgrounds within a single organizational structure creates a significant advantage in terms of innovation. Since heterogeneous teams are able to approach problems from multiple perspectives rather than a single viewpoint, they are more capable of developing creative, flexible, and inclusive solutions. For this reason, global human resource management should not be considered merely as a mechanism for supplying labor; rather, it represents a strategic integration domain that brings together diverse sources of knowledge and experience to foster organizational innovation.

While providing flexibility, global human resource management must simultaneously develop policies that protect employee well-being. At this point, sustainable and digital human resource management emerges as one of the key strategic axes that strengthen organizational competitiveness. Today, competitive advantage can no longer be explained solely through cost advantages, production capacity, or market visibility. The real determining factor lies in how quickly organizations can adapt to changing conditions, how effectively they can develop their human resources, how successfully they can transform knowledge into organizational value, and how they can maintain continuity in uncertain environments. Therefore, sustainable and digital human resource management has moved beyond being a supportive function and has become a strategic domain that directly shapes competitiveness. What is decisive here is not merely possessing technology, but integrating it into a management approach that strengthens human resources, accelerates organizational learning, and enhances organizational resilience [8; 34, p. 370].

The first major contribution of this approach is its capacity to enhance the protection and regeneration of human capital. While traditional human resource approaches often view employees as operational elements responsible for performing specific tasks, sustainable human resource management considers employees as fundamental carriers of the organization's long-term existence. Digital tools make this process of protection and development more systematic, traceable, and analytical. Mapping employees' skill profiles, identifying development needs, detecting burnout risks at an early stage, and planning career paths based on data contribute to safeguarding human capital from erosion [9, p. 223; 21, p. 1077].

Secondly, this approach strengthens organizational agility and adaptive capacity. The global economy, technological advancements, and market uncertainties are forcing organizations to move beyond static structures and transform into more flexible and learning-oriented systems. Digital human resource applications make workforce planning more dynamic, enabling organizations to respond more rapidly to changing demands. The systematic monitoring of indicators such as employee performance, skill gaps, labor costs, absenteeism rates, and turnover tendencies provides managers not only with the ability to evaluate current conditions but also with the opportunity to generate future-oriented forecasts.

A third important dimension is organizational learning and innovation capacity. Sustainable competitiveness cannot be achieved solely through the efficient use of existing resources; rather, it depends on the ability to generate new knowledge, integrate different types of knowledge, and transform them into innovation. Sustainable human resource management promotes learning as a continuous component of organizational life because it does not reduce employee development to short-term performance objectives. Digital human resource applications institutionalize this learning process through e-learning systems, personalized training modules, online development platforms, and data-supported competency analyses. In this way, employees' individual knowledge and skills do not remain

merely as personal advantages; instead, they are transformed into organizational memory, innovation, and problem-solving capacity, thereby returning value to the organization [4; 24, p. 119]. In knowledge-based economies, this transformation represents one of the most critical sources of competitive advantage.

Another critical role of sustainable and digital human resource management is its capacity to strengthen employee engagement and organizational commitment. Employee engagement represents a multidimensional form of participation that emerges when individuals perceive themselves as integral parts of the organization, internalize organizational goals, and willingly direct their energy toward their work. Employees with high levels of engagement do not merely fulfill assigned tasks; they are more willing to participate in innovation processes, support their colleagues, and voluntarily contribute to organizational development [22, p. 3; 23, p. 17]. The emphasis placed by sustainable human resource management on employee well-being, work–life balance, safe working conditions, and participatory management significantly strengthens this engagement. Digital systems further enhance employees’ trust in their organizations through transparent communication, accessible processes, rapid feedback mechanisms, and personalized development opportunities. In particular, the ability to access leave, training, performance, and career processes through a single digital structure facilitates employees’ participation in organizational processes and supports their sense of belonging.

Similarly, the capacity to attract, develop, and retain talent represents another major dimension through which this approach influences competitiveness. In today’s business environment, competition takes place not only between products and services but also through organizations’ ability to recruit qualified human resources and retain them over time. While globalization provides organizations with access to broader talent pools, digitalization has made recruitment processes faster and more targeted. Applicant tracking systems, AI-supported pre-screening tools, and international digital employment platforms enable organizations to reach suitable talent in a shorter time frame. However, the core challenge lies in creating conditions that encourage these employees to remain within the organization. Sustainable human resource management achieves this objective to the extent that it offers employees not merely employment, but also opportunities for development, meaning, security, and career continuity.

The data-driven decision-making capacity enabled by digitalization also strengthens competitive rationality. For a long time, human resource management was largely perceived as a domain based on managerial intuition and general observation. However, digital systems now make it possible to generate concrete and analyzable data in areas such as performance, engagement, absenteeism, turnover, training participation, leadership potential, and skill development. This transformation moves human resource management beyond being merely an operational function and positions it as a strategic center that produces critical knowledge for organizational decision-making processes. Decisions regarding which skills require

investment, which departments face higher turnover risks, which leadership styles foster stronger employee engagement, and which training programs contribute more effectively to performance can only be accurately determined through robust data infrastructures.

In multinational and multi-location organizational structures, maintaining a balance between standardization and flexibility is another essential function of sustainable and digital human resource management. Policies that are managed entirely from a central authority may lead to the neglect of local differences, whereas fully localized practices may weaken organizational coherence. The sustainable approach establishes common organizational standards by preserving fundamental principles such as fairness, inclusiveness, well-being, and long-term development. Digital infrastructures facilitate the implementation of these standards in ways that are adaptable and traceable across different geographical contexts. In this manner, global human resource management achieves both managerial consistency and operational flexibility.

This management approach also strengthens organizational reputation and employer branding. Contemporary employees no longer make career decisions solely based on salary and benefits. Factors such as an organization's ethical orientation, the quality of its digital infrastructure, the development opportunities it offers, its approach to diversity, and the importance it places on employee well-being have become key determinants of employee preferences. The structure of sustainable human resource management—characterized by protecting human dignity, prioritizing employee health, supporting work–life balance, and promoting fair practices—combined with the transparent, accessible, and user-friendly processes offered by digital human resource management, makes organizations more attractive within labor markets. A strong employer brand, in turn, enhances talent attraction capacity, employee loyalty, and organizational prestige, thereby generating an indirect yet powerful competitive advantage.

7 Human Capital Resilience, Organizational Future, and Strategic Recommendations

The acceleration of digitalization, the intensification of global competition, the continuous transformation of skill requirements, and the deepening of uncertainty conditions have directly linked sustainable competitive advantage to the quality of human capital. The extent to which an organization can protect, develop, and reorganize its human resources in response to new conditions has become one of the fundamental determinants of its future organizational existence. Organizations with high levels of human capital resilience are able to strengthen employee engagement, limit talent loss, maintain continuity of organizational knowledge, and

adapt more rapidly to change. Such organizations do not remain merely reactive structures responding to crises; rather, they develop agile learning capacities that enable them to identify and capitalize on emerging opportunities.

Within this framework, employee engagement emerges as one of the most critical outcomes of a competitive organizational structure. Engagement does not simply mean that individuals perform assigned tasks; it also involves identifying with organizational goals, voluntarily contributing to institutional success, and perceiving oneself as an integral part of the organization's future. For this reason, sustainable and digital human resource management practices should be evaluated as strategic mechanisms that establish a direct link between employee well-being and organizational performance. As engagement levels increase, knowledge sharing, innovation capacity, collaborative tendencies, and organizational solidarity are also strengthened. Each of these elements constitutes a core dynamic that directly supports organizational competitiveness.

In line with this theoretical framework, several fundamental orientations should be adopted to enable sustainable and digital human resource management to support organizational competitiveness more effectively. First and foremost, human resource strategies should be structured according to long-term human capital resilience rather than short-term productivity targets. Organizations should not evaluate employees solely based on immediate performance outputs; they should also consider employees' knowledge accumulation, learning potential, contribution to organizational memory, and capacity to adapt to change. Accordingly, recruitment, training, career planning, and retention policies should be designed not with a "rapid results" logic but with a "long-term value creation" perspective.

In connection with this, digital human resource systems should not be established solely for automation purposes. Many organizations perceive digitalization merely as a technical tool that accelerates processes such as payroll, leave management, and personnel records. However, true competitive advantage emerges when these systems are utilized in more strategic areas such as skill mapping, turnover risk analysis, monitoring employee engagement, identifying development needs, and evaluating leadership potential. Therefore, HR analytics should not be treated as an independent technical infrastructure but rather as a direct decision-support mechanism integrated into organizational strategy.

Similarly, continuous learning and reskilling should become integral components of institutional policy. In an era marked by rapid technological transformation and intensified global competition, employees' existing knowledge and skills can quickly become insufficient. For this reason, organizations should conceptualize in-service training not as a periodic activity but as part of a continuous learning architecture. E-learning platforms, micro-learning modules, personalized development pathways, and digital certification systems should be considered complementary elements of this structure.

Employee well-being and work–life balance should be regarded not as secondary, but as essential components of competitiveness strategies.

Particularly within hybrid and global working models, burnout, excessive workload, digital fatigue, and uncertain working hours represent some of the primary risks that weaken human capital. Therefore, flexible working models should not be designed solely as productivity-enhancing tools, but as balanced structures that safeguard employee well-being. Supporting psychological well-being, strengthening mental health mechanisms, protecting the right to rest, and recognizing the right to disconnect are particularly important in this context.

The performance management approach must also evolve from a control-oriented structure toward a development-oriented model. When digital performance systems transform into mechanisms that continuously monitor employees and generate pressure, trust and engagement may be undermined. In contrast, reconstructing performance management on the basis of regular feedback, skill development, coaching, and learning support is likely to produce more constructive outcomes. Systems such as OKRs (Objectives and Key Results) should be used not only for tracking targets, but also for making individual contributions visible in meaningful alignment with organizational objectives.

In global human resource management, a balanced structure should be established between common principles and local adaptations. Uniform HR policies may not always be effective for organizations operating across different countries or regions. Therefore, while universal principles such as fairness, inclusiveness, ethical governance, and employee well-being should be preserved, areas such as compensation, benefits, communication styles, and leadership practices should be adapted flexibly according to local cultural and legal conditions. Such a balance preserves organizational integrity while ensuring alignment with local contextual requirements.

Similarly, diversity and inclusion policies should not remain at a symbolic level. The mere presence of employees from diverse cultural and social backgrounds within the same organization does not automatically generate innovation or competitive advantage. For this potential to translate into tangible value, inclusive leadership approaches must be developed, bias-awareness training programs should be expanded, equal participation mechanisms must be established, and fair promotion processes should be implemented. Additionally, how diversity is reflected in organizational decision-making processes should be systematically monitored and evaluated.

In digital human resource practices, placing data security, ethical use, and algorithmic fairness at the center is of vital importance. Protecting employee data, minimizing algorithmic bias, and ensuring transparency in decision-making processes are fundamental factors determining the legitimacy of digitalization. Particularly in AI-supported recruitment, performance analysis, and talent

evaluation tools, establishing ethical oversight mechanisms and maintaining human supervision in final decisions are essential requirements.

In addition, the role of HR professionals must evolve from administrative expertise toward strategic transformation leadership. Contemporary HR managers should not merely implement procedures; they must be professionals capable of interpreting data, utilizing digital systems effectively, possessing intercultural awareness, designing employee experiences, and guiding organizational transformation. Therefore, the competencies of HR departments themselves must also be redeveloped in line with digitalization and sustainability perspectives.

Limitations and Future Research Agenda

Although the HCRIF clarifies the theoretical relationships among Sustainable HRM, digital HRM, human capital resilience, and competitiveness, its propositions are not empirically tested in this study. Future research should first operationalize the four dimensions of human capital resilience and develop a reliable measurement scale. Scale development should establish whether preservation, adaptive renewal, ethical digital enablement, and organizational conversion are empirically distinct yet sufficiently related to form a higher-order construct.

Second, longitudinal and multilevel research is needed to examine how resilience develops before, during, and after disruption. Employee-level perceptions of well-being, fairness, trust, and learning should be connected to team-level knowledge sharing and organization-level outcomes such as agility, innovation, turnover, and continuity. Such designs would help distinguish temporary crisis responses from durable resilience capabilities and would provide stronger evidence about causal direction.

Third, comparative studies should test the framework across countries, sectors, organizational sizes, and forms of work. The effects of sustainable and digital HR practices may differ according to labor regulation, cultural expectations, technological maturity, skill intensity, and exposure to global competition. Cross-context research would clarify when global standardization supports resilience and when local adaptation is necessary.

Fourth, the ethical boundary conditions of digital HRM require direct empirical attention. Future studies should examine whether transparency, employee voice, explainability, privacy protection, and human oversight strengthen the positive effects of analytics and artificial intelligence, and whether surveillance intensity, algorithmic bias, or digital fatigue undermine trust and engagement. This line of research is essential for determining when digitalization functions as a resilience resource and when it becomes a new source of vulnerability.

Finally, mixed-method, configurational, and intervention-based research can test the complementarity claim at the center of the framework. Surveys and structural models can examine the proposed mediating and moderating effects; case studies

and interviews can reveal how resilience practices are interpreted by employees and managers; social network analysis can assess whether knowledge is genuinely converted into organizational memory; and quasi-experimental designs can compare outcomes before and after the introduction of sustainable-digital HR initiatives. These approaches would progressively refine, challenge, or extend the proposed framework.

Conclusion

This study moves beyond a descriptive account of Sustainable HRM and digital HRM by specifying how the two approaches jointly contribute to organizational competitiveness through human capital resilience. Its central argument is that resilience is not a vague capacity to survive disruption, but a higher-order organizational capability that must be actively constructed through the preservation of human resources, the continuous renewal of skills and roles, ethically governed digital enablement, and the conversion of individual knowledge into organizational memory and coordinated action.

The principal theoretical contribution is the Human Capital Resilience Integration Framework. By distinguishing antecedent HR practices, four resilience capacities, transmission mechanisms, competitive outcomes, and boundary conditions, the framework clarifies relationships that are often implicit in the literature. Sustainable HRM provides the protective and regenerative foundation of resilience, while digital HRM strengthens sensing, learning, coordination, and adaptation. Their integration creates greater value than either approach alone only when digital systems are transparent, fair, privacy-conscious, and subject to meaningful human oversight. Employee engagement and organizational learning explain how these practices become collective capability, and human capital resilience explains how that capability is translated into agility, innovation, continuity, talent retention, and competitiveness.

The methodological contribution of the study lies in making the logic of the literature synthesis explicit. The structured integrative review organizes the 36-source corpus into conceptual domains, compares mechanisms and tensions, and derives five propositions that can be empirically examined. At the same time, the purposive and non-exhaustive character of the corpus limits claims of comprehensiveness and prevents statistical causal inference. The proposed relationships should therefore be understood as a theory-building platform rather than as confirmed empirical effects.

For organizations, the framework implies that digitalization should not be pursued as automation alone and sustainability should not be reduced to isolated well-being initiatives. Competitive value emerges when HR systems simultaneously protect employees, develop future-oriented capabilities, use data ethically, support participation, and institutionalize learning. For research, the next step is to operationalize the four resilience capacities, test the proposed mediating and

moderating relationships across contexts, and examine the long-term effects of integrated sustainable-digital HR architectures. Human capital resilience can then develop from a promising conceptual idea into a cumulative and empirically validated field of inquiry.

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Human Factors in Information Security and Technological Risk: A Systematic Literature Review

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Abstract: The increasing complexity and interconnectedness of digital technologies have transformed information security from a predominantly technical challenge into a broader socio-technical risk problem. Human behaviour, risk perception, trust, organisational conditions, and decision-making increasingly influence whether technological vulnerabilities translate into actual security consequences. This study systematically reviews recent research on the human dimensions of information security and technological risk, with particular attention to the relationships between technological vulnerabilities, perceived risk, trust, security-related decision-making, and behaviour. The review focuses on studies published between 2020 and 2026 and covers diverse technological contexts, including conventional information systems, mobile technologies, IoT, BYOD environments, autonomous systems, and critical infrastructures. The literature is synthesised into five interconnected themes: human factors and security behaviour; risk perception and security-related decision-making; trust and organisational security; technological risk, failure, and reliability; and cybersecurity challenges in critical infrastructures and emerging technologies. Based on this synthesis, the study proposes an Integrated Human-Centred Cybersecurity Risk Framework linking technological and contextual conditions to risk perception, trust and perceived control, security-related decisions, behaviour, and subsequent security and resilience outcomes. The review highlights the need for closer integration between technical risk assessment and behavioural and organisational approaches to information security.

Keywords: cybersecurity; human factors; technological risk; risk perception; trust; security behaviour

1 Introduction

The growing interconnectedness of digital technologies has transformed information security from a predominantly technical challenge into a socio-technical problem in which technological, behavioural, and organisational factors

interact [1], [2]. This is particularly evident in IoT and other complex digital environments, where technical safeguards cannot eliminate vulnerabilities associated with human behaviour [3]. Human factors can increase vulnerability through inadequate awareness or unsafe practices, but knowledge, appropriate decision-making, and supportive organisational conditions can also strengthen security and resilience [4]. A central challenge is the distinction between objective technological risk and subjective risk perception. Technical vulnerabilities and failures can be identified through engineering-oriented risk and reliability methods [5], but users' responses depend on how these risks are perceived and evaluated. Risk perception, trust, perceived control, and security-related decision-making therefore provide important mechanisms through which technological conditions are translated into actual security behaviour [6]. Despite increasing recognition of these relationships, the literature remains fragmented across technological and disciplinary contexts. Human-centred cybersecurity and organisational security are often examined separately from technological reliability, while risk perception and trust are conceptualised differently across conventional information systems, autonomous technologies, and critical infrastructures [7]. What remains insufficiently integrated is the process through which objective technological conditions, subjective risk appraisal, trust, and organisational factors jointly shape security-related decisions and outcomes across different technological contexts. To address this gap, this study systematically reviews 47 publications published between 2020 and 2026 on the human dimensions of information security and technological risk. It examines the relationships among technological vulnerability, risk perception, trust, perceived control, and security-related decision-making across different technological contexts. The review aims to identify recurring patterns, integrate technical and behavioural perspectives, reveal research gaps, and develop an Integrated Human-Centred Cybersecurity Risk Framework.

2 Conceptual Background

2.1 From Technological Vulnerability to Human-Centred Cybersecurity

Building on the socio-technical perspective, human-centred cybersecurity research emphasises users' cognitive characteristics, motivations, work practices, and organisational contexts [1], [2]. This is evident in IoT and healthcare environments, where human behaviour, awareness, organisational practices, and exposure to social-engineering threats remain important despite technical safeguards [3], [4]. Organisational and information-security cultures further influence employee compliance and security behaviour [8]. Human factors, however, are not

exclusively sources of vulnerability. Knowledge, awareness, effective decision-making, and supportive organisational conditions can strengthen security and resilience, reinforcing the view that human capabilities can also enhance cybersecurity [9]. Earlier research focusing on Generation Y similarly highlighted the relevance of user awareness and attitudes in information security, indicating that the human dimension of cybersecurity had already emerged as an important concern before the period covered by the systematic corpus [45]. BYOD environments illustrate this dual role particularly clearly: employee autonomy introduces security and governance challenges, while policy compliance and organisational responses require attention to both behavioural and managerial factors [10], [11]. Human factors should therefore be considered integral components of cybersecurity rather than external sources of error.

2.2 Risk Perception, Decision-Making, and Security Behaviour

Objective technological vulnerability does not automatically produce risky behaviour. Security responses depend on how users interpret threats through knowledge, perceived vulnerability, expected consequences, self-efficacy, and individual risk tendencies. Cybersecurity knowledge and personal characteristics are associated with security practices [12], while passive risk tendencies demonstrate that insecure outcomes may result from inaction rather than deliberate risk-taking [13]. Perceived vulnerability [14] and broader cognitive and motivational mechanisms [15] further influence whether technological threats lead to protective behaviour. Information-security policy compliance is likewise shaped by interacting motivational, self-regulatory, and deterrence mechanisms [16]. Password security illustrates this distinction between objective and perceived risk. Users balance technical recommendations against convenience, cognitive effort, and perceived benefits [17]. Memory anxiety can affect password behaviour [18], while adaptive and maladaptive mechanisms influence password-manager adoption [19]. Recent evidence also questions whether unique passwords necessarily impose greater memorability costs than reused or modified passwords [20]. Security behaviour should therefore be understood as the outcome of a decision process in which objective technological risks are interpreted before being translated into protective action, risky behaviour, or inaction.

2.3 Trust, Reliability, and Emerging Technological Contexts

Trust is another central mechanism linking technological risk with behaviour. Because users cannot fully evaluate the internal operation and vulnerabilities of complex digital systems, some degree of reliance is unavoidable. However, excessive trust may increase inappropriate reliance; cybersecurity therefore requires calibrated trust rather than simply greater trust. This relationship is particularly visible in connected and autonomous technologies. Trust and perceived risk

influence autonomous-vehicle adoption [21], cybersecurity attacks can reduce trust in automated operation [22], and cyber readiness and system responses affect both trust and blame attribution [23]. Trust also operates at the organisational level, where interpersonal and institutional relationships can influence safety and security [24]. In critical infrastructures, these human factors become particularly important because failures may affect organisational continuity and broader societal functions [25], [26]. Similar socio-technical interactions occur in BYOD environments, where organisational policies, device ownership, user preferences, and security behaviour interact [27], [28], encouraging more integrated security-management approaches [29]. Emerging technologies extend these challenges: quantum computing may threaten established encryption mechanisms [30], while AI-supported environments raise new questions concerning security governance and trust calibration [31]. Across these contexts, a common structure emerges: technological conditions create vulnerabilities, users and organisations interpret these risks, and trust and perceived control influence subsequent responses. Technological risk, risk perception, trust, organisational context, and security behaviour can therefore be treated as interconnected components of a broader human-centred cybersecurity process.

3 Research Questions

Based on the conceptual background and the identified fragmentation between technological and human-centred approaches to cybersecurity, the review addresses the following research questions:

RQ1. *What human factors are most frequently associated with secure and insecure information-security behaviour?*

RQ2. *How do risk perception, perceived vulnerability, and trust influence security-related decision-making and behaviour?*

RQ3. *How are technological risks, system failures, and reliability issues connected to human responses and security outcomes?*

RQ4. *To what extent do common human and organisational mechanisms emerge across different technological contexts, including mobile technologies, IoT, BYOD, autonomous systems, and critical infrastructures?*

4 Methodology

4.1 Review Design

This study adopts a systematic literature review design to identify and synthesise recent research on human factors, information security, and technological risk. The review was structured according to the reporting principles of PRISMA 2020 [32]. The systematic corpus was restricted to studies published between 2020 and 2026, while earlier publications were used only as background references. The final literature search was conducted on August 19, 2026; consequently, publications from 2026 represent studies available up to the search cut-off date.

4.2 Search Strategy

The primary search covered Scopus and Web of Science, complemented by IEEE Xplore, ScienceDirect, and SpringerLink. Searches targeted titles, abstracts, and keywords using combinations of cybersecurity, technological-risk, and human-factor terms. The core search string was:

("cybersecurity" OR "information security" OR "cyber risk" OR "security risk" OR "technological risk") AND ("human factor*" OR "human behaviour" OR "human behavior" OR "user behaviour" OR "user behavior" OR "security behaviour" OR "security behavior" OR "risk perception" OR "perceived vulnerability" OR "trust" OR "decision making" OR "decision-making" OR "perceived control")

Additional searches targeted the technological contexts represented in the review:

("cybersecurity" OR "information security" OR "technological risk") AND ("BYOD" OR "Internet of Things" OR "IoT" OR "mobile device*" OR "smartphone*" OR "autonomous vehicle*" OR "automated vehicle*" OR "critical infrastructure*" OR "quantum computing")

Search syntax was adapted to individual databases where necessary.

Additional eligible publications identified through supplementary author- and reference-based searches were assessed using the same inclusion and exclusion criteria and incorporated into the final corpus.

4.3 Eligibility and Study Selection

Studies were eligible if they (1) were published between 2020 and 2026; (2) were peer-reviewed journal articles, review articles, or scholarly book chapters/proceedings contributions; (3) addressed cybersecurity, information security, technological risk, or system reliability; (4) explicitly considered a human or organisational dimension, such as behaviour, risk perception, trust, awareness, decision-making, compliance, or perceived control; and (5) provided sufficient

methodological or conceptual detail for thematic analysis. Publications in English and Hungarian were considered. Studies focusing exclusively on technical mechanisms, general technology adoption without a meaningful security or risk component, non-scholarly material, and duplicate records were excluded. Study selection followed four stages consistent with PRISMA 2020: identification, screening, eligibility assessment, and inclusion [32]. After duplicate removal, titles and abstracts were screened against the eligibility criteria, followed by full-text assessment. The final systematic corpus comprised 47 publications. Methodological and pre-2020 background sources were not included in the systematic corpus.

4.4 Data Extraction and Thematic Synthesis

For each publication, information was extracted on publication year, technological or organisational context, research design, principal human or organisational constructs, technological-risk dimension, and findings relevant to the research questions. The corpus included quantitative and qualitative studies, systematic reviews, conceptual contributions, and selected scholarly book chapters and conference contributions.

The studies were compared iteratively and organised into five recurring themes:

- Human factors and security behaviour
- Risk perception and security-related decision-making
- Trust and organisational security
- Technological risk, system failure, and reliability
- Critical infrastructures and emerging technologies

Studies could contribute to more than one theme; the categories were therefore treated as interconnected rather than mutually exclusive. The cross-thematic synthesis was subsequently used to develop the Integrated Human-Centred Cybersecurity Risk Framework presented in the Discussion.

5 Results and Thematic Synthesis

The review identified five interconnected domains: (1) human factors and security behaviour, (2) risk perception and security-related decision-making, (3) trust and organisational security, (4) technological risk, system failure, and reliability, and (5) critical infrastructures and emerging technologies. These themes overlap substantially, particularly through risk perception, trust, and decision-making, which connect technological conditions with behavioural and organisational security outcomes. Together, these five themes address the four research questions by covering individual and organisational determinants of security behaviour

(RQ1), risk perception and trust (RQ2), technological risk and reliability (RQ3), and recurring mechanisms across technological contexts (RQ4).

Theme	Main constructs	Main analytical focus
Human factors and security behaviour	Awareness, knowledge, human error, compliance, self-efficacy, motivation	Determinants of secure and insecure behaviour
Risk perception and decision-making	Perceived vulnerability, severity, risk propensity, benefits, coping appraisal	Interpretation of threats and behavioural responses
Trust and organisational security	Technological and organisational trust, perceived control, security culture	Role of trust and organisational context
Technological risk and reliability	Failure, vulnerability, reliability, FMEA, technical risk	Objective technological risk and human response
Critical infrastructures and emerging technologies	IoT, BYOD, autonomous systems, critical infrastructure, quantum computing, AI	Human-technology interaction in evolving environments

Table 1.
Thematic structure of the reviewed literature

5.1 Human Factors and Security Behaviour

Human factors emerged as a consistent determinant of cybersecurity outcomes. Knowledge and personal characteristics are associated with security practices [12], while insecure behaviour may result from passive inaction rather than deliberate risk-taking [13]. Organisational and information-security cultures further influence compliance [8], confirming that security behaviour is embedded within broader socio-technical environments [2]–[4]. Motivational mechanisms are similarly diverse. Protection motivation interacts with stewardship [33], while intrinsic and identity-based motivations [34], as well as prosocial, self-regulatory, and deterrence-related mechanisms [16], can also contribute to security behaviour. BYOD research reinforces the contextual nature of these relationships: individual preferences, organisational policies, compliance requirements, knowledge, and everyday working practices jointly shape security behaviour [27], [28], [35], [11]. Human factors can therefore represent both sources of vulnerability and components of security resilience [9]. The broader ICT environment of SMEs further demonstrates that organisational technology use and innovation practices form an important contextual layer within which security-related behaviour takes place [47].

5.2 Risk Perception and Security-Related Decision-Making

The reviewed studies distinguish technological vulnerability from its subjective interpretation. Perceived vulnerability [14], cognitive and motivational mechanisms [15], knowledge [12], and passive-risk tendencies [13] influence whether users respond protectively to cybersecurity threats. Password management illustrates this relationship particularly clearly. Users balance security requirements against perceived risks, benefits, convenience, and cognitive effort [17]. Memory anxiety affects password-security decisions [18], adaptive and maladaptive factors influence password-manager use [19], and recent findings challenge assumptions concerning the memorability costs of unique passwords [20]. Additional password-security research similarly highlights the continuing importance of user-side practices in determining the effectiveness of technical protection [36]. Comparable decision processes occur in smartphone and BYOD environments [27], [28], [37]. These findings support a central distinction between objective technological risk and subjective risk perception: technical vulnerability creates the possibility of harm, while subjective appraisal influences whether users adopt, postpone, circumvent, or reject protective measures.

5.3 Trust and Organisational Security

Trust connects technological conditions with human responses but is not uniformly beneficial. At the organisational level, security culture and trust shape employee behaviour and relationships among users, technologies, and institutions [8], [24], while BYOD governance requires organisations to balance control, autonomy, and technological risk [10]. This relationship is particularly visible in autonomous systems. Trust and perceived risk influence technology adoption [21]; cybersecurity attacks can substantially reduce trust [22]; and cyber readiness and response affect trust and blame attribution [23]. Readiness and societal perceptions of autonomous vehicles further demonstrate that technological capability alone does not determine preparedness or acceptance [38], [39]. Recent human-centred research also differentiates driver responses to cyber-attacks in automated vehicles, further demonstrating that cybersecurity incidents can produce heterogeneous behavioural responses [40].

5.4 Technological Risk, System Failure, and Reliability

Engineering-oriented studies provide an objective-risk perspective by identifying technological failures and vulnerabilities. FMEA-based smartphone analysis demonstrates how failures can be systematically prioritised [5], while mobile-device research identifies hardware and software factors affecting reliability [41]. Human-centred research complements this perspective by examining whether users recognise these risks and respond appropriately. Password security illustrates how

technically stronger practices may conflict with cognitive or practical considerations [17]–[20], [36], while mobile and BYOD environments require security measures to coexist with usability and everyday organisational practices [27]–[29]. The same relationship extends to cyber-physical systems. Connected and autonomous vehicle research integrates technological, human, and contextual cybersecurity dimensions [7], while expert evidence identifies cybersecurity and privacy as significant concerns [42]. Thus, technological reliability and human behaviour represent complementary dimensions of security risk rather than independent problems. Blockchain-based solutions provide a complementary technological perspective, illustrating how decentralised and cryptographically protected data storage can be incorporated into security-sensitive digital systems [48].

5.5 Critical Infrastructures and Emerging Technologies

Critical infrastructures make the interaction between technological and human risk particularly consequential. Human factors can contribute to both vulnerability and resilience [25], and security-management research demonstrates the importance of incorporating users and operators into interconnected critical-infrastructure protection [26]. Comparable socio-technical challenges arise in IoT and BYOD environments, where interconnectivity and organisational boundaries increase the importance of integrated technological, behavioural, and governance approaches [3], [29]. Cross-context comparisons between BYOD and autonomous vehicles further suggest that similar user-related cybersecurity challenges can recur across otherwise distinct technological environments [43]. Autonomous systems similarly combine cybersecurity, privacy, trust, readiness, and institutional concerns [7], [21], [22], [38], [42], [39], with military applications adding further safety and security considerations [44]. Emerging technologies extend these challenges. Quantum computing may undermine established encryption mechanisms [30], while AI-supported environments introduce new requirements for governance and trust calibration [31]. Across these contexts, increasing technological complexity simultaneously creates new vulnerabilities and greater dependence on systems that users and organisations cannot fully evaluate. Blockchain-based applications further illustrate how emerging digital architectures can reshape data management, verification, and security requirements across organisational environments [49].

5.6 Cross-Thematic Synthesis

Across the five themes, technological conditions, risk perception, trust, perceived control, decision-making, and security behaviour emerged as recurrent and interconnected dimensions. Individual factors—including knowledge, awareness, experience, self-efficacy, motivation, and risk tendencies—shape how threats are interpreted [12]–[20], [33], [34], while organisational factors such as security

culture, policies, management practices, trust, and governance influence the decision environment [8], [10], [24]–[29]. Security outcomes can, in turn, affect subsequent perceptions and behaviour. Cybersecurity incidents and technological failures may modify risk perception and trust [22], [23], while research on behavioural responses to attacks further indicates that these effects need not be uniform across users or situations [40]. These cross-thematic relationships provide the basis for the Integrated Human-Centred Cybersecurity Risk Framework developed in the Discussion.

6 Discussion

The findings indicate that cybersecurity cannot be adequately explained from either a purely technical or behavioural perspective. Across the reviewed contexts, technological conditions acquire behavioural relevance through risk perception, trust, perceived control, and decision-making. The main contribution of the synthesis is therefore to integrate these mechanisms within a common socio-technical process.

6.1 From Technological Risk to Human Behaviour

Security behaviour reflects a combination of individual and organisational mechanisms. Knowledge and personal characteristics influence security practices [12], while insecure outcomes may result from passive inaction rather than deliberate risk-taking [13]. Motivation [33], [34] and organisational security culture [8] further shape behavioural responses. These findings challenge the conventional characterisation of users simply as the “weakest link.” Human involvement can generate vulnerability but also provide adaptability, threat recognition, judgement, and resilience [2], [9]. Security interventions should therefore address not only knowledge but also users’ capabilities, motivation, perceived relevance of threats, and organisational environment. The findings also reinforce the distinction between objective technological risk and subjective risk perception. Technical methods identify vulnerabilities and failures [5], [41], whereas behavioural responses depend on how these risks are interpreted [14]–[20]. The two dimensions are therefore complementary: technological risk defines the underlying conditions, while risk perception determines their behavioural relevance. Cybersecurity management should consequently seek risk calibration rather than risk maximisation, as both underestimation and excessive perceived risk may produce undesirable responses.

6.2 Trust and Technological Context

Trust should similarly be calibrated rather than maximised. Excessive trust can encourage inappropriate reliance, while insufficient trust can inhibit or distort technology use. Autonomous-system research illustrates this clearly: trust and perceived risk affect adoption [21], cybersecurity incidents can produce persistent reductions in trust [22], and cyber readiness and response influence both trust and blame [23]. Human responses to cyber-attacks may also vary substantially across users and situations [40]. Organisational trust extends this mechanism beyond direct human–technology interaction [24]. Although these mechanisms recur across technological contexts, their consequences vary. Passwords, mobile devices, BYOD, IoT, autonomous vehicles, and critical infrastructures differ substantially in complexity and potential impact [3], [7], [25], [27], [38], [42]. Cross-context comparisons between BYOD and autonomous vehicles nevertheless indicate recurring user-related cybersecurity challenges [43]. The evidence therefore suggests that risk perception, trust, perceived control, and decision-making may represent transferable mechanisms, while the magnitude and consequences of risk remain technology-specific.

6.3 Integrated Human-Centred Cybersecurity Risk Framework

Based on the cross-thematic synthesis, this review proposes an Integrated Human-Centred Cybersecurity Risk Framework linking technical, cognitive, behavioural, and organisational dimensions: Technological and contextual conditions include vulnerabilities, reliability, attack exposure, complexity, and the operational environment. These conditions are interpreted through threat appraisal and subsequently influence trust, perceived control, decision-making, and security behaviour, including protective action, circumvention, or inaction [13]. As summarised in Figure 1, the process is shaped by cross-cutting individual, organisational, and technological factors. It is also recursive rather than strictly linear: security incidents, system failures, protective actions, and organisational responses can modify subsequent risk perception and trust, creating feedback into future decisions and behaviour [22], [23]. The framework represents a conceptual synthesis rather than a statistically validated causal model. Its purpose is to integrate relationships that are often examined separately and provide a structure for future empirical testing.

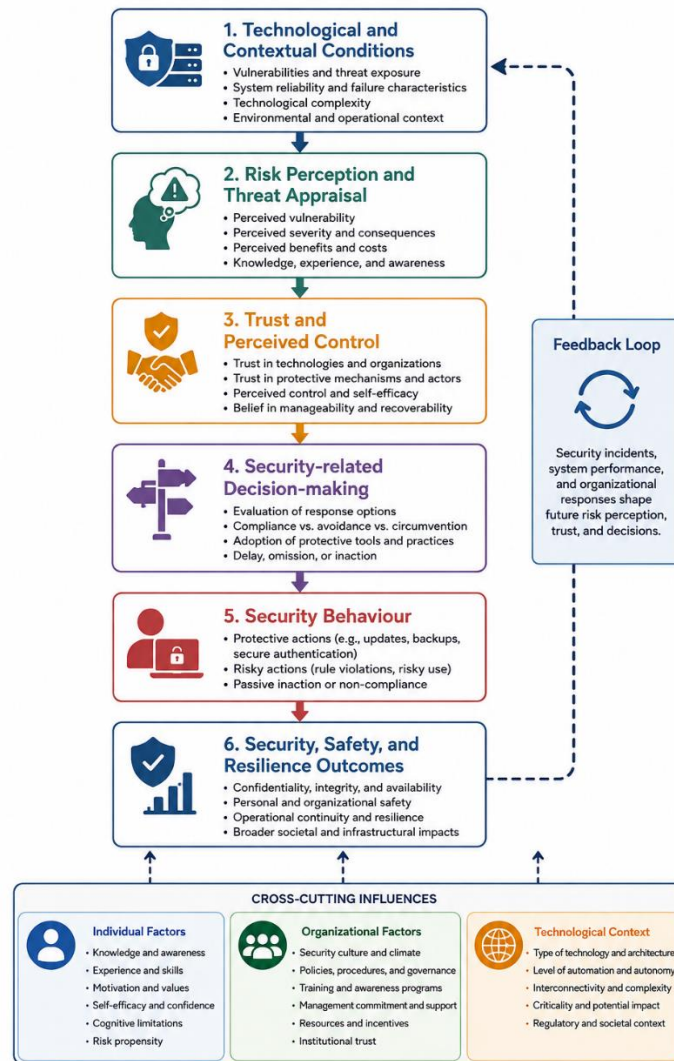


Figure 1.
Integrated Human-Centred Cybersecurity Risk Framework

6.4 Theoretical and Practical Implications

The principal theoretical contribution is the integration of technical risk assessment with behavioural and organisational explanations of cybersecurity outcomes. This

perspective distinguishes objective technological conditions from their subjective interpretation while incorporating calibrated trust as a mechanism connecting risk appraisal with behaviour. These relationships are particularly relevant in autonomous, AI-supported, and critical systems [31].

For practice, security management should combine technical controls with behavioural and organisational interventions. Awareness and training should be complemented by attention to perceived vulnerability, self-efficacy, usability, cognitive burden, organisational culture, and the practical costs of compliance. BYOD research demonstrates how security measures that conflict with everyday practices may encourage circumvention [27]–[29], [35]. Risk communication should likewise seek to align perceived and objective risk while providing understandable and feasible protective responses. As systems become increasingly interconnected and autonomous—including developments associated with quantum computing and AI [30], [31]—human-centred risk management should be treated as an integral component of cybersecurity strategy. More broadly, differences in organisational digital transformation may shape the technological and managerial context in which cybersecurity practices and risk-management measures are implemented [46].

7 Limitations and Future Research

This review has several limitations. First, the systematic corpus was restricted to studies published between 2020 and 2026, with the 2026 coverage limited to publications available by the final search date; earlier contributions were used only selectively as background literature. Second, the reviewed studies are heterogeneous in technological context, research design, theoretical perspective, and measurement of constructs such as risk perception, trust, and security behaviour. This supports cross-context conceptual synthesis but limits direct quantitative comparison and meta-analytic interpretation. Finally, the five thematic categories are interconnected rather than mutually exclusive and should therefore be interpreted as a synthesis framework rather than a rigid taxonomy. Future research should examine objective technological risk and subjective risk perception simultaneously, particularly whether discrepancies between them influence security behaviour. Longitudinal and experimental studies are also needed to investigate how security incidents alter trust and how trust is subsequently restored or recalibrated [22], [23]. Comparative research across technological contexts could further establish which relationships among risk perception, trust, perceived control, and security behaviour are generalisable and which remain technology-specific. Finally, the Integrated Human-Centred Cybersecurity Risk Framework proposed here requires empirical validation. Future studies could operationalise its

components and test their relationships using structural models, experiments, longitudinal designs, or mixed-method approaches.

Conclusion

This systematic literature review synthesised 47 publications from 2020 to 2026 to examine the relationship between human factors, information security, and technological risk. The findings demonstrate that cybersecurity is inherently socio-technical: technological vulnerabilities acquire behavioural relevance through risk perception, trust, perceived control, decision-making, and organisational conditions. A central conclusion is that objective technological risk and subjective risk perception should be distinguished but analysed jointly. Technical vulnerability alone does not determine security behaviour, while perceived risk depends on how technological conditions are interpreted. Similarly, effective cybersecurity requires calibrated rather than maximised trust, aligning users' confidence with actual system capabilities, vulnerabilities, and safeguards. Based on these relationships, the study proposes an Integrated Human-Centred Cybersecurity Risk Framework that integrates technological, cognitive, behavioural, and organisational dimensions of cybersecurity within a recursive socio-technical process. The framework provides a basis for examining how technological conditions are translated into security behaviour and outcomes across different technological contexts. Overall, human factors should not be treated merely as vulnerabilities within otherwise technical systems. Human judgement, knowledge, adaptation, and organisational behaviour are integral components of cybersecurity. As digital systems become increasingly interconnected and autonomous, effective security will require the integration of technical reliability, human behaviour, calibrated trust, and organisational resilience.

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Research and Development, Innovation and Competitiveness in the Age of the Fourth Industrial Revolution

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Abstract: This study examines the relationships between research and development (R&D), innovation, and national economic competitiveness, with particular attention to Hungary's situation. The author reviews the conceptual frameworks of competitiveness and innovation (Schumpeter, Porter, Krugman, OECD, Lengyel), presents the forms in which innovation manifests, and then, based on the Hungarian Central Statistical Office's latest data for 2022–2025, assesses the evolution of domestic R&D expenditure and innovation activity. The study also addresses Hungary's position in international competitiveness and innovation rankings (European Innovation Scoreboard, IMD World Competitiveness Ranking), as well as the impact of the Fourth Industrial Revolution and the data-driven economy on R&D. The author concludes that the key to lasting competitiveness lies in building a knowledge-based society and in the systematic, long-term support of corporate and state R&D&I activity.

Keywords: research and development, innovation, competitiveness, Fourth Industrial Revolution, knowledge-based economy

1 Introduction

Research and development (R&D) is an important priority in national economic strategy. In 2025 – according to preliminary data – Hungary spent 1.33% of GDP, a total of HUF 1,154 billion, on R&D activity, 8.0% more at current prices than in 2024; the share of the employed population engaged in R&D activity reached 1.14% [14]. R&D expenditure as a share of GDP has persistently exceeded 1% since 2009, reaching its peak to date in 2020 (1.61%), followed by a moderate decline and subsequent stagnation [12].

Competitiveness, research and development, and innovation are closely interlinked. Innovation also held a prominent place among the European Union's strategic priorities valid until 2020 (Europe 2020): smart growth aimed at building an economy based on knowledge and innovation, sustainable growth aimed at a more resource-efficient and competitive economy, and inclusive growth aimed at high

employment and social cohesion. This earlier strategy has now been superseded by the European Innovation Strategy (2022) and the objectives of the Digital Decade 2030 [7], which continue to place knowledge-based, innovation-driven and sustainable growth at their centre.

The theoretical foundations of innovation were first laid down by Schumpeter [26]. Competitiveness was originally a microeconomic concept; Porter and Krugman consider its examination at the national economic level meaningless [25, 10]. Nevertheless, the OECD has defined the concept as “the degree to which a country can, under free market conditions, produce goods and services that meet the test of international markets, while simultaneously maintaining and expanding the real incomes of its people over the longer term” [22]. More recently, the OECD has also formulated a unified definition of competitiveness: “the ability of companies, industries, regions, nations and supranational regions to generate, while being exposed to international competition, relatively high income and employment levels on a sustainable basis” [16].

Today's competitiveness-enhancing trends place the main emphasis on knowledge, innovation and human resource development, which necessitates the continuous rethinking of measurement methods [17]. Rather than the earlier approach based on the spatial reallocation of resources, post-modern regional policy seeks to activate internal resources — regional, social, organisational, cultural, environmental and economic factors — and to explore new opportunities; it envisages development through the acquisition of information, the extension of knowledge and innovation, and the building of relational networks [17].

Entering the era of the Fourth Industrial Revolution, the pace of innovation, technological development and data generation is faster than ever before, posing new challenges for both corporate and state R&D policy.

2 Research and Development and Innovation: Conceptual Frameworks

Research and development and innovation form the basis of competitiveness. Competitiveness has been addressed in the work of numerous authors [15, 2, 3], who agree that no universally accepted definition or uniform method of measurement exists to this day [20, 21].

The OECD distinguishes between micro-, macro- (national economic) and structural competitiveness; structural factors are linked to the firm, such as infrastructure, services, and the characteristics of innovation and R&D&I [22]. According to Török, “at the micro level, the concept of competitiveness means the ability to gain a position and hold one's own in market competition among

individual firms and competitors, while at the macroeconomic level it refers to competition among national economies” [28]. Competitiveness, therefore, does not merely denote market success but also encompasses the capacity for successful adaptation.

Analyses show that it is not only the competitiveness of the business sector that determines a country's competitiveness, but also the innovativeness of the non-business sector and society as a whole [19]. Innovation capacity and opportunities are shaped by asset elements that were previously little valued and difficult to quantify, intangible yet decisive — trust, knowledge, relational capital, and willingness to cooperate [18].

Innovation manifests itself in the following forms:

1. Product development – new products and services that either create new demand or satisfy existing demand.
2. Technological development – the introduction of new technology, or the establishment or development of a production process.
3. Organisational development – internal organisational transformation brought about by changing circumstances or mergers.
4. Market innovation – entry into a new market.

According to a widely used definition, innovation is “the transformation of an idea into a new or improved product introduced onto the market, or into a new or improved process used in industry or commerce, or into a new approach to a social service” [22]. Schumpeter divides the innovation process into three phases: invention (the emergence and development of new ideas), innovation (turning ideas into marketable products/production processes), and diffusion (the spread of new products and processes as they conquer markets); together, these ultimately generate revenue [26].

3 Innovation Activity among Domestic Enterprises

In accordance with the methodological requirements of the European Union's Community Innovation Survey, the Hungarian Central Statistical Office (KSH) surveys the innovation-related data of enterprises employing at least 10 people

every two years.² The scope and methodology of the data collection have been revised several times over the years.³⁴

According to the most recent survey, covering the 2022–2024 period, 36% of the enterprises observed carried out some form of innovation activity, 5.7 percentage points higher than the share recorded for 2020–2022 [13]. The improvement is primarily attributable to the growing share of enterprises introducing business process innovation, and, in terms of employment size, the innovation activity of medium-sized enterprises (50–249 employees) improved most markedly [13]. This represents significant progress compared with the 25.6% recorded for 2012–2014 [11], although, owing to methodological changes, the two periods can only be compared to a limited extent (Table 1).

Period	Share of enterprises carrying out innovation activity
2012–2014	25.6%
2020–2022 (derived value)	~30.3%
2022–2024	36.0%

Table 1

Trend in the share of enterprises carrying out innovation activity

Source: KSH, 2016; KSH, 2025, own compilation

According to the earlier 2012–2014 survey, a significant proportion of innovative enterprises carried out activities related to product or process innovation, and in many cases also achieved favourable environmental effects [11]. At the time, there was still a considerable difference by size: among enterprises employing more than 250 people, the share of innovative enterprises exceeded 55%, whereas among those with fewer than 50 employees it stood at around 22%, with innovation being particularly high in the pharmaceutical and petroleum-processing industries [11]. The most recent, 2022–2024 survey — as noted above — has already narrowed this size-related gap somewhat, since it was precisely the innovation activity of medium-sized enterprises that improved most over the last two cycles [13]; the most recent, detailed data on activities related to product and process innovation, as well as on environmental effects, are available in the KSH STADAT database.

² The KSH collects data in accordance with the methodological requirements of the European Union's Community Innovation Survey.

³ In 2012, the scope of the observed sectors was expanded to include film, video and television programme production, sound recording and music publishing, programming and broadcasting activities, scientific research and development, as well as advertising and market research.

⁴ Act LXXVI of 2014 on Scientific Research, Development and Innovation.

4 Hungary's International Competitiveness and Innovation Position

The long-term set of conditions affecting competitiveness has been analysed by numerous researchers [23, 1], which can be summarised as follows: predictable economic policy; a supportive state (quality institutions, quality legislation, stable administration of justice, etc.); a well-trained, adaptive, healthy workforce; flexible, developing enterprises capable of adapting to competition; an efficient financial sector providing financing; a stable, growth-supporting tax policy; and a skilled workforce receptive to innovation.

The European Commission's annual European Innovation Scoreboard (EIS) report classifies Member States' innovation performance into the groups of Innovation Leaders, Strong, Moderate and Emerging Innovators. According to the 2025 edition, Hungary — despite achieving a 16.2 percentage point improvement compared with 2018 — slipped from the Moderate Innovators group into the Emerging Innovators group, as other countries improved relatively faster [5]. According to the 2026 edition, however, Hungary returned to the Moderate Innovators group [6]. This shift clearly illustrates that relative position depends at least as much on the performance of other Member States as on Hungary's own absolute progress.

Török distinguishes three approaches to macro-level competitiveness analysis: in the supply-side and demand-side approaches, the main determinants of competitiveness are the cost factors of external economic performance and the value of performance itself, while according to a third approach, competitiveness is an overall indicator of the state of the economy [29]. It is this third view that is represented by the institutes that annually publish countries' competitiveness rankings.

The World Economic Forum's previously frequently cited Global Competitiveness Index was suspended by the organisation in 2020, citing the coronavirus pandemic, and it has not published a regular, ranking-based competitiveness report since [30]. Analyses now rely more on the Switzerland-based IMD World Competitiveness Center's annual World Competitiveness Ranking publication. In the 2025 ranking, Hungary improved by six places compared with the previous year, and finished ahead of its regional competitors — Romania, Poland, Croatia, Bulgaria and Slovakia — owing primarily to its performance in the infrastructure and economic performance sub-factors [9].

As shown in Section 1, Hungary's GDP-proportionate R&D expenditure reached its peak to date in 2020 (1.61%), after which it gradually declined (Figure 1). This declining trend continues to lag significantly behind the EU average: in 2020, according to preliminary data, the EU27 average was 2.32%, exceeding 3% in the

traditionally R&D-intensive Member States (Belgium, Sweden, Austria, Germany, Denmark), while in Romania, the lowest, it did not even reach half a percent [12].

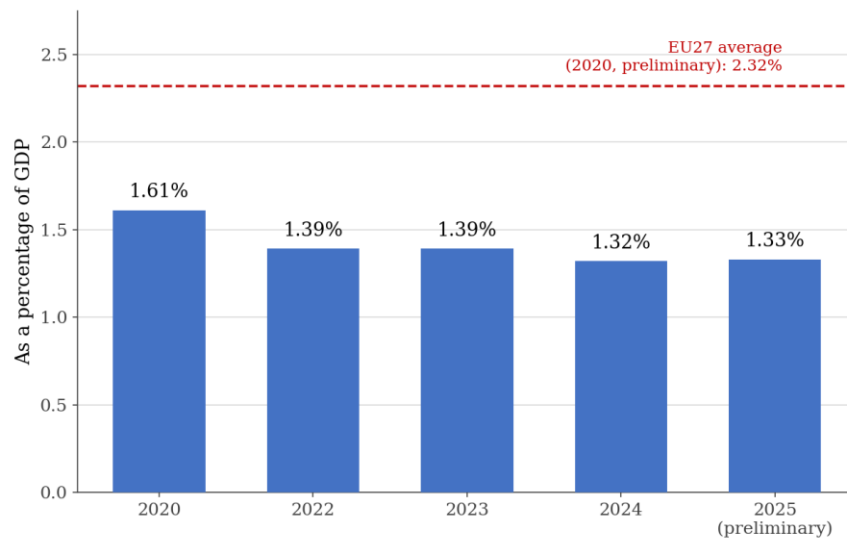


Figure 1

Trend in domestic R&D expenditure as a percentage of GDP, 2020–2025

Source: KSH, 2024; KSH, 2026, own compilation

Figure 1 clearly illustrates that, following the 2020 peak (1.61%) — also distorted by the pandemic — the indicator fell to 1.39% in 2022–2023, then to 1.32% in 2024, and the 2025 preliminary figure (1.33%) shows only a minimal improvement. Compared with the EU average shown in the figure (2.32%), Hungary's shortfall has therefore not narrowed; indeed, the domestic indicator has moved further away from its peak value since 2020, while — as shown earlier in this section — innovation activity (the share of enterprises engaging in innovation) improved over the same period. This suggests that the level of R&D expenditure and the trend in innovation activity do not necessarily move together, and that a decline in GDP-proportionate expenditure does not necessarily imply a decline in innovation performance.

5 The Fourth Industrial Revolution and the Data-Driven Economy

The successive waves of industrial revolution have brought about ever faster change: the first primarily transformed industrial labour, the second brought mass

production, and the third brought technological automation, programmability and telecommunications. The Fourth Industrial Revolution now under way surpasses these, bringing breakthroughs in cyberspace, information technology, robotics and numerous other fields.

The global volume of data is growing exponentially: while the world's digital datasphere stood at 33 zettabytes in 2018, estimates suggest it grew to 175–181 zettabytes by 2025 — more than a fivefold increase in just seven years [8]. The continuous growth in the number of internet-connected devices (IoT) and the volume of data they generate is further accelerating the spread of data-driven innovation and artificial intelligence, thereby also transforming the framework of R&D activity. According to Perez, the qualitative engine of economic development is innovation, which can contribute significantly to growth [24], particularly for small and medium-sized enterprises, which provide a substantial share of employment.

Rapid change in the information environment brings both advantages and disadvantages. Among the advantages is the fact that decision-makers are not left behind on relevant developments, and that ample data is available for mathematical and statistical analysis from which conclusions can be drawn. Among the disadvantages, however, is precisely the uncertainty created by the rapidly changing environment: the sheer volume of available data does not in itself guarantee sound decisions if the organisation lacks the methodological and human resources needed to process and interpret it. This reinforces the view that, alongside technological development, at least as much emphasis must be placed on the human factor and its training, so that organisations can make well-founded decisions that also take moral considerations into account [31].

6 The Corporate Environment of Innovation and Future Factors of Competitiveness

The most widely applied innovation framework today is the open innovation model, which is based on the integrated management of technologies and knowledge sources both within and outside the firm [4] (Figure 2).

THE OPEN INNOVATION CHANNEL

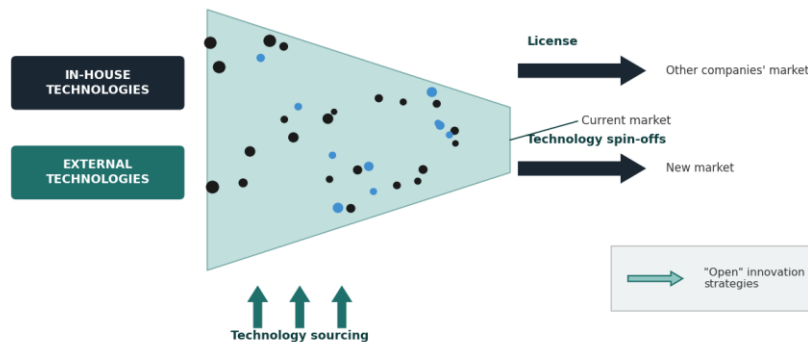


Figure 2

The open innovation model

Source: Döry, 2012

Figure 2 clearly illustrates the essence of open innovation: the firm does not rely solely on its own internally developed technologies but deliberately draws external technologies into its development channel, and then exploits the resulting innovations in several directions — licensing them to other companies, creating technological spin-off firms to target new markets, or introducing them in its current market. This model stands in sharp contrast to the traditional, closed innovation logic, according to which a firm must realise every idea, development and market launch using only its own internal resources, within its own walls. The importance of open innovation lies precisely in the fact that it reduces individual firms' development risk and time: externally sourced technology can accelerate market entry, while licensing and spin-off channels generate revenue even from innovations that would not fit the firm's own core business. However, since every firm — and the cultural and economic environment surrounding it — is unique, no single, universally applicable innovation model can be established; the extent and form of open innovation can vary considerably by industry, and even by firm.

The corporate innovation environment is shaped by several factors. Changes in consumer demand and purchasing power force innovative firms into continuous adaptation. The pace of competitors' innovation is likewise decisive: the risks of excessively accelerated product development cycles are well illustrated by Samsung's complete recall of the Galaxy Note 7 in 2016 for safety reasons, a reminder that shortening the time devoted to prototype testing and user feedback can pose serious reputational and financial risks. The role and extent of state support vary from country to country, while cooperation among firms is often hindered by

distrust related to the protection of intellectual property, particularly in the large-enterprise sector; micro- and small enterprises tend to be more of an exception in this respect. Responsible management of natural resources and environmental awareness can now, in themselves, constitute a market advantage. Finally, the pace of corporate growth has also accelerated: some companies are now taken public within 2–3 years, raising the question of whether this pace risks diluting the pool of stable companies with unstable players.

Patent activity remains an important indicator of competitiveness; in this respect, the United States, China, South Korea and Japan are the most active centres of innovation [32]. The innovation environment also depends heavily on cultural space: firms operating in the same industry and at the same technological level can differ considerably in their propensity for innovation and risk-taking, depending on how open the surrounding economic and social environment is to innovation and how tolerant it is of failure — this is one of the reasons why, even under the same EU regulatory framework, persistent differences in innovation performance remain among Member States.

Summary

The analyses clearly show that research and development and innovation are, and will remain, the driving forces of the economy, both now and in the future. In this context, building a knowledge-based society is one of the most important strategic goals. Hungary's R&D expenditure and innovation activity have improved considerably over the past decade, yet domestic indicators continue to lag behind the EU average and the leading innovator countries. It is not always advisable to compete on the basis of a large mass of human labour; for Europe — and for Hungary within it — it is primarily the development of knowledge and innovative thinking that can lay the foundations for lasting competitiveness.

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Consumer Perceptions of AI Influencers

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Abstract: The paper reviews how consumers perceive the AI-powered influencers on social media. AI influencers represent a relatively new form of communication between brands and consumers. The topic has gained increasing attention because a growing number of brands started using human-like avatars in marketing communication while consumer opinion has not yet been fully determined. As a result, they raise new questions about authenticity and credibility in influencer marketing. This paper seeks to offer insight into consumer perceptions of AI influencers, particularly the role of authenticity, credibility, trust, humanness, and uniqueness. The study is based on a review and synthesis of existing academic literature. Previous studies show that human-like AI-generated influencers may increase the uncertainty about brand and have a strong influence on the formation of attitudes and engagement. At the same time, some studies suggest that novelty and uniqueness may increase consumer interest and engagement among younger and digitally active audiences.

Keywords: AI influencers, consumer perceptions, authenticity, trust, social media marketing

1 Introduction

1.1 Background and relevance of the topic

Social media has been part of brand communication for years, but in the last decade it has become a key tool for business growth and marketing communication. Brands no longer just post irregularly as they used to but increasingly integrate social media into their marketing strategies. Social media marketing has also moved away from the more frontal advertising style that was common in its earlier period. Brands

realised that they do not always need to spend blockbuster amounts of money on Facebook ads. This shift created room for a more personal and less formal kind of communication, which is where influencers entered the picture. Influencer marketing has become far more prominent in recent years, partly because marketing noise has become almost unbearable and younger audiences have become numb to traditional ads. In this crowded environment, everyday people started to share their opinions on products, and some of them gradually became influential voices on the web. Influencers now affect how consumers think and what they buy. As a result, companies invest more in collaborations with online influencers, and influencer marketing is no longer a niche practice but a widely adopted marketing approach [2].

In the last few years, with the growth of artificial intelligence, brands have started to realise that they can benefit from it and adapt it to content creation and digital communication. Human influencers have always had the potential to make a wrong move and make a brand regret working with them. This is one reason why brands have become more interested in virtual alternatives that offer greater control and fewer reputational risks. Developments in artificial intelligence and computer-generated content have transformed digital communication in a new way. In the beginning, inconsistent and often mediocre AI-generated images flooded social platforms, but brands adapted quickly and learned how to create computer-generated characters with human-like appearance and behaviour in a more consistent way. These characters are now able to interact with audiences and promote products similarly to human influencers. A number of AI influencers collaborate with global brands and attract millions of followers [2].

What makes AI influencers particularly attractive for brands is not only their novelty, but also their predictability. Unlike human influencers, AI influencers are not exposed to personal scandals or unpredictable behaviour. This makes them a more stable and manageable communication tool for brands. It also gives companies the possibility to build carefully designed and highly consistent identities around them [1], [5].

1.2 Research gap and research problem

At first glance, controllability and consistency could make AI influencers seem like a perfect solution for brands. However, the question remains whether artificial creations can build the same kind of connection and credibility as human influencers. Can a computer-generated, human-like influencer really influence the public in a way that cuts through the constant noise of digital media? Although AI influencers may bring real advantages for brands, they also raise doubts about authenticity and credibility [1], [5].

Several factors seem to shape how consumers perceive AI influencers. Among the most frequently discussed are authenticity, credibility, and trust. At the same time,

the human-like characteristics of these digital figures also appear to play an important role in consumer reactions [2]. Still, the overall picture is far from clear. Existing research does not provide a consistent understanding of these factors, and in many cases they are examined in isolation rather than as part of a broader framework [2], [5]. Because of this, it is still difficult to see how these dimensions work together in shaping consumer reactions.

1.3 Research questions

The aim is to examine how consumers perceive AI influencers in social media marketing. Special attention is given to dimensions such as authenticity, credibility, trust, humanness, and uniqueness [5]. To guide the discussion, the paper addresses the following research questions:

RQ1: How are AI influencers perceived by consumers in social media environments?

RQ2: Which dimensions are most strongly associated with behavioural openness toward AI influencers?

RQ3: How do AI influencers compare with human influencers in terms of authenticity, trust, and credibility?

In addition to the literature review, the paper also includes a short exploratory primary study based on a non-representative online questionnaire.

2 Literature review over artificial intelligence

2.2 Defining AI influencers

To understand why AI influencers have gained such an important role in marketing communication, they first need to be defined. According to Ma and Li [7], AI influencers are computer-generated digital characters designed to operate as influencers in social media environments. Their role is similar to that of human influencers. They create content, engage with audience and promote brands, products, or services. However, they differ from human influencers in such a unique way that brands can shape them into carefully designed promotional tools. Brands are able to build an AI avatar from the ground up without inconvenient factors such as a problematic personal history [2].

The category is not uniform. According to Davlembayeva et al. [2], virtual influencers can be grouped into several categories, such as non-human like, human-

like and brand mascots. Furthermore, it can be distinguished by their roles in brand communication: entertainment-driven virtual figures, commercially managed influencers, or brand mascots.



Figure 1.

Examples of virtual influencers. From left to right: Nobody Sausage (@nobodysausage), Lil Miquela (@lilmiquela), and Lu of Magalu (@magazineluiza). Source: Davlembayeva et al. [2].

For instance, @nobodysausage represents a more entertainment-oriented non-human-like virtual influencer without promoting a specific brand, @lilmiquela are commercially managed human-like virtual influencers with brand collaborations, while @magazineluiza function as brand mascots created to represent specific brands [2].

This distinction is important because different types of virtual influencers may trigger different reactions from audiences, especially when their level of human likeness changes. This helps explain why brands increasingly turn to AI influencers [2], [7].

2.3 Why brands use AI influencers

Brands choose AI influencers not just for the hype, they have exact strategic reasons. The main reasons that the paper identifies are controllability, consistency, reliability, always-on availability and long-term sustainability. The AI variant of influencers easier to manage, they do not age, they do not need rest, they are not able to make mistakes. For this reason, brands do not see them as alternative of human influencers, but rather a carefully planned and controlled marketing communication tool, that can be used for exact strategic purposes [5], [6].

The other main reason why brands use AI influencers is the precise digital identity they can create. Koles et al. [6] states that not only the present what can be controlled, but also the past. Brands can create the origin story of their AI influencers. They can make the most fitting avatar for their brand. This is so important in fields like fashion, where aesthetics, image and symbolism are crucial. Not only they promote, but also convey the brand's narrative, visual identity and values in such a unique, never seen way that a human influencer would not be able to do [6].

Volles et al. [9] argue that AI influencers value is not only in their ability to be controlled, but also in their uniqueness. Virtual influencers may be seen as less trustworthy, yet their uniqueness can still work in their favor and lead to positive consumer responses. This is especially important if the consumer can relate to the AI influencer. As the paper discusses in the previous section, the AI influencers is not a uniform category. Yan et al. [10], states that artificial avatars may trigger different emotional attachments and consumer motivations. This means that brands need to choose the right narrative persona depending on the communication context. Some cases the realistic, human-like virtual persona is the most fitting, in other cases a more stylized, cartoon-like avatar may be more entertaining [9], [10].

The appeal of digital characters for brands is further strengthened by the fact that their authenticity and credibility does not necessarily work on the same basis as human influencers. Koles et al. [6] argue that credibility can take different forms, AI avatars do not need to be copied from real people, for instance by relating to an ideal, an objective reality, or an individual's internal sense of self-consistency. Put it simply, this means the created character do not need to be realistic but satisfy the consumer's expectations and here lies the key. It may be more effective for brands to recognize that consumers do not need another highly standardized influencer figure, rather an avatar that consumers can identify with and who carries symbolic meaning to them [6].

Overall, the appeal of AI influencers from a brand perspective can be explained by greater control, more consistent identity building, and more flexible communication opportunities. At the same time, it is important to note that these advantages do not automatically guarantee success. For this reason, the next section will examine the main dimensions that shape consumer perceptions of AI influencers.

2.4 Consumer perceptions of AI influencers

From a brand perspective, AI influencer technology is attractive because agencies can manage several aspects of the influencer marketing process. But on the other hand consumer perceptions of AI influencers are shaped by a variety of factors. Although the idea that brands gain full control is an advantage for them, it may negatively affect consumer perceptions. The literature most often highlights authenticity, credibility, trust, humanness, and uniqueness among them [6].

According to Koles et al. [6] authenticity is one of the most important factor. Consumers may easily question how real or genuine they are. The authors explain that virtual influencers can be perceived as authentic in different ways, including true-to-ideal, true-to-fact, and true-to-self. In simple terms, this means that a virtual influencer may appear authentic by matching an expected ideal, by seeming believable or by remaining true to their character.

Credibility is another important dimension in how consumers perceive AI influencers. Perceived credibility and trustworthiness are key conditions of their effectiveness. However, credibility may be weakened when consumers perceive AI influencers as overly controlled by brands. In line with this, Franke et al. [3] suggest that virtual influencers may be viewed as innovative and effective, but at the same time as uncanny or even deceiving. Nevertheless, this does not necessarily mean that their credibility collapses completely, as factors such as uniqueness and strong storytelling may partly offset these concerns [2], [3], [9].

Uniqueness is also frequently mentioned as a factor that can positively shape consumer responses to AI influencers [9]. Uniqueness is one of the most appealing aspects of the influencer that brands can make whatever they need for their new campaign [1], [2]. Uniqueness came from the fact that the technology is mostly new. This newness makes the avatars interesting for consumers, and this can make an impact on their lack of trust. However, novelty alone is not enough to compensate for the lack of trust and identification [9].

Humanness can be seen as a factor that can positively shape consumer responses to AI influencers if they are perceived as human-like [7], [10]. If consumers perceive AI influencers human-like, they are more likely to see not just a tool for marketing purposes. This can increase anthropomorphism, which can lead to parasocial interactions [7]. Although brands need to be aware if a virtual influencer appears too human-like without seeming fully real, it may also trigger an uncanny reaction and create discomfort instead of connection [3], [4].



Figure 2.
Examples of uncanny valley, the 2019 film adaptation of Cats
Source: [11]

Trust is a fundamental key factor. Unlike credibility, which is more closely linked to believability, trust refers to whether consumers are willing to rely on the influencer and its recommendations. This is important in the case of AI influencers, since these avatars are highly controlled by brands. For this reason, the level of transparency and disclosure surrounding their identity may strongly affect trust [5], [8]. As Khalfallah and Keller [5] suggest, trust also plays a mediating role between

authenticity, disclosure, and engagement, which means that weak trust may reduce positive consumer responses even when other characteristics appear favorable.

Taken together, these dimensions show that consumer perceptions of AI influencers are not shaped by a single factor, but by a complex balance of attraction and skepticism. While some characteristics, such as uniqueness, human-likeness, or narrative coherence, may support positive reactions, concerns related to authenticity, credibility, and trust continue to limit broader consumer acceptance.

3 Materials and Methods

This section presents the research design, the sample and data collection process, the questionnaire and measurement, and the analytical approach used in the exploratory study.

3.1 Research design

The paper uses exploratory primary data collected through an online questionnaire. The goal of the questionnaire was to examine how consumers perceive AI influencers in social media marketing. The survey was based on the dimensions identified in the literature, including general attitude, authenticity, credibility, trust, humanness, uniqueness, comparison with human influencers, and behavioural openness, while also collecting basic background data on prior exposure, age, gender, and social media use. The empirical part of the study followed an exploratory descriptive and correlational approach rather than a dimension-reduction approach.

3.2 Sample and data collection

The data were collected through an anonymous online questionnaire. The target group consisted of social media users, as the study focused on perceptions of AI influencers in social media environments. The final sample consisted of 50 respondents. The sample was non-representative and should therefore be interpreted as an exploratory convenience sample.

3.3 Questionnaire and measurement

The questionnaire consisted of 18 items. The first question measured whether the respondent had previously seen an AI-generated influencer on social media. The main perception-related statements were measured on a five-point Likert scale,

where 1 meant strongly disagree and 5 meant strongly agree. Items 2-4 examined general attitude toward AI influencers, while 5-9 represented literature-based indicators of authenticity, credibility, trust, humanness, and uniqueness. Items 10–12 and 15 focused on comparing AI and human influencers, whereas items 13–14 measured behavioral openness toward AI influencers. The final questions collected demographic and background information, including age group, gender, and frequency of social media use.

Since the majority of the dimensions examined were represented by single questionnaire items, the analysis was conducted primarily at the item level rather than treating them as latent, multi-item constructs. Items 13 and 14 were combined into an indicator of behavioral openness, as they capture closely related behavioral intentions and demonstrated acceptable internal consistency (Cronbach's $\alpha = 0.72$).

3.4 Data analysis

Because of the exploratory nature of the study and the small non-representative sample, the analysis focused primarily on descriptive statistics and bivariate associations. Individual questionnaire items were described using means and standard deviations. The General Attitude composite used in the initial analysis was not retained because its internal consistency was low (Cronbach's $\alpha = 0.48$). Instead, the related items were analysed separately.

Spearman's rank correlation was used to examine how the main perception-related indicators authenticity, credibility, trust, humanness, and uniqueness, are associated with behavioural openness toward AI influencers. This method was chosen because the variables were measured on five-point Likert scale and it aimed to examine the strength and direction of associations rather than causal effects. As the study is exploratory, factor and cluster analyses were not applied.

4 Results

The following section of the paper presents the descriptive results of the exploratory questionnaire, followed by the associations between the main perception-related indicators and behavioural openness toward AI influencers.

4.1 Sample characteristics

The final sample consisted of 50 respondents. Most respondents were already familiar with AI influencers, with 80% ($n=40$) having heard of them before. The sample was young, 50% ($n=25$) was between the ages of 18 and 24. The majority

of respondents were female. Overall, the sample was highly active on social media, 88% (n=44) of respondents used social media several times a day. This is relevant because the study focuses on social media-based consumer perceptions.

Variable	Category	N	%
1. Have you ever seen a virtual or AI-generated influencer on social media?	Yes	40	80
1. Have you ever seen a virtual or AI-generated influencer on social media?	Not sure	10	20
16. Age group	18–24	25	50
16. Age group	25–34	20	40
16. Age group	45–54	4	8
16. Age group	55 or above	1	2
17. Gender	Female	34	68
17. Gender	Male	16	32
18. How often do you use social media?	Several times a day	44	88
18. How often do you use social media?	Once a day	4	8
18. How often do you use social media?	Less than once a week	2	4

Table 1.
Sample composition
Source: Author's own elaboration

4.2 Main findings

The main findings suggest a rather cautious attitude toward AI influencers. The general attitude toward AI-generated influencers was relatively low, moreover, the behavioural openness was even lower. This means that people were not open to engaging with AI influencers or buy their products. In contrast, human influencers were seen as preferable.

Item	Indicator	Mean	SD
Q2	Interest in AI influencers	2,50	1,27
Q3	Natural part of digital environment	1,88	1,12
Q4	Openness to AI influencers in brand communication	1,92	1,12
Q5	AI influencers perceived as less authentic	3,78	1,67
Q6	Credibility	1,54	1,01
Q7	Trust	1,52	0,86
Q8	Humanness	2,26	1,19

Q9	Uniqueness / attention	2,32	1,27
Q10	Human influencers perceived as more real	4,20	1,50
Q11	Greater brand control over AI influencers	4,20	1,14
Q12	Human influencers perceived as more persuasive	3,78	1,17
Q13	Willingness to follow an AI influencer	1,82	1,12
Q14	Purchase openness	1,98	1,17
Q15	Preference for engaging with human influencers	4,34	1,06

Table 2.
Descriptive statistics of the main questionnaire items
Source: Author's own elaboration

The descriptive results indicate generally cautious evaluations of AI influencers. Respondents showed relatively low credibility ($M = 1.54$) and trust ($M = 1.52$), while willingness to follow ($M = 1.82$) and purchase products promoted by AI influencers ($M = 1.98$) were also low. In contrast, human influencers were strongly preferred for engagement ($M = 4.34$) and were perceived as more real ($M = 4.20$) and more persuasive ($M = 3.78$). Respondents also strongly agreed that brands have greater control over AI influencers ($M = 4.20$).

4.3 Association with behavioural openness

Spearman's rank correlation was used to examine the relationship between the main perception-related indicators and behavioural openness toward AI influencers. Trust showed the strongest positive association with behavioural openness ($\rho = 0.681$, $p < 0.001$), followed by credibility ($\rho = 0.580$, $p < 0.001$) and authenticity ($\rho = 0.426$, $p = 0.002$). Humanness ($\rho = 0.242$, $p = 0.091$) and uniqueness ($\rho = 0.277$, $p = 0.052$) showed weaker relationships and were not statistically significant at the $p < 0.05$ level. These findings suggest that trust and credibility are particularly relevant to behavioural openness toward AI influencers.

Indicator	Spearman's ρ	p-value	N	Significant ($p < .05$)
Authenticity (Q5)	0.426	0.0020	50	Yes
Credibility (Q6)	0.580	< 0.001	50	Yes
Trust (Q7)	0.681	< 0.001	50	Yes
Humanness (Q8)	0.242	0.0911	50	No
Uniqueness/ novelty (Q9)	0.277	0.0519	50	No

Table 3.
Spearman rank correlations with behavioural openness toward AI influencers
Source: Author's own elaboration

Conclusions

For brands, AI influencers may be attractive because they can be used for a more personal and less template-based kind of communication. Moreover, they have full control over the influencer, not just the content but the story, appearance and behaviour too. They also provide consistency, flexibility, and novelty. However, these advantages do not automatically lead to positive consumer perceptions. Authenticity, credibility, and trust remain central barriers.

The exploratory questionnaire supports these statements. Regarding RQ1, respondents showed low general attitudes toward AI influencers, and behavioural openness was even lower. Regarding RQ2, trust showed the strongest positive association with behavioural openness, followed by credibility and authenticity. At the same time, regarding RQ3, respondents still tended to prefer human influencers in several cases. These results show that AI influencers may attract attention, but this does not necessarily turn into trust, identification, or engagement.

To sum up, brands should not rely only on novelty of AI-generated influencers. The effective use of AI influencers requires a clear role, coherent storytelling, consistent personality, and strong fit with the target audience. It is also important to maintain transparency and not mislead the audience. At the same time, study has limitations. The sample was small and non-representative, so the results should be interpreted as exploratory. Future research should focus on a larger sample, compare different types of AI influencers, or test how transparency, humanness, and brand control may affect consumer reactions.

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Albanian Musical Folklore Heritage and Sustainable Cultural Tourism: Opportunities, Challenges and Strategic Approaches

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Abstract: The preservation and promotion of musical folklore represent universal and enduring themes within cultural heritage studies. Albanian musical folklore is distinguished by a rich diversity of traditional instruments and genres that reflect the country's historical, cultural, and identity-based values. In recent years, the growing demand for authentic tourist experiences has increased the importance of preserving and promoting these traditions, positioning them as valuable assets for attracting visitors interested in experiencing Albania's cultural authenticity. This paper aims to analyze the role of Albanian musical folklore in the development of sustainable cultural tourism. It examines the current state of traditional stringed instruments, the challenges faced by instrumentalists in the context of globalization, and the impact of technological developments on the evolution and preservation of these instruments. The study also seeks to provide recommendations for improving the preservation and promotion of musical folklore in support of sustainable tourism development in Albania. The research methodology combines the analysis of secondary sources with qualitative data collected through interviews with instrumentalists, primarily from northern Albania. The study contributes to the existing literature by conceptualizing musical folklore as a strategic resource for sustainable cultural tourism. It highlights the importance of preserving intangible cultural heritage and emphasizes the role of community and institutional involvement. From a practical perspective, the findings offer strategic recommendations for integrating musical folklore into tourism products and destination branding, thereby enhancing cultural identity, competitiveness, and long-term socio-economic development.

Keywords: Sustainable Cultural Tourism, Cultural Heritage Management, Albanian Musical Folklore

1 Introduction

In the age of globalization and increasing competition in the international tourism market, tourist destinations are faced with the need to present themselves with a distinctive identity that distinguishes them from their competitors. In this situation, tourist destinations are increasingly using cultural heritage as a strategic key to create and enhance their identity, to develop and fortify themselves as a genuine and a desirable destination in the world tourist market, [1], [2], [3]. Cultural heritage is more than a relic or monument of the past. It refers to the traditional values, history, , knowledge, collective memory and cultural practices passed down through generations that differentiate a community from others and contribute to building the sense of belonging among its members, becoming the foundation of their cultural identity [4], [2]. Cultural heritage represents a living testament of the creative aspect of human nature and the ability of humans to save and transmit it from generations to generation, giving future generations the same chance to be amazed at the cultural wealth we all have. Cultural heritage is considered as a strategic asset to draw visitors, providing them unique and memorable tourist experiences and helping countries to construct and convey a unique tourist identity in order to compete effectively in the environment of globalization [5], [1], [6]-[7], [3], [8], [9].

Cultural heritage is recognized as the primary source of cultural tourism, which create a unique selling position for the tourist destination in the global tourism market [5], [2], [10], [12]. International studies and reports identify cultural tourism as one of the most important and high-growth potential key segments in global tourism. [5], [11], [1], [2], [6]-[7], [12], [8], [9]. Cultural tourism is a development opportunity for all countries, as they all have their own culture [1], [6], [12], [2]. With successfully managed, cultural tourism is increasingly considered as a driver of sustainable development, as long as offers socio-economic, cultural and environmental benefits to local residents [5], [11], [6], [2], [10], [12]. On the other hand, it promotes national identity while supporting the preservation, vitalization and valorization of cultural heritage [5], [11], [1], [7]. To contribute to the sustainable development of a tourist destination, cultural tourism must be developed in a sustainable manner [11], [2]. Having cultural heritage as its foundation, cultural tourism cannot be developed sustainably without the awareness and engagement of local communities, who play a key role in preserving the authenticity, intergenerational transmission and promotion of cultural heritage that constitutes the basis of tourist attractiveness [5], [11]. Recent studies emphasize the need for sustainable integration of cultural heritage, local communities and tourism activities in order to develop cultural tourism sustainably [3], [11], [12], [10], [13], [15]. In the face of competitive market pressures, this requires appropriate management of cultural heritage, preservation of cultural authenticity, active community participation and use of cultural heritage as a resource for diversification and long-term development of tourist destinations [5], [10], [2], [3]. In this context, cultural

tourism has received more attention both at the level of public policy and in academic research [5], [1], [6] - [7], [12].

The literature points out that the development of cultural tourism has been more focused towards an experiential and meaningful engagement, where visitors are interested in learning, exploring and coming into contact with local traditions and ways of life [5], [11], [1], [6]-[7], [13], [16], [8], [9]. Hence, intangible cultural heritage is now considered as one of the most crucial resources of cultural tourism, in order to enrich the core product of cultural tourism and to generate a 'sense of place' [5], [11], [1], [6]-[7]. In this spirit, traditional musical folklore has an important role in cultural heritage and a lot of potential for the sustainable development of cultural tourism [17], [18]. As an intangible cultural asset, it conveys historical narratives, social values, emotional expressions and collective memory, which are all vital components of cultural and musical identity formation [4]. Therefore, making emotional connections with tourist consumers, also enriching the tourist experience, in by producing a distinctive image, that significantly promotes the distinctive character of the destination, contributing greatly to the differentiation and diversification of the tourist destination [19].

With concentration of tangible and intangible cultural heritage assets, Europe is regarded as the major cultural tourism region in the world [5], [11]. In this point, Albania, as a destination with its rich cultural heritage but not fully promoted at the international level, and also due to its strategic geographical position, has great potential to improve its position as an important destination on the map of cultural tourism [9], [13]. Within this rich cultural heritage, Albanian musical folklore is valuable vector in providing cultural identity and memory of local communities. Albania enjoys a diversity of musical folklore across its geographical regions, which lies firmly embedded in the historical background and traditions and culture of the Albanian people. Despite its cultural and touristic values, the degree of integration of Albanian musical folklore into the tourist offer continues to be relatively low. In order to integrate of musical folklore with tourism, appropriate strategies and sustainable responses need to be designed that reconcile the socio-economic advantages for the local people with the conservation of that cultural base, and the greater significance of tourist value if the tourist offering: (1) the authentic experiences of the visitors but also (2) the competitive advantage in the market for the destination [20]. Intangible cultural heritage is related closely to the communities creating, performing and promoting it; and their continuity and preservation largely rely depend on the invivment and work of these communities [21]. Thus, in order to fully realize the integration of musical folklore in the tourist offer, engagement of local people and instrumentalists, musicians in particular become indispensable, serving as an attachment to traditional folk music and ensuring the long-term development of cultural tourism, which is essential for the promotion of cultural diversity [20]. Just, the community-based tourism models that aim to engage the local community in tourist activities contribute to ensuring authenticity, visitor satisfaction, the competitive advantage of the destination and,

in turn, increase the socio-economic benefits of the tourist destination as well as the local public interest in the protection of intangible cultural heritage [22], [3], [7]. In this light, the valorization of Albanian musical folklore is not limited only to the preservation of culture, but should also be included in activities that support the economic and social development of local communities. The integration of musical folklore is one of the main methods to achieve this objective through the development of cultural tourism that opens up space for the preservation, vitalization and valorization of musical folklore, the active involvement of the community, and the provision of authentic experiences for tourists along with a higher socio-economic well-being of the locality.

Regardless of the growing interest in cultural tourism, Richards [9] notes that that intangible cultural heritage has been relatively understudied, leaving aside its role in the contemporary life of communities and the need for policies that guarantee the sustainability of the practices that keep it alive. Likewise, Bridge [23] pointed out that it is crucial to explore how music can be integrated with tourism as a source of destination development and a mechanism for exploring the role of music in it further. For Albania, little research has been conducted regarding the association between musical folklore and the development of sustainable cultural tourism. This research gap indicates the need of understanding the opportunities, challenges and strategic directions of valuing Albanian musical folklore in the context of sustainable cultural tourism development. Accordingly, our study, seeks to investigate and evaluate the current state of Albanian musical folklore, to analyze the impacts of integrating Albanian musical folklore into the cultural tourism offer, to identify and evaluate strategic approaches to integrating Albanian musical folklore into tourist offers in function of developing sustainable cultural tourism. To achieve this goal, the study addresses the following research questions:

RQ1: What is the current state of Albanian musical folklore?

RQ2: What are the impacts of integrating Albanian musical folklore into the cultural tourism offer?

RQ3. What are the strategic directions for valorizing Albanian musical folklore for the sustainable development of cultural tourism?

2 Literature Review

2.1 Sustainable Cultural Tourism

Tourism has emerged in recent decades an important form for the economic, social and cultural development of destinations. Nevertheless, to guarantee long-term benefits, its development needs to base itself on sustainability principles. World

Tourism Organization (WTO) (24) defines sustainable tourism as development form that assists to satisfy the current needs of tourists and host communities on the one hand and to protects and promote the future opportunities of local populations through wise and responsible management of economic, socio-cultural and environmental assets. Likewise, Swarbrooke (25) contends that sustainable tourism should be economically effective without harming the resources on which future tourism growth is depend. In this regard, sustainability does not reflect a final state, but a continuous process of improvement of development towards sustainable principles for all forms of tourism [26], [25], [27]. Sustainable cultural tourism within this perspective seeks to balance the preservation of cultural heritage with tourism development and the benefit of local communities. It is based on the preservation of cultural values and environmental protection and responsible usage of resources according to the European Association of Historic Towns and Regions (EAHTR) [28], that the active involvement of local communities and stakeholders are provided,, the distribution of economic benefits is fair, the quality experiences for visitors are guaranteed to visitors, while the integrated and flexible management of destinations is realized in the goal of long-term development. Similarly, the European Commission [29] identifies the concept of sustainable cultural tourism as the combined integrated management of cultural heritage and tourism activities with cooperation of local communities that brings long-term economic, social and environmental benefits for all actors and maintains tangible and intangible cultural heritage. By creating links between cultural heritage protection, community participation and local economic development, sustainable cultural tourism is considered an appropriate approach to harmonizing heritage conservation with the long-term development of tourist destinations [29], [11], [2], [30], [31]. SCT is recognized in present studies as an important tool for realization sustainable development objectives, because it can enhance the conservation and cultural asset valorization, local identity strengthening, local host population's development and long-term economic profit accumulation [4], [5], [30], [31], [32].

2.2 Musical folklore and sustainable cultural tourism

The importance of cultural heritage in sustainable development is becoming more evident in the literature today. In this context, Potts [33] contends that cultural heritage is not only a matter of preserving the values of the past but as one of strategic asset needed for long-term development that contributes to the formation of a more sustainable future.. This perspective view indicates that sustainability is a critical determinant for the long-term success of development initiatives on howthe cultural heritage is used as it helps to conserve cultural values, the continuity of traditional practices and the creation of sustainable benefits for local people. As stated by UNWTO [5] tourism and cultural heritage interaction in this regard can make destinations to become sustainable since the main basis of the attractiveness and offer of destinations is the cultural heritage, which is considered to be the source

of cultural tourism. The position of cultural heritage in the development of cultural tourism is present to both its material and intangible elements. Nonetheless, intangible cultural heritage has gained increasing attention in recent years, as an important part of the cultural tourism offer, reflecting increasing demand for authentic cultural experiences among visitors [1], [6] – [7]. Its values lie in its capacity to provide authentic cultural practices, to extend visitors' knowledge for local culture, to rise the uniqueness of destinations in the tourism market, as well as to produce socio-economic benefits for local communities and stakeholders involved in tourism development [4], [6] – [7]. Indeed, the heritage should help to improve and nurture sense of cultural pride and identity and promote the transmission of this heritage between generations, that will help maintain the cultural continuity of communities [4], [21]. In addition, the economic value generated through tourism creates financial opportunities for the preservation and promotion of heritage, as well as raising awareness among communities about the importance of protecting and sustaining this heritage. This importance is also reflected in UNESCO's position expressed in 2003 in the Convention for the Safeguarding of the Intangible Cultural Heritage, which considers intangible cultural heritage as a fundamental pillar of cultural diversity and an important factor for sustainable development [4]. However, realizing the long-term benefits from integrating intangible cultural heritage into tourism requires an approach based on the principles of sustainable development. This means preserving the cultural values and authenticity of the heritage, ensuring a balance between tourism promotion and its long-term protection. The World Tourism Organization [35] stresses that intangible cultural heritage can contribute in sustainable cultural tourism development when its cultural values are protected and local communities and tourism actors are actively involved in its preservation and valorization. Intangible cultural heritage as defined by UNESCO [4] is any practice, expression, knowledge skills and representation, together with the instruments, objects, artifacts and cultural spaces associated with them, which make individuals groups and communities, recognize them as part of their cultural heritage.

In this framework, musical folklore is one of the most important forms of intangible cultural heritage, as it reflects the history collective memory, cultural identity and traditional values of local community. Musical folklore signifies the totality of traditional songs, instrumental music, traditional instruments, performance practices and related knowledge with them, which are transmitted from generation to generation and are known by communities as part of their cultural identity [4], [36]. As a kind of intangible cultural heritage, it serves as a carrier of the collective memory, values and cultural traditions of a community. Musical folklore plays an important role in the development of sustainable cultural tourism. So, through songs, traditional instruments and performance practices, it contributes to the preservation and transmission of local culture, strengthening the sense of identity and cultural belonging [18]. Beyond its cultural function, studies on cultural tourism show that traditional music can play an important role in tourism development, creating authentic experiences for visitors, strengthening the image of the destination and

contributing to its differentiation in the tourism market [37], [18], [19], [20]. In the context of sustainable development, the integration of musical folklore into tourism offers can generate socio-economic and cultural benefits for local communities. It can create new sources of income, and support employment for the local community, strengthening their cultural pride [17], [18]. These positive effects encourage the active involvement of local communities in the preservation, interpretation and promotion of musical folklore, which contributes to the continuity of cultural practices and the preservation of their authenticity [21]

However, the literature warns that the use of intangible cultural heritage in tourism must be carefully managed to avoid uncontrolled commodification and loss of authenticity. In an attempt to adapt to market demands, intangible heritage elements can lose their original cultural meaning, function and context, thereby jeopardizing their authenticity and their function as carriers of cultural identity and collective memory [33], [21], [12], [38]. For this reason, UNWTO [35] and UNESCO [34] emphasize the need for policies and approaches to the tourism valorization of intangible cultural heritage that ensure a balance between economic benefits, the preservation of cultural values and the active involvement of local communities. In this context, the valorization of musical folklore through cultural tourism should be based on the principles of sustainability, in order to contribute simultaneously to the preservation of authenticity and the long-term development of the destination and the cultural continuity of local communities. In this way, musical folklore can serve not only as a cultural asset, but also as a strategic resource for the sustainable development of cultural tourism.

2.3 Albanian Musical Folklore

Albanian musical folklore is a very fundamental part of the national intangible culture, which captures the historical experiences, cultural identity and collective memory of Albanian societies. Stemming from centuries-old tradition, it has been transmitted mostly through oral traditions and traditional performance methods, playing an important role in promoting the cultural values of the Albanian nation and consolidating national pride [36], [39]. The tradition of Albanian folk music began with the use of indigenous instruments, most of which were made from natural materials such as wood, reed, stone and animal resources [40]. An important characteristic of Albanian musical folklore is the variety of traditional instruments, including the lute, *çiftelinë*, *sharkinë*, *bakllamajen*, *llauten* and instrumental ensembles known as *saze*. These instruments are closely linked to specific geographical regions and musical traditions and are part of the rich and diverse cultural folklore of Albania [41], [40]. In particular, the lute is of great interest due to its historical connections with the performance of heroic epics and the preservation of collective memories, especially in the northern regions of Albania [42]. The contribution of Albanian musical folklore to Albanian cultural heritage gained international recognition in 2025 when the “Art of Playing, Singing and

Making the Lute” was inscribed on the UNESCO List of “Intangible Cultural Heritage in Need of Urgent Safeguarding” [43]. This international recognition concerns not only the instrument itself, but also the traditional knowledge and practices used in the construction of the instrument, the way it is performed, and the singing of Albanian heroic epic songs, recognizing the role of the lute as an essential aspect/factor of cultural identity, collective and intergenerational transmission of Albanian musical traditions. Albanian musical folklore is still transmitted mainly through family and community events, cultural celebrations, festivals and other traditional events, thus transmitting musical knowledge and skills between generations [43], [42], [40], which help not only in preserving musical traditions, but also in motivating younger generations to study and practice traditional music. The authenticity, cultural significance and regional diversity of Albanian musical folklore offer many opportunities for the development of cultural tourism. This can be a means by which traditional music can enhance visitors’ experiences and evoke a sense of destination and can contribute to the formulation of indigenous cultural tourism products. However, the sustainability of these traditions depends on the preservation of musical repertoires, musical instruments and performance strategies. Therefore, the inclusion of Albanian musical folklore in tourism projects should adhere to the theory of sustainable development by focusing on promoting tourism and economic success for the community, as well as preserving culture for future generations.

3 Research methodology

This study uses a combined research approach, which integrates the analysis of secondary sources with empirical research to provide a more complete understanding of the research questions regarding the current state of Albanian musical folklore, its role in the development of cultural tourism, and directions for its valorization for sustainable cultural tourism development. This research approach enables a more comprehensive understanding of the research issue and increases the reliability of the study results [44]. The theoretical part of the study is based on the analysis of scientific literature on intangible cultural heritage, musical folklore, and sustainable cultural tourism. Special attention was paid to the exploration of Albanian musical folklore and traditional stringed instruments. The literature review highlighted that, although studies on cultural heritage and cultural tourism exist, research that specifically addresses Albanian musical folklore in the context of tourism remains limited, highlighting the need for further empirical research. To address this gap in the literature, the study uses a qualitative approach to empirical research. Qualitative research is considered appropriate when it aims to understand the perceptions, experiences, and attitudes of individuals related to a particular phenomenon [44]. Given the exploratory nature of this study and the limited availability of previous research on this topic, a qualitative approach was

considered the most appropriate method to gain in-depth insights into the perspectives of individuals directly involved in the preservation and transmission of Albanian musical folklore. Semi-structured interviews were used to collect primary data. This method offers sufficient flexibility to explore participants' perspectives in more depth than standard quantitative methods, while maintaining a focus on the study objectives [45].

The sample in the study consists of ten Albanian folk music instrumentalists from northern Albania, who are performers of traditional stringed instruments. The selection of instrumentalists was considered particularly important, as they represent direct bearers of intangible cultural heritage and possess authentic knowledge on the current state, challenges and potential of Albanian folk music and possible strategies for its valorization for sustainable cultural tourism. They were selected purposively (purposive sampling) on the basis of their experience, active involvement in folk music practices and their recognized role in the preservation and transmission of musical tradition. Purposive sampling is commonly used in qualitative research when participants with the necessary information are asked to provide detailed knowledge about the phenomenon under investigation [44]. Each interview lasted 30-40 minutes and was conducted face-to-face. To ensure the privacy of the participants and confidentiality of the data, the interview participants were coded. The data collected from the interviews were analyzed through the thematic analysis of Brawn and Clarke [46], which involves familiarizing themselves with the interview information by repeatedly reading it, coding key information, and grouping the codes into themes related to the research questions. The analysis focused on the perception of instrumentalists on the current assessment of Albanian musical folklore, its role in the development of cultural tourism, as well as strategic directions for its valorization in function of the development of sustainable cultural tourism.

This study presents some limitations related to the small sample size and the focus only on instrumentalists of stringed instruments of musical folklore of Northern Albania. Consequently, the results should be interpreted in the context of the studied group. However, the qualitative nature of the research and the experience of the participants enabled the collection of in-depth information on the potential and challenges of valorization of Albanian musical folklore for the sustainable development of cultural tourism.

4 Research Analysis and Findings

The research analysis and findings from the interviews of Albanian musical folklore instrumentalists are structured around three main themes related to the study's objectives: the current state of Albanian musical folklore, the advantages of its

integration into the cultural tourism offer and strategies for its valorization in support of the sustainable development of cultural tourism.

4.1 Current state of Albanian musical folklore

The analysis of the interviews shows that Albanian musical folklore is considered one of the most real expressions of the intangible cultural heritage of their country, rich in regional characteristics and with specific types of interpretation that reflect the cultural identity of the community. They believed that such cultural wealth constitutes an important value not only for the preservation of musical traditions, but also for the promotion of Albanian cultural identity. However, the interviewees were of the opinion that Albanian musical traditions are subject to several problems in their survival and development. The main concern was related to the limited financial and institutional support for traditional musical instrumentalists/activities. According to participants, the lack of sustainable support programs makes it difficult to preserve, promote and transmit this heritage to future generations. Another issue raised in the interviews is the consequences that modernization and globalization have on traditional music practices. Instrumentalists emphasized that the increasing dominance of contemporary music and digital platforms has contributed to the decline of public interest, especially among young people, in traditional instruments and repertoire. According to them, traditional instruments are often perceived as elements of the past, making it more difficult to involve younger generations in learning and practicing them. Interviewees stated that the economic aspect constitutes a critical issue for the continuity of musical folklore. Most participants stated that current traditional musical activities do not provide instrumentalists with sufficient and sustainable income. Therefore, one consequence for ordinary people is that many of them have to return to their other professions to make a living, reducing their time and opportunity to dedicate themselves to the preservation and transmission of an ancient musical heritage. An issue highlighted by instrumentalists is related to the way Albanian musical folklore is commercialized. The way in which traditional musical repertoire has been revised to meet market needs also, they say, risks losing its authenticity and the sense of cultural values that accompany it. According to instrumentalists, protecting the authenticity of the musical repertoire, interpretive practices and traditional instruments is a prerequisite for the long-term preservation of this heritage and for its sustainable valorization in the cultural tourism offer.

4.2 Impacts of integrating Albanian musical folklore into the cultural tourism offer

The analysis of the interviews shows that the instrumentalists see Albanian musical folklore as a sustainable resource for the development of cultural tourism. Its integration into the tourist offer can be very useful in many areas, benefiting the improvement of the tourist experience and the local economy, as well as the empowerment of the community and the long-term preservation of cultural heritage. The main benefit highlighted by the interviewees relates to the potential of musical folklore to create authentic and experiential tourist experiences. According to the instrumentalists, contemporary tourists increasingly seek experiences related to local culture or traditions, and traditional musical performances offer avenues for direct contact with the local community. Thus, musical folklore helps to make the tourist offer distinctive and to strengthen the cultural identity of the country. An additional theme highlighted in the interviews is that of the economic effects that come from the integration of musical folklore into the tourist offer. The promotion of traditional music is also considered a good way to help artists, organizers of cultural activities and local communities by contributing to an additional source of income for them. Furthermore, tourism products that rely on musical folklore, by bringing in a tourist market, can provide employment opportunities and economic benefits for the entire local economy and local community, especially small businesses in rural parts of the country with a rich musical heritage. They emphasized that musical folklore also contributes to the empowerment of the local community and ensuring the cultural identity of local people. The integration of traditional music in the tourism offer opens up opportunities for the intergenerational transmission of cultural knowledge and practices and engages young people in local musical traditions, according to the instrumentalists. Also, the promotion of specific musical traditions in geographical areas can contribute to a more equitable distribution of tourism benefits and the development of less prominent tourist areas. A recurring aspect of the participants in the discussion was that the development of cultural tourism will provide economic incentives for the preservation and promotion of musical folklore. In their opinion, the growing interest of tourists in authentic local experiential experiences facilitates investments in the preservation of the tradition in music, the repair and hand-making of traditional musical instruments, as well as the coordination of festivals, cultural events and educational activities. In this way, tourism can vitalize traditional practices that are at risk. On another point, in addition to the economic and cultural, some instrumentalists emphasized that tourism using musical folklore tends to attract a segment of tourists who seek an authentic experience with a relatively low impact on the environment. They also found that the promotion of musical folklore can strengthen cultural exchanges, improve the international image of Albania by contributing to the recognition of the country as a destination with a unique cultural identity.

4.3 Strategies for the valorization of Albanian musical folklore in support of the sustainable development of cultural tourism

The analysis of the interviews reveals that instrumentalists believe that it is necessary to formulate an integrated approach to the valorization of Albanian musical folklore that combines the preservation of the cultural heritage of the region and also the sustainable growth of cultural tourism. The preservation and dissemination of musical folklore cannot be reduced to artistic performances alone, they argue; this should be supported through education, documentation, inter-institutional cooperation and the active engagement of local communities. One of the most frequently cited strategic directions by the interviewees involves the transmission of traditional musical knowledge between generations. Instrumentalists support the introduction of folk music for young people in educational programs, the development of courses, trainings and live events with traditional music and the provision of scholarships for young people who attend these training courses, and who perform with folk instruments at cultural events, in order to preserve the tradition and increase interest in traditional musical instruments among young people. Education is one of the most promising methods to keep the Albanian musical tradition alive, they say. However, the interviewees also emphasized the focus on the structured study and documentation of Albanian musical folklore. It is vital to collect oral testimonies, record and publish traditional musical repertoires, document the techniques of interpretation and production of folk musical instruments, as well as create digital archives accessible to researchers and the public, the participants emphasized. The expansion of research and documentation projects on the historical, cultural and social aspects of musical folklore and the financial support from the relevant institutions, not only contributes to the promotion of these cultural practices on a global and national level, but also to the protection of authenticity, guaranteeing the sustainability of this tradition and minimizing the risk of excessive commercialization. The analysis of the interviews also reveals that instrumentalists prioritize the formation of partnerships and collaborations in the field of cultural tourism. They recommend increasing cooperation between cultural institutions, local communities, artists and tourism operators, as well as the creation of interregional and cross-border collaborative projects. Based on this information, the development of cultural itineraries between regions within the country and those bordering Albanian ethnicity should be an important factor that helps generate the diversity of Albanian musical folklore and enrich the overall travel experience of tourists. An important theme raised in these interviews is the active participation of local communities in the development of cultural tourism. The instrumentalists understood the vital roles that communities play in preserving, interpreting and promoting musical folklore, as the main bearers of this tradition. Community participation in planning cultural and tourism activities is not only a way to create more authentic tourism experiences, but also increases the socio-economic benefits to the community from tourism activities, according to

their views. Meanwhile, participants said that it is important for tourism operators to make more extensive use of musical folklore in the products and activities they offer. Some also recommended creating opportunities for regular participation of folk artists within cultural and tourist activities, and with performances in bars and restaurants, to create a more sustainable income stream and a potential role for these artists to continue to promote cultural heritage. Respondents also stressed the importance of good interpretation and presentation of musical folklore to tourists. They argue, for example, that more modern types of cultural communication, including interactive exhibitions and multimedia presentations, interpretive guides, and participatory activities, can be used to deepen the appreciation and understanding of the historical and cultural content of traditional music, which can contribute to tourists' learning about the tradition of traditional music. In addition, designing participatory activities that promote engagement, through performances, workshops or community-based activities, can result in an effective form of real and meaningful connections between tourists and local culture. Last but not least, the instrumentalists also argue that musical folklore should be integrated into the tourism promotion of the regions and of all of Albania through integration into cultural itineraries, tourist activities, festivals and promotional activities. They stated that the inclusion of musical folklore as part of national and local cultural tourism strategies and programs, and the participation of locals, as bearers of musical folklore, in the drafting of these strategies, would make this heritage more visible, the strategies more feasible and new economic opportunities would be created for locals. Taken together, the instrumentalists believe that the realization of these strategies will depend on the support of public institutions. Public policy should develop permanent support mechanisms for the education, documentation and dissemination and further integration of musical folklore into the cultural tourism offer, according to them. Therefore, in such a context, they emphasized the financing of cultural activities; the support of artists and producers of traditional instruments; scientific research; and better cooperation between cultural institutions and local communities, as well as the tourism sector. As the interviewees emphasized, only through a coordinated system of policies, institutions, support measures and cooperation between stakeholders can the preservation and intergenerational transmission of Albanian musical folklore be ensured, transforming it into a sustainable resource for long-term development of cultural tourism.

Conclusions

This study aimed to analyze the current state of Albanian musical folklore, the advantages of its integration into the cultural tourism offer and the strategic directions for its valorization in the function of sustainable cultural tourism. The results of the study show that Albanian musical folklore represents an important component of the country's intangible cultural heritage, characterized by special historical, artistic and identity values. However, its continuity faces challenges related to limited institutional support, the declining interest of younger generations,

the economic sustainability of artists and the risk of losing the authenticity of traditional practices. The study also highlights that the integration of Albanian musical folklore into the cultural tourism offer can contribute to the creation of authentic experiences for visitors, the differentiation of tourist destinations, the generation of economic benefits for local communities and the strengthening of the processes of preservation and transmission of cultural heritage. In this sense, musical folklore presents considerable potential to become an important source of sustainable development of cultural tourism in Albania. The findings show that the sustainable valorization of musical folklore requires an integrated approach that combines education and intergenerational transmission of knowledge, documentation and scientific research, the active involvement of local communities, cooperation between cultural institutions and the tourism sector, as well as sustainable institutional support mechanisms. Only through such an approach can the preservation of the authenticity of this heritage be ensured, its continuity between generations strengthened and its potential for the long-term development of cultural tourism utilized.

Despite the results achieved, the study presents some limitations related to the limited sample size and the focus only on musical folklore instrumentalists of northern Albania. For this reason, future studies may include other bearers of folk music, tourism actors, and other regions of the country, with the aim of creating a more comprehensive understanding of the role of Albanian musical folklore in the development of sustainable cultural tourism

Theoretical and practical implications

The research addresses some theoretical and practical implications for the fields of cultural heritage, tourism research and sustainable development. Theoretically, it enriches the existing literature on intangible cultural heritage and sustainable cultural tourism by linking Albanian musical folklore and tourism development. In pursuit of this goal, this study contributes to the debates on the importance of folkloric musical heritage for tourism as a cultural asset with potential for the development of tourist destinations, as it contributes to building and promoting the identity of the destination, strengthening the connection of the community with the place, attracting tourists interested in authentic experiential tourism experiences and supporting the sustainable development of cultural tourism. Furthermore, this research enriches the discourse on the valorization of cultural heritage by addressing the delicate balance between preservation and commercialization. It underlines the necessity of preserving authenticity by including traditional musical practices in tourist offers. Focusing on a less studied issue of the valuation of Albanian musical folklore in the sustainable development of cultural tourism, the article positions Albanian musical folklore as a strategic resource rather than an expression of cultural memory and traditional artistic heritage. Most importantly, this study adds importance to the academic discourse on this topic by promoting instrumentalists' understandings of community-based tourism theory positioning instrumentalists as key actors in the preservation, provision and promotion of musical folklore [47], [48].

On a practical level, this research has useful lessons for local policymakers, tourism planners, cultural organizations and community development institutions as we strive to find effective ways to preserve and protect Albanian musical folklore as a resource for the sustainable development of the cultural tourism industry. The results suggest approaches and guidelines for developing sustainable policies that integrate the protection or preservation of cultural heritage with the development of an authentic tourism experience. These can help create sustainable tourism products, ranging from traditional music festivals, cultural routes, heritage workshops and brand development focused on traditional music, strengthening Albania's position in the cultural tourism industry, local economies and encouraging community involvement. Furthermore, community participation, cultural education programs and mutual cooperation between stakeholders are considered key elements of the sustainable use of musical folklore in the tourism offer. In addition, this study provides strategic suggestions for increasing the popularity of Albanian musical folklore through sustainable tourism development strategies that specifically aim to promote the preservation of cultural heritage, improve the competitiveness of the destination and promote the socio-economic development of local communities

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General Attitudes Toward Artificial Intelligence

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Abstract: In the last few years, digitalization has experienced a rapid growth with the help of artificial intelligence. Many fields such as healthcare, education, customer service and data analysis benefited from the use of AI. AI is often associated with major promises about what humanity can achieve with the help of AI. For example, it is often considered to improve efficiency, associated with faster decision making and expected to provide more convenient services. Nevertheless, there are voices warning us about the unknown societal consequences of AI, which may negatively affect everyday people. These concerns include data privacy, reduced human control, job transformation, ethical uncertainty and lack of transparency. This paper aims to broaden our view of general attitudes toward artificial intelligence based on a secondary analysis and synthesis. The reviewed studies showed that the general attitudes towards AI are not simply positive or negative, reflecting a tension between its innovative potential and ethical concerns.

Keywords: artificial intelligence (AI), societal impact, ethical concerns, public attitudes, digitalization

1 Introduction

The use of artificial intelligence (AI) has become an everyday phenomenon in recent years, ranging from a key tool for business growth and innovation to an important part of public services [3], [6]. AI-based solutions are used in many fields such as healthcare, education, customer service, data analysis, content creation and in many automated decisions [6], [7]. The technology has gained increasing attention because of the faster decision making, convenience and the promise of innovation [6]. Meanwhile, concerns are also becoming increasingly prominent,

such as effects on society, data privacy, reduced human control, job transformation, lack of transparency and ethical uncertainty [2], [7], [8].

Based on the literature attitudes towards AI are not simply positive or negative, reflecting a tension between its innovative potential and ethical concerns [2], [6]. According to Schepman and Rodway [2], the positive and negative dimensions of general attitudes toward AI are distinct, meaning that people can simultaneously recognize the usefulness of the technology while also raising issues about it. This is particularly important because the societal perception of AI is not just a technical issue, but a cultural and ethical one [2], [6].

The acceptance of AI depends strongly on the field in which it is applied [2], [8]. Previous studies have shown that people are more likely to accept AI in areas that involve data analysis, automation or technical support, but less likely to accept it in areas that need ethical decision-making [2], [8]. For example, healthcare decision-making, law enforcement, military applications, and the handling of personal data [2], [8].

Another key determinant of social acceptance is the weighing of risks and benefits [6]. According to Brauner et al. [6], people form their opinions about AI mainly based on how useful or risky they think a given application is.

Trust is another key factor in the acceptance of AI [4], [7]. People do not only consider that the technology is efficient, but if the decision is understandable, whether they can be checked and whether the organizations behind the technology can be held responsible [4], [5]. This is the reason why the focus is not only on the technical aspects [3], [7]. Need to be considered transparency, human control, data security, regulation and institutional safeguards as well [3], [7], [8].

This paper examines how the literature explains the ambivalent nature of attitudes toward AI, the role of context, the weighing of risks and benefits, and the importance of trust and ethical issues [2], [4], [6]. It argues that the social perception of AI cannot be understood simply as support or rejection, but rather as a conditional, multidimensional phenomenon that depends on the specific application [2], [6], [8].

2 Methodological approach

The study is based on a targeted literature review, aiming to summarize the main patterns in the academic literature on general attitudes toward artificial intelligence. The chapter is not intended to be a comprehensive systematic review, but rather synthesizes findings from selected peer-reviewed studies that are directly related to the social perception of AI, the evaluation of risks and benefits, ethical concerns, and issues of trust and transparency [2], [6], [7].

The selection of the literature was based on studies that do not view AI simply in a positive or negative way, but examine it as a multidimensional and context-dependent phenomenon [2], [6], [8]. In this regard, the literature review focuses on studies that analyze the positive and negative aspects of general attitudes toward AI, the role of application areas, the relationship between risks and benefits, and the conditions for trust in AI [2], [4], [6].

The eight studies were selected based on their direct relevance to the main themes of the review. Only peer-reviewed studies were included, focusing on general attitudes toward AI, context dependence, risk and benefit perceptions, trust, transparency, and governance. Together, these studies provide complementary perspectives on the main factors shaping the social acceptance of AI.

The analysis follows a thematic logic. The review is based on four main themes, which are, the ambivalent nature of attitudes toward AI; the role of application context; the evaluation of risks and benefits; and the importance of trust, transparency, ethical considerations, and the regulatory environment. This structure allows the study to not present the literature as a simple list of isolated studies, but rather as a coherent and integrated whole, where each theme is examined in relation to the others [2], [3], [6], [8].

3 The ambivalent nature of general attitudes toward AI

The most important feature of general attitudes regarding AI is that they cannot be described simply as positive and negative approaches [2]. According to the literature, people sense both the opportunities and risks of AI: for example, they recognize the effectiveness, convenience, and innovative potential of the technology, whilst they express concerns about data security, transformations in workplaces, reduced human control, ethical dilemmas, and lack of transparency [2], [6], [7]. According to Schepman and Rodway [2], a recurring pattern in earlier studies is that professionals, the public, and the media present both positive and negative narratives of AI at the same time, meaning that the social perception of AI is fundamentally dual in nature.

The empirical research of Schepman and Rodway [2] is particularly important from this perspective, because during the validation of the General Attitudes towards Artificial Intelligence Scale (GAAIS) they identified two distinct attitude dimensions. The positive subscale mirrored the excitement, societal usefulness and personal benefit towards AI, while the negative subscale captured the concerns and doubts. This suggests that the perception of AI is not placed between two endpoints but positive and negative rates may be both present in an individual's way of thinking [2].

This ambivalence also appears in the perceptions of specific application areas. According to the results of Schepman and Rodway [2], respondents evaluated more positively those AI applications that were related to processing and automation of greater amount of data, or technical tasks. In contrast, they felt less comfortable with applications addressing human judgement, personal decision-making and other sensitive social scenarios, for instance in case of a medical treatment or psychological counselling.

The ethical aspects further strengthen this ambivalent nature. According to Ikkatai et al. [8], public attitudes toward AI ethics differ markedly depending on what application context is in question. The military use of AI elicited a particularly high anxiety in the research, which indicates that concerns regarding AI are raising in scenarios relating human life, control and responsibility.

In conclusion, according to the literature, AI-related general attitudes have an ambivalent character [2], [6]. People do not simply support or reject AI, but evaluate its expected benefits, potential risks, societal consequences, and ethical conditions [2], [6], [8]. Thus, the societal perception of AI can be interpreted as a multidimensional phenomenon, in which technological utility, risk perception, human control, and application context all play a role [2], [6], [8].

4 Context dependence in AI acceptance

The social acceptance of AI depends on the field of application and the context in which it is used. Based on the literature, individuals do not generally reject or support AI as a whole, but rather form their opinions about AI based on the context. This means that the same technology can be perceived as acceptable in low-risk, technical or data-driven contexts, while it can be perceived as unacceptable in high-risk, human-centric contexts [2], [8].

Schepman and Rodway [2] examined this context dependence. They found that individuals' attitudes were likely higher if AI was used for huge scale data analysis, automation or technical based tasks. In these cases, AI was used for efficient and effective tasks, which were make the process faster and more accurate or more comfortable. On the other hand, individuals' attitudes were likely lower if AI was used for human-centric tasks such as healthcare, psychology or other sensitive areas. This could be mean that the acceptance of AI depends not just on the technology itself, but also if it is considered appropriate for a specific task by the user [2].

Context dependence is particularly important in ethically sensitive applications. Ikkatai et al. [8] examine the public's views on the use of AI in ethical contexts in four different scenarios. Based on the results, people's reactions differed significantly in different scenarios. For example, use in customer service or creative tasks were perceived as more acceptable, while use in military contexts was

perceived with anxiety. This means that the more directly AI affects human life, safety, responsibility, or control, the more critical its societal evaluation becomes [8].

A more specific example of context-dependent attitudes can be found in higher education. Toktosunova et al. [1] examined the use and perception of ChatGPT among university students in Hungary. The results showed generally positive attitudes, as 95.7% of the respondents who had used ChatGPT considered it helpful in their studies, while 61.7% preferred using it for learning over traditional methods. At the same time, the authors also highlighted ethical, privacy and security concerns related to its use. These findings further suggest that attitudes toward AI depend on the specific context and on the benefits and concerns associated with its application.

The role of context is further supported by the findings of Brauner et al. [6]. The authors examined 71 different AI scenarios and found that people do not have a uniform assessment of future applications of AI. Some applications are considered useful and socially valuable, while others are considered risky or less acceptable. The evaluation is therefore not by the mere presence of AI, but by the benefits, risks, and societal consequences associated with a given application.

Overall, the adoption of AI is strongly tied to the application area. People are generally more open to AI when it provides technical support, processes data, or performs automated tasks. They are more cautious when the technology is involved in sensitive decisions, processes that affect human lives, or situations that involve ethical responsibility.

5 Risk, benefit, and perceived societal value

One of the most important factors in acceptance is understanding the risks and benefits [6]. Based on the literature, people do not only consider whether an AI-based solution is technologically advanced or how likely it is to become widely adopted, but also what advantages and possible harms they associate with it [6]. This approach is important because the value of AI is not determined by technological novelty, but by what consequences users and citizens expect from it [6].

Brauner et al. [6] examined this question on a nationally representative German sample. In their research, 1,100 respondents evaluated 71 different AI scenarios, including in the fields of autonomous transportation, healthcare, art, politics, warfare, and social inequality. For each scenario, participants were asked how likely they considered the application to be, how much risk and benefit they saw in it, and how socially valuable it was.

One of the most important findings of the research is that the perceived social value of AI applications was primarily explained by perceived benefits and risks. According to Brauner et al. [6], benefits had a positive effect on value judgment, while risks had a negative effect. In the model, the effect of perceived benefits was stronger than that of perceived risks, with coefficients of $\beta = +0.672$ and $\beta = -0.490$, respectively. The two factors together explained 96.5% of the variance in value judgments, while the perceived likelihood of a given AI scenario did not prove to be a significant factor [6].

Variable	Std. $\beta = B$	SE	T	<i>p</i>
(Intercept)	0.012	0.011	1.125	.265
Perceived Risk	-0.490	0.033	-14.722	< .001
Perceived Benefit	0.672	0.046	14.564	< .001
Perc. Risk $\times$ Benefit	0.138	0.134	1.035	.305

Table 1.

Multiple regression analysis predicting the average overall value of the 71 AI-related topics from perceived risk and perceived benefit

Source: Brauner et al. [6]

This means that people do not necessarily accept or reject an AI solution because how close or distant they perceive it to be. What matters far more to them is the specific benefits the technology promises, and the social, ethical or personal risks associated with it [6]. In other words, an AI-based solution can be acceptable if the benefits are clear, and the risks are manageable and institutionally controlled [3], [6].

This finding also aligns well with the ambivalent nature of general attitudes toward AI [2], [6]. People do not take a stand for or against AI in itself, but rather consider what value a given application creates, whom it benefits, whom it may negatively affect, and the extent to which it remains under human or institutional control [3], [6]. For this reason, social acceptance cannot be taken for granted [6].

6 Trust, transparency and governance

The acceptance of AI is not only a question of attitude or utility, but also of trust. Users do not only consider whether AI can function effectively, but it is also important how trustworthy, clear, verifiable and responsibly applied AI is. It is particularly important, because AI systems often make decisions or give recommendations, whose operations are not fully transparent to users. Therefore,

trust does not arise automatically, but it is linked to the operation of the technology, application context and the environment standing behind it [4], [7].

According to research of Choung et al. [4], trust in AI is a multidimensional phenomenon. Authors distinguished two main dimensions of trust: human-like trust and functionality trust categories. Human-like trust refers to AI's similar characteristics to humans such as helpfulness or communicative nature, whereas functionality trust applies to the system's capabilities, reliability, security and performance. Based on results trust-related to functionality may have a greater impact on the intention to use AI, than human-like features. This suggests that for the users, seeming to be human-like is not necessarily the most essential, but to function reliably, accurately and predictably [4], [7].

Afroogh et al. [7] also highlight that AI reliability is not only a technical matter. Some of trust's technical factors are for example accuracy, safety, resilience, transparency and interpretability. However, non-technical factors are also significant such as ethical responsibility, data protection, fairness, accountability, and legal regulation. This is important because an AI system cannot be automatically accepted, even if it performs well technically. The operation of the system must be perceived fair, safe and responsible to be socially accepted [7].

Transparency is a particularly essential trust-building factor. According to Park and Yoon [5], algorithmic transparency may lower the impact of negative attitudes regarding AI and strengthen trust not only in AI's system but in the organization using it. It means that transparency does not only mean technical explanation, but it is also communicational and institutional signal. If users see that an organization communicates clearly about AI's operation, limits and accountability structure, that can improve the technology's acceptance [5].

Lahusen, Maggetti and Slavkovik [3] look at the issue of trust from an AI-governance point of view. They think that reliable AI cannot only be interpreted only at the level of algorithms. AI applications, institutional practices, and regulatory systems also need to be considered. This is essential in public services and in governmental decision-making, where AI directly affects citizens' rights, access, or opportunities. In situations like this trust does not only mean a system's effective functioning, but that there are oversight, accountability and redress mechanisms [3].

In conclusion, according to the literature, one of the fundamental requirements of accepting AI is trust. However, trust cannot be built solely on technological achievement. There is a need for transparent operation, auditability, data protection, human oversight, institutional accountability, and regulatory safeguards. Thus, AI's social acceptance does not depend only on what the system is capable of, but also on how responsible, clear, and accountable its use appears to be [3], [4], [7].

7 Discussion

Based on the reviewed literature, general attitudes towards AI can best be understood as a conditional and multidimensional phenomenon. Positive perceptions of AI can be strengthened if the technology is seen not only as effective, but also as socially beneficial, safe, and responsibly applied. People are not simply pro-AI or anti-AI. Rather, they form their opinions based on the specific context of application, the perceived benefits, the potential risks, and the conditions of trust [2], [6].

A common finding in the literature is that acceptance of AI is stronger when the technology serves a specific, understandable and socially useful purpose. In contrast, concerns are heightened when AI is used in sensitive decision-making contexts, situations requiring human oversight, or areas involving ethical responsibility [2], [8]. This is especially evident in applications related to healthcare, law enforcement, the military, or personal data.

Trust is another theme that connects the findings in the literature. Trust in AI depends not only on the system's performance, but also on whether its operation is transparent and auditable, and whether the organizations behind it can be held accountable [4], [5]. Therefore, the social acceptance of AI cannot be treated as a purely technological issue. Transparency, human oversight, data protection, accountability and regulatory guarantees are also part of the conditions for acceptance [3], [7].

Overall, the literature suggests that the social perception of AI is not stable or uniform, but rather situational. Positive attitudes can be strengthened when the benefits of AI are clear, its risks are manageable, its operation is understood, and its application is surrounded by appropriate human and institutional controls. The acceptance of AI is not an automatic consequence of technological development, but a process linked to social trust and responsible application [2], [3], [6].

Conclusion

The literature suggests that social acceptance of AI is not uniform but conditional. People are more likely to accept AI when its benefits are clear, its risks are manageable, its operations are transparent, and its use remains under human or institutional control [2], [6].

Positive attitudes therefore do not stem from technological advances themselves, but from how useful, safe and responsibly AI is perceived to be. This is particularly important in situations where AI affects human decisions, personal data or socially sensitive areas. In such cases, trust, transparency and accountability are not additional aspects but rather fundamental conditions for acceptance [4], [7].

Future research should examine in more detail which AI applications people are more likely to accept and which ones they continue to distrust. It may be particularly important to compare applications in healthcare, education, customer service, the labor market, law enforcement, and generative AI. Future studies should also consider cultural differences, levels of knowledge about AI, previous user experience, and the extent to which transparent communication and human oversight can reduce concerns [3], [5], [8].

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Ethics as a Management Tool: Why Institutional Integrity Matters for Organizational Performance

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Abstract: Ethics and integrity have become central themes in debates on public governance, accountability, and institutional performance. While the literature recognizes organizational integrity as a prerequisite for trust, risk reduction, and sustainable performance, contributions remain largely conceptual and offer limited guidance for public managers seeking to operationalize integrity within administrative structures. Moreover, although studies argue that integrity is a condition for organizational performance, this relationship is rarely examined in a systematic, management-oriented manner within public institutions.

This paper reframes institutional integrity as a management tool rather than merely a normative or cultural attribute. Drawing on governance and public management literature, the study develops an analytical framework that links integrity-based governance mechanisms, such as transparency, accountability structures, and internal control systems, to organizational performance in public institutions. Using a conceptual-analytical approach supported by document analysis of governance frameworks, the paper demonstrates how integrity is embedded in administrative processes and how this affects organizational effectiveness, risk management, and institutional credibility.

Findings suggest that public institutions which integrate integrity into their managerial and governance structures demonstrate greater organizational resilience, improved procedural efficiency, and enhanced public trust. Integrity emerges not only as a moral requirement but also as a functional asset that supports performance and institutional sustainability. The paper contributes to the literature by moving beyond abstract discussions of ethics and offering a performance-oriented perspective on integrity in public administration. From a societal perspective, strengthening integrity as a managerial tool in public institutions may

improve service delivery, reinforce democratic accountability, and enhance citizens' trust in public governance.

Keywords: public integrity, ethics, governance, organizational performance, public administration

1 Introduction and Research Gap

Despite the growing emphasis on ethics and integrity in public administration, a persistent gap remains between strong theoretical claims and practical managerial applicability. Recent scholarship has convincingly argued that organizational integrity is a fundamental prerequisite for sustainable performance, risk reduction, and institutional trust [1]. However, these contributions remain largely at the level of theoretical modelling. In particular, existing research acknowledges that public organizations still lack sound and systematic tools to assess and manage integrity in an operational way [1].

At the same time, influential contributions in the integrity literature posit a strong relationship between integrity and performance. Erhard, Jensen, and Zaffron [2] argue that integrity is a necessary condition for organizational “workability” and, consequently, for performance, and even conceptualize integrity as a factor of production comparable to knowledge or technology. Yet, these claims remain largely theoretical, and robust empirical evidence linking organizational integrity, especially in public institutions, to concrete performance outcomes is still limited [2].

As a result, integrity in the public sector is often discussed either as a normative ideal, a leadership virtue, or a component of organizational culture, rather than as a management and governance tool that can be systematically integrated into administrative structures and evaluated in terms of performance effects [1]. This paper addresses this gap by reframing ethics and institutional integrity in public institutions as a management tool rather than merely a symbolic or legal requirement. It contributes to the literature by translating existing conceptual insights into a management-oriented analytical framework and by exploring how integrity-based governance mechanisms can be linked to organizational performance and societal outcomes.

2 Literature Review

2.1 Ethics, Integrity, and Public Administration

Ethics and integrity have long been recognized as foundational principles of public administration, closely linked to legitimacy, accountability, and democratic governance. Public institutions differ from private organizations not only in their objectives but also in their ethical obligations toward citizens and society [3]. In this context, integrity is not merely a personal virtue of public officials but an institutional quality that shapes how public power is exercised and how public resources are managed. Classic contributions to public administration ethics have similarly emphasized the institutional and constitutional foundations of ethical conduct, portraying public officials as fiduciaries bound by role-based obligations [4], [5], while understanding accountability as a structural property of complex organizations rather than an individual trait alone [6].

Recent literature increasingly frames public sector integrity as a systemic and organizational phenomenon rather than as an individual moral trait. International organizations such as the OECD and UNODC conceptualize public integrity as a coherent set of values, principles, and mechanisms embedded in administrative systems, aimed at preventing corruption, ensuring accountability, and promoting trust in public institutions [7], [8]. This perspective reflects a shift from ethics understood as personal conduct to ethics understood as a governance capacity of institutions.

However, much of the literature still focuses on normative principles and legal frameworks, such as codes of conduct, conflict-of-interest rules, and anti-corruption legislation [3], [9]. While these instruments are essential, they often emphasize formal compliance rather than the broader organizational processes through which integrity is translated into everyday administrative practice.

This body of scholarship on institutional and administrative ethics remains connected to broader currents of moral philosophy that emphasize the cultivation of virtue, practical wisdom, and shared standards of conduct as prerequisites for coherent ethical practice [10]. Beyond public administration research, growing attention has also been paid to how ethical reasoning is taught and cultivated, including through narrative-based methods and thought experiments designed to strengthen ethical judgment [11], [12]. These educational contributions complement the institutional literature by highlighting that integrity-based governance ultimately depends on the ethical competence of the individuals who operate within administrative systems.

2.2 Organizational Integrity and Governance

The concept of organizational integrity has gained prominence in management and governance scholarship. Fuerst, Luetge, Max, and Kriebitz [1] argue that organizational integrity should be understood as the consistent alignment between declared principles, institutional structures, and actual organizational behaviour. According to this view, integrity is not a static attribute but a dynamic organizational capacity that requires continuous institutionalization through procedures, decision-making processes, and internal controls.

This approach is particularly relevant for public sector governance, where organizations are expected to act not only efficiently but also lawfully, transparently, and in the public interest. Governance-oriented studies suggest that integrity systems in public institutions typically include a combination of ethical standards, transparency requirements, accountability mechanisms, audit and control structures, and leadership commitment [7]. These mechanisms are designed to embed ethical values into organizational routines and to reduce the gap between formal rules and actual practices.

At the same time, the literature highlights important limitations. Despite the development of sophisticated conceptual models, organizations still lack robust and widely accepted tools for assessing and measuring organizational integrity in a systematic way [1]. As a result, integrity often remains a broad and abstract concept that is difficult to translate into concrete management decisions and performance evaluations, particularly in the public sector.

2.3 Integrity and Organizational Performance

A central claim in the integrity literature is that integrity is not only a moral requirement but also a functional condition for organizational performance. Erhard, Jensen, and Zaffron [2] advance a theoretical model in which integrity is presented as a necessary condition for “workability” and, consequently, for performance. In this framework, integrity is conceptualized as a factor of production comparable to knowledge or technology.

While this argument has been influential, it remains largely theoretical. Even its proponents acknowledge that the proposed relationship between integrity and performance is empirically testable but has not yet been sufficiently validated through systematic empirical research [2]. In the field of public administration, performance is typically measured through indicators such as efficiency, effectiveness, service quality, and public trust. However, studies rarely integrate integrity as a core explanatory variable in performance analysis, focusing instead on institutional design, resources, or managerial capacity.

Some applied governance frameworks, such as the OECD public integrity framework or the Common Assessment Framework [13], implicitly link integrity-related mechanisms to organizational performance and quality management in public institutions [7], [13]. Yet, these approaches often remain at the level of policy guidance and self-assessment tools, rather than providing analytically robust models that demonstrate how integrity operates as a management tool influencing concrete organizational outcomes.

2.4 From Compliance to Integrity-Based Management

A recurring theme in both public administration and governance literature is the limitation of purely compliance-based approaches. Compliance-oriented systems focus primarily on rule enforcement, sanctions, and formal control, which are necessary but often insufficient to prevent misconduct or to promote high-quality public service [3], [9]. In contrast, integrity-based approaches emphasize the internalization of values, ethical leadership, and organizational learning, aiming to shape behaviour not only through external constraints but also through internal motivation and institutional culture.

The Organisation for Economic Co-operation and Development [7] explicitly promotes a shift from “checklist” ethics policies toward comprehensive integrity systems that integrate ethics into risk management, human resource management, and strategic decision-making. Despite this evolution, the literature still offers limited guidance on how to conceptualize and analyse integrity as a management tool in public institutions. Most studies remain normative or descriptive, and there is a notable lack of analytical frameworks that systematically link integrity mechanisms to organizational performance and societal outcomes.

2.5 Synthesis and Identified Gap

Overall, the literature demonstrates a growing recognition of the importance of integrity in public governance, both as a normative principle and as an organizational capacity. It also provides valuable conceptual models of organizational integrity [1] and strong theoretical arguments about the integrity–performance relationship [2]. However, three main limitations remain evident: integrity is difficult to operationalize and measure; the link between integrity and performance is more often asserted than systematically analysed, and integrity is rarely treated explicitly as a management and governance tool embedded in organizational processes. These gaps justify the need for a conceptual and analytical approach that reframes ethics and institutional integrity in public institutions as a functional component of management.

3 Methodology and Conceptual Framework

This study adopts a qualitative, conceptual-analytical research design aimed at developing a management-oriented understanding of ethics and institutional integrity in public institutions. This approach is appropriate for theory-building and framework development in an area where empirical indicators and standardized measurement tools are still underdeveloped. Rather than testing hypotheses through large-scale quantitative data, the paper synthesizes existing theoretical insights and examines international governance frameworks to construct an integrated analytical model explaining how integrity can function as a management tool influencing organizational performance.

The analysis draws on publicly available policy documents and governance frameworks, including the OECD Public Integrity Handbook, UNODC guidance on integrity and ethics in public institutions, and the Common Assessment Framework [7], [8], [13]. The document analysis focuses on how integrity is defined and framed, which governance mechanisms are proposed to operationalize integrity in organizational practice, and how these mechanisms are linked to performance, risk management, and public trust.

The selected documents represent established international frameworks addressing integrity and governance in public administration. Their analysis was guided by the main dimensions identified in the literature, with particular attention to recurring relationships between integrity mechanisms, organizational performance, and societal outcomes.

Building on the literature and document analysis, the paper proposes an analytical framework structured around four interconnected dimensions: institutional integrity, governance mechanisms, organizational performance, and societal impact. The framework conceptualizes integrity as a management resource that is operationalized through governance mechanisms and translated into performance outcomes and broader societal trust.

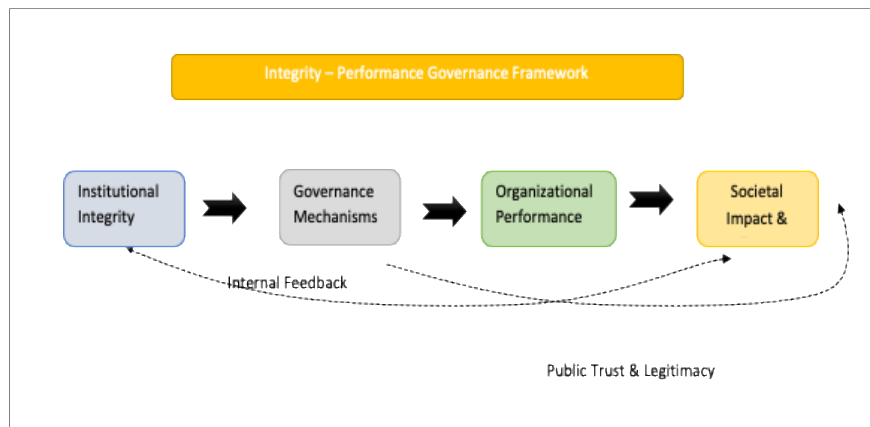


Figure 1
Analytical framework linking institutional integrity, governance mechanisms, organizational performance, and societal impact

As illustrated in Figure 1, institutional integrity constitutes the normative and organizational foundation of the framework, which is operationalized through governance mechanisms and translated into organizational performance outcomes and broader societal impact.

Institutional integrity is understood as the consistent alignment between values, rules, and organizational behaviour within public institutions. Governance mechanisms represent the instruments through which integrity is embedded in practice, including codes of ethics, transparency rules, internal control and audit systems, accountability arrangements, and leadership responsibilities. Organizational performance is understood broadly to include efficiency, procedural quality, risk management, and institutional credibility. Societal impact captures the effects of integrity-based governance on public trust, legitimacy, and democratic accountability. The framework assumes a sequential but interactive relationship in which integrity is operationalized through governance mechanisms, shaping organizational performance and, ultimately, societal trust. The framework is used as an analytical lens to interpret integrity-related governance instruments as performance-relevant management mechanisms in public institutions.

4 Findings and Analytical Discussion

The analysis indicates that integrity in public institutions is increasingly framed as an organizational capacity rather than merely an individual or normative attribute. Integrity is embedded in systems, procedures, and decision-making routines, supporting the view that it can be treated as a functional component of governance rather than as an abstract ethical ideal.

Governance mechanisms play a central role in translating ethical principles into practice. Instruments such as transparency rules, internal controls, and accountability arrangements form an “integrity infrastructure” that structures decision-making and reduces governance risks [7]. This supports a shift from narrow compliance-based models toward integrity-based management approaches. Importantly, these governance mechanisms do not merely constrain behaviour through formal rules and sanctions. They also structure decision-making processes, allocate responsibilities, and shape organizational expectations regarding acceptable conduct. In this sense, integrity-based governance shifts the focus from a narrow compliance-oriented model toward an integrated management approach in which ethics becomes part of organizational design and risk management. This perspective reinforces the view that integrity is not an external add-on to administration, but an internal component of how public institutions plan, implement, and evaluate their activities.

The analysis further suggests that integrity-based governance has potential implications for organizational performance, particularly in terms of procedural reliability, risk mitigation, and institutional credibility. Where integrity is embedded in management systems, the framework suggests that institutions may achieve more predictable procedures, clearer lines of responsibility, and reduced exposure to governance failures. This supports the theoretical claim that integrity contributes to organizational workability and performance [2].

Beyond internal performance effects, integrity-based governance is closely linked to public trust and institutional legitimacy. Consistency between rules, values, and practices strengthens credibility and supports democratic accountability, reinforcing the relationship between integrity, performance, and societal trust.

Conclusion, Recommendations, and Limitations

This paper has argued that ethics and institutional integrity in public institutions should be understood not only as normative or legal requirements, but also as functional components of effective public management. By developing a conceptual-analytical framework linking integrity, governance mechanisms, organizational performance, and societal impact, the study contributes to bridging the gap between abstract ethical principles and managerial practice. In this sense, the paper supports a broader mindset shift in public management, from viewing

ethics as a compliance burden toward understanding integrity as a strategic organizational resource.

From a societal perspective, treating integrity as a management tool can improve service delivery, reinforce democratic accountability, and strengthen citizens' trust in public institutions. On this basis, three recommendations follow. First, integrity should be integrated into core management systems, including strategic planning, risk management, and performance evaluation. Second, public organizations should move beyond narrow compliance-based approaches and invest in comprehensive integrity systems combining clear rules, leadership commitment, and accountability mechanisms. Third, greater attention should be paid to developing indicators and assessment tools that allow managers and oversight bodies to monitor how integrity mechanisms influence performance and public trust over time.

The study is subject to limitations. It relies on a conceptual-analytical design and does not draw on primary empirical data and therefore does not permit causal inference or statistical generalization. The framework is necessarily broad and does not capture all contextual variables, such as political pressures or organizational culture. Future research should therefore test and refine the model through empirical case studies, comparative analyses, and the development of measurement instruments for organizational integrity and performance in the public sector.

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