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Enhancing Agritourism 4.0: Key Technologies and Benefits

Elena Loredana Stăncioiu
University of Petrosani, Romania
Andreea Cristina Ionică
University of Petrosani, Romania
Monica Leba
University of Petrosani, Romania

Abstract

Background: This article seeks to address this gap by investigating the role of user-centric design, comprehensive feature integration, and the seamless incorporation of cutting-edge technologies. **Objectives:** The study aims to provide insights into how emerging technologies can support agritourism development from the entrepreneurs' perspective. The specific goals are to analyse the current state of popular tourism platforms to identify innovative Industry 4.0 elements that can be integrated into a new agritourism platform. **Methods/Approach:** The paper uses analysis and synthesis methods to reveal the potential benefits of emerging technologies in agritourism. Also, qualitative research methodologies scrutinise existing Internet platforms and identify characteristics of an Agritourism 4.0 platform. **Results:** The study identifies key requirements for an Agritourism 4.0 platform, such as a user-friendly interface, mobile responsiveness, and excellent customer support. Additionally, it explores the integration of Industry 4.0 technologies, like Cloud Computing, Blockchain, IoT, and AI, to enhance platform functionality and user experience. **Conclusions:** Integrating emerging technologies into agritourism can be complex and challenging. Through an interdisciplinary lens, this research aims to contribute insights that not only enhance the functionality of agritourism platforms but also foster the long-term resilience of agricultural communities in the face of evolving global challenges.

Keywords: industry 4.0; tourism 4.0, agritourism; sustainability

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Introduction

The tourism sector is heavily engaged in digital transformations, increasingly being referred to with terms like Tourism 4.0 (Pencarelli, 2020). This involves the integration of Industry 4.0-specific digital technologies and big data analytics in the tourism industry, which is recognized as a potential solution to enhance the visitor experience, streamline operations, and improve destination management.

Agritourism, which is the practice of visiting rural farms and enjoying their agricultural activities and rural atmosphere, is a growing tourism sector that offers visitors a unique and authentic experience. Agritourism is an effective way of promoting local agriculture, preserving cultural heritage, and supporting rural economies. Agritourism is still facing challenges, such as limited resources, lack of market access, and limited visibility to potential visitors.

Agritourism is a form of tourism that is gaining in popularity worldwide due to its unique blend of agricultural experiences, cultural immersion, and sustainable tourism practices (Tseng et al., 2019). As the demand for agritourism grows, so does the need for innovative technologies that can support its development while preserving its intrinsic values. Existing Tourism 4.0 platforms are not tailored to the specific needs of agritourism, which may require a different approach that ensures the preservation of the natural and cultural heritage of rural areas, targets the sustainability trend, and ensures the quality of life and social value (Maquera et al., 2022). There is a lack of attention given to the potential benefits of innovative technologies in agritourism. Agritourism is a growing niche market within the tourism industry that offers unique experiences for visitors by showcasing local agriculture and food systems (Basile et al., 2023). This research paper aims to investigate whether emerging technologies can be the path towards agritourism development, by analysing the current state of existing tourism platforms and identifying the innovative elements of Industry 4.0 that can be integrated into these platforms to benefit.

This paper explores how emerging technologies can benefit agritourism by analysing existing tourism platforms to identify best practices and key factors for the successful integration of Industry 4.0 technologies (Mhlanga, 2021). The research aims to provide insights into how these technologies can support sustainable development in agritourism from the entrepreneurs' perspective.

The research question guiding this study is: Can Tourism 4.0 technologies be the path towards agritourism development? This question stems from the hypothesis that integrating emerging technologies into agritourism platforms will significantly benefit entrepreneurs, as these technologies have done in many other fields lately.

The specific research goals (RG) are: (i) RG1. To analyse the current state of the most popular tourism platforms in the analysed area, both general and agritourism-dedicated, and (ii) RG2. To identify innovative elements of Industry 4.0 technology that can be integrated into a new platform dedicated to agritourism.

Since agriculture and tourism are among the oldest industries, and agritourism combines both, it is timely to consider the emergence of Industry 4.0 and its innovative technologies to enhance agritourism platforms.

Background: Key enabling technologies

Agritourism 4.0 stands on a digital foundation that is both diverse and deeply interconnected. As Figure 1 illustrates, nine technologies—wireless connectivity, big data analytics, cloud computing, high-performance computing, augmented reality, the Internet of Things, artificial intelligence, blockchain, and cybersecurity—act as mutually reinforcing building blocks that propel the sector toward smarter production

and richer visitor engagement. Collectively, these Key Enabling Technologies create an end-to-end value chain: ubiquitous sensors and WC capture real-time data; BD, CC and HPC turn that data into actionable insight; AI and IoT deliver precision interventions on the farm; AR enriches the storytelling that welcomes guests; blockchain secures provenance and payments; and CS safeguards every digital touchpoint. The remainder of this chapter examines each element, highlighting how synergy can boost efficiency, sustainability, and experiential value across agritourism.

Figure 1
Key Enabling Technologies for Agritourism 4.0

Source: Author's illustration

Wireless connectivity

Wireless connectivity enables the seamless integration of various technologies used in the industry (Prodanović et al., 2020). Wireless connectivity turns every corner of the farm fields, barns, and visitor centres into a data-rich node by replacing hard-wired networks with low-power, long-range links. Continuous sensor feeds flow seamlessly to cloud dashboards, enabling real-time monitoring of soil, crops, and livestock; bidirectional links trigger automated irrigation or pest-control routines exactly when and where needed; and mobile access keeps farmers and guests equally informed through their smartphones. In short, wireless connectivity is more than a

communication layer: the circulatory system makes precision farming, dynamic visitor services, and on-the-fly decision-making possible.

Table 1 shows some ways wireless connectivity can benefit Agritourism 4.0. Wireless connectivity is a critical component of Agritourism 4.0, enabling farmers to improve efficiency, reduce waste, and enhance the visitor experience. By leveraging wireless technology, farmers can implement precision farming techniques, optimize resource usage, and increase productivity, while visitors can have a more interactive and educational experience.

Table1
Wireless Connectivity in Agritourism 4.0.

Applications	Benefits for Agritourism 4.0
Real-time monitoring	Wireless connectivity allows for real-time monitoring of various farm aspects, such as soil moisture, temperature, humidity, and crop growth. This information can be collected through wireless sensors placed throughout the farm and transmitted to a central database for analysis.
Automation	Wireless connectivity enables the automation of various farming tasks, such as irrigation, fertilization, and pest control. This can be achieved through wireless sensors and actuators that can be remotely controlled and monitored.
Precision farming	Wireless connectivity can be used to implement precision farming techniques that help optimize crop yields and reduce waste. For example, wireless sensors and drones can monitor crop health, detect diseases, and apply pesticides only where needed.
Mobile access	Wireless connectivity enables farmers and visitors to access farm data and services from anywhere using mobile devices. This can include access to real-time data on weather conditions, crop performance, and visitor traffic.
Improved communication	Wireless connectivity can help improve communication between farmers, visitors, and service providers. This can include real-time messaging, alerts, and notifications about farm events, product availability, and other important information.

Source: Authors

Big Data

Big Data is a valuable resource in Agrotourism 4.0. It provides farmers with insights into farming operations and visitor preferences. By analysing this data, farmers can make informed decisions to improve farm productivity and efficiency and enhance the visitor experience (Amiri-Zarandi et al., 2022). The sheer volume, velocity, and variety of agricultural and visitor information become a strategic asset in Agritourism 4.0. When streaming sensor readings, transaction logs, and guest touch-points are aggregated and mined with advanced analytics, farms gain a panoramic, near-real-time view of production and hospitality operations.

Table 2 presents some ways big data can benefit Agrotourism 4.0. The use of big data in Agritourism 4.0 has the potential to revolutionize the way we approach agriculture and tourism. By leveraging the power of big data, farmers and agritourism operators can make more informed decisions, reduce waste, and enhance the guest experience.

Table 2
Big data in Agritourism 4.0.

Applications	Benefits for Agritourism 4.0
Visitor experience	Big data analytics can be used to analyse visitor data, such as demographics, behaviour patterns, and preferences, to create personalized visitor experiences. These can include customized tours, interactive exhibits, and other activities tailored to individual interests.
Resource management	Big data analytics can monitor resource usage, such as water, fertilizer, and energy, helping farmers reduce waste and improve efficiency. This can also lead to cost savings for the farm.
Crop monitoring	Big data analytics can monitor crop growth and health, providing farmers with insights into water usage, temperature, and pest activity. This can help farmers identify issues early and take corrective action before they become problematic.
Weather monitoring	Big data analytics can monitor weather patterns, providing farmers with real-time information on temperature, precipitation, and other factors impacting crop growth and health. This information can be used to adjust irrigation and fertilization schedules, helping to optimize crop yields.
Marketing and sales	Big data analytics can analyse visitor and sales data, providing insights into visitor preferences and trends. This can help farmers create marketing campaigns targeted to specific audiences and adjust their product offerings to meet changing demand.

Source: Authors

Cloud computing

Cloud computing provides a scalable and flexible platform for storing, analysing, and sharing BD. Farmers can use powerful analytics tools and services by leveraging cloud computing without investing in expensive hardware and infrastructure (Liu, 2022). Table 3 presents some ways cloud computing can benefit Agrotourism 4.0. Cloud computing is a valuable tool for Agrotourism 4.0, providing farmers with a scalable and flexible platform for storing, analysing, and sharing big data. By leveraging cloud computing, farmers can make informed decisions that can lead to higher yields, better quality crops, and a more sustainable farming industry.

Table 3
Cloud computing in Agritourism 4.0.

Applications	Benefits for Agritourism 4.0
Big data storage	Cloud computing provides a secure and scalable platform for storing big data, allowing farmers to store and access large amounts without investing in expensive hardware and infrastructure.
Analytics	Cloud computing provides powerful analytics tools and services for analysing big data, providing insights into farming operations and visitor preferences. This can help farmers make informed decisions that improve farm productivity and efficiency while enhancing the visitor experience.
Collaboration	Cloud computing provides a platform for collaboration between farmers, researchers, and other stakeholders in the agriculture industry. This can facilitate sharing data and best practices, leading to improved farming practices and a more sustainable agriculture industry.
Accessibility	Cloud computing allows farmers to access powerful analytics tools and services from anywhere with an internet connection, allowing them to monitor and manage their operations remotely.
Cost savings	Cloud computing can help farmers save on hardware and infrastructure costs and reduce maintenance and upgrade expenses.

Source: Authors

High-Performance Computing

Integrating high-performance computing (HPC), big data, and cloud technologies meets the increasing computational demands of data analytics (Georgiou et al., 2020), facilitating advanced data-driven decision-making and optimizing agritourism operations. (Table 4). HPC is a valuable tool for Agrotourism 4.0, allowing farmers to process and analyse large amounts of data in real-time, leading to improved productivity and efficiency and more sustainable farming practices.

Table 4
High-Performance Computing (HPC) in Agritourism 4.0.

Applications	Benefits for Agritourism 4.0
Crop modelling	HPC can create complex crop models that simulate crop growth and development under different environmental conditions. These models can help farmers decide about planting schedules, water usage, and fertilizer applications.
Weather modelling	HPC can be used to create high-resolution weather models that provide accurate forecasts and simulations of weather patterns. These models can help farmers plan irrigation and fertilization schedules and prepare for extreme weather events.
Precision agriculture	HPC can process large amounts of data from sensors and other sources to create detailed maps of soil characteristics, crop growth, and other factors that impact farm productivity. This can help farmers optimize their operations by making more informed decisions about crop selection, planting density, and irrigation.
Livestock modelling	HPC can be used to create models of livestock behaviour and physiology, providing farmers with insights into animal health and welfare. This can help farmers optimize feed and water usage and identify potential health issues early.
Genome analysis	HPC can analyse large amounts of genetic data from plants and animals, helping researchers identify beneficial traits and develop new varieties that are more resistant to pests and disease.

Source: Authors

Augmented reality

Augmented reality (AR) is an innovative technology that can enhance the visitor experience in Agrotourism 4.0 by providing immersive and interactive experiences that educate visitors about agricultural practices and products (Pilaiwan & Sheau, 2019; Bheda et al., 2021). AR combines computer-generated images with the real world, providing visitors with a digital overlay of information to enhance their understanding and engagement (Table 5).

AR is a valuable tool for agrotourism 4.0. It provides visitors with immersive and interactive experiences that can enhance their understanding and engagement with agriculture. By leveraging AR, farmers can educate visitors about agricultural practices and products, promote sustainable farming practices, and enhance the visitor experience.

Table 5
Augmented Reality (AR) in Agritourism 4.0.

Applications	Benefits for Agritourism 4.0
Farm tours	AR can be used to provide virtual farm tours that showcase different aspects of the farm, such as crops, livestock, and equipment. Visitors can use their mobile devices to scan markers on the farm to reveal interactive 3D models and information about the farm.
Product information	AR can inform visitors about products, such as how they are produced and their nutritional value. Visitors can use their mobile devices to scan product labels or packaging to reveal augmented reality overlays with product information.
Interactive exhibits	AR can be used to create interactive exhibits that allow visitors to learn about agricultural practices and technologies. For example, visitors could scan exhibits using their mobile devices to reveal interactive 3D models and information about sustainable farming practices.
Education	AR can be used to create educational content for visitors, such as interactive quizzes and games that teach visitors about agriculture. Visitors could use their mobile devices to scan markers or exhibit panels to access educational content.
Marketing	AR can be used as a marketing tool to promote agricultural products and services. For example, farmers could use AR to create interactive advertisements that allow customers to scan product labels to reveal augmented reality overlays with product information.

Source: Authors

Internet of Things

The Internet of Things (IoT) is a technology that can benefit Agrotourism 4.0 by enabling farmers to monitor and control various aspects of their operations remotely using connected sensors and devices. IoT uses sensors, data collection, and analytics to give farmers real-time information about their crops, livestock, and equipment products (Raj et al., 2021). Table 6 presents some ways IoT can benefit Agrotourism 4.0. IoT is a valuable tool for Agrotourism 4.0, providing farmers with real-time data and insights that can improve productivity, reduce costs, and promote sustainability.

Table 6
Internet of Things (IoT) in Agritourism 4.0.

Applications	Benefits for Agritourism 4.0
Smart farming	IoT can create more innovative, more efficient, and sustainable farms. Sensors can monitor soil moisture, temperature, nutrient levels, livestock behaviour, and health. This information can be used to optimize farming operations, reduce waste, and improve productivity.
Precision agriculture	IoT can create detailed maps of soil characteristics and crop growth, allowing farmers to make more informed decisions about planting density, irrigation, and fertilization. This can help farmers optimize their operations and reduce costs.
Livestock monitoring	IoT can monitor livestock health and behaviour, providing farmers real-time animal welfare data. This can help farmers optimize feed and water usage and identify potential health issues early.
Equipment monitoring	IoT can monitor the performance and maintenance of farm equipment, reducing downtime and improving efficiency. Sensors can also monitor equipment health and usage, and schedule maintenance and repairs.
Environmental monitoring	IoT can monitor environmental conditions, such as temperature, humidity, and air quality, to ensure optimal growing conditions.

Source: Authors

Artificial intelligence

Artificial intelligence (AI) is an emerging technology that can benefit Agrotourism 4.0. It enables farmers to make more informed decisions about their operations using machine learning algorithms and predictive analytics (Mhlanga, 2021). AI involves using computer algorithms that can analyse large amounts of data and identify patterns, providing farmers with insights that can help them optimize their operations (Table 7). AI is a valuable tool for Agrotourism 4.0, providing farmers with data-driven insights to help them make more informed decisions about their operations. Farmers can optimize their operations, reduce waste, and improve productivity and sustainability by leveraging AI.

Table 7
Artificial Intelligence (AI) in Agritourism 4.0.

Applications	Benefits for Agritourism 4.0
Crop and livestock monitoring	AI can analyse data from sensors and cameras to monitor crop and livestock health and behaviour. Machine learning algorithms can identify patterns and anomalies, alerting farmers to potential issues before they become serious.
Yield prediction	AI can predict crop yields based on environmental conditions and farming practices. This information can help farmers optimize crop management strategies, such as fertilization and irrigation.
Pest detection and control	AI can detect pests and diseases in crops using computer vision and image recognition algorithms. This can help farmers identify issues early and take corrective action to minimize crop damage.
Supply chain optimization	AI can optimize the supply chain by analysing inventory levels, demand, and shipping logistics data. This can help farmers reduce waste and improve efficiency.
Precision agriculture	AI can create precise maps of soil and crop characteristics, allowing farmers to make more informed decisions about planting and fertilization. This can help farmers optimize yields and reduce costs.

Source: Authors

Blockchain

Blockchain is a distributed ledger technology that can benefit Agritourism 4.0 by providing a secure and transparent way to record and verify transactions. It can also improve supply chain transparency, increase trust between farmers and tourists, and enhance payment processing (Xiong et al., 2020) (Table 8). Blockchain is a promising technology for Agritourism 4.0, providing a secure and transparent way to record and verify transactions. By leveraging blockchain, farmers and tourists can benefit from increased transparency, trust, and efficiency in the Agritourism industry.

Table 8.
Blockchain in Agritourism 4.0.

Applications	Benefits for Agritourism 4.0
Supply chain transparency	Blockchain can record every supply chain step, from farm to table. This provides transparency and traceability, allowing farmers and tourists to see where their food comes from and how it was produced. This can increase trust and confidence in the food supply chain.
Verification of quality and authenticity	Blockchain can be used to verify the quality and authenticity of food products. This can help farmers differentiate their products and command a premium price, while providing tourists with assurance that they are getting high-quality, authentic products.

Smart contracts	Blockchain can automate payment processing and enforce contracts between farmers and tourists. Smart contracts can be programmed to execute automatically when certain conditions are met, such as the delivery of a product or the completion of a service. This can reduce the need for intermediaries and increase efficiency.
Decentralized booking platforms	Blockchain can be used to create decentralized booking platforms that connect farmers directly with tourists. This can reduce intermediaries' fees and give farmers more control over their pricing and marketing strategies.
Digital identities	Blockchain can be used to create digital identities for farmers and tourists. This can provide a secure and tamper-proof way to verify identity, reducing the risk of fraud and increasing trust.

Source: Authors

Cybersecurity

Integrating cybersecurity (CS) measures into Agritourism 4.0 is essential for maintaining the safety and integrity of operations. Agritourism 4.0 merges agriculture with modern technologies like IoT, AI, and automation, presenting unique cybersecurity challenges. These technologies, widely used in Industry 4.0, can be adapted for agriculture, but the primary challenge lies in ensuring security and privacy. This is particularly crucial due to deploying numerous IoT devices in open fields (Ferrag et al, 2022). By prioritizing cybersecurity in Agritourism 4.0 initiatives, stakeholders can mitigate risks, protect sensitive data, and build trust among agricultural stakeholders and tourists.

Table 9.
Cybersecurity (CS) in Agritourism 4.0

Applications	Benefits for Agritourism 4.0
Data Protection	Agritourism 4.0 uses various technologies for farm management and visitor engagement, such as IoT sensors, drones, and cloud computing. Implement robust encryption protocols to secure data transmission and storage, especially when dealing with tourists' personal or financial information and sensitive agricultural data.
Network Security	Establish secure networks to prevent unauthorized access to critical systems. Use firewalls, intrusion detection systems, and regular network monitoring to detect and mitigate cyber threats effectively.
Device Security	Ensure that all devices connected to the agritourism network are adequately secured. This includes implementing strong passwords, regularly updating firmware and software, and restricting access to only authorized personnel.
Awareness and Training	Educate agricultural workers and tourists about cybersecurity best practices. Train staff to recognize common cyber threats, such as phishing attacks and social engineering tactics, to minimize the risk of breaches.
Incident Response Plan	Develop a comprehensive incident response plan to address and mitigate cybersecurity incidents effectively. This plan should outline the steps during a data breach, including communication protocols and recovery procedures.
Regulatory Compliance	Ensure compliance with relevant cybersecurity regulations and standards, such as GDPR (General Data Protection Regulation) and industry-specific guidelines. This may involve conducting regular audits and assessments to assess compliance levels and identify areas for improvement.

Vendor Management	If outsourcing certain services or utilizing third-party solutions, vet vendors for their cybersecurity measures and ensure they adhere to industry best practices. Include contractual provisions that require vendors to maintain adequate security controls.
Continuous Monitoring and Updates	Cyber threats constantly evolve, so it is essential to monitor the agritourism network for any signs of suspicious activity and regularly update security measures and patches to address newly identified vulnerabilities.

Source: Authors

Ultimately, this research aims to contribute to the ongoing conversation around the future of agritourism and the potential of Tourism 4.0 and Industry 4.0 technologies to support its development innovatively and sustainably. By leveraging Tourism 4.0 technologies, agritourism businesses and destinations can enhance their marketing strategies, optimize resource management, and improve the visitor experience, while preserving the authenticity and intrinsic values that define the agritourism experience.

Methodology

The research approach methodology investigates the scientific literature, examines platforms on the Internet, and identifies the typical characteristics of an Agritourism 4.0 platform, and how the innovative elements of technology from Industry 4.0 can be integrated in a platform based on the identified characteristics, to respond to the research question.

The literature review was relevant to establish the basis of the research, pointing out the key enabling technologies and their potential benefits for Agritourism 4.0 development.

Analysing existing tourism platforms is important in identifying their potential to support agritourism and the limitations that may hinder their effective integration into this sector. This involved analyzing the features of these platforms and assessing their suitability for agritourism.

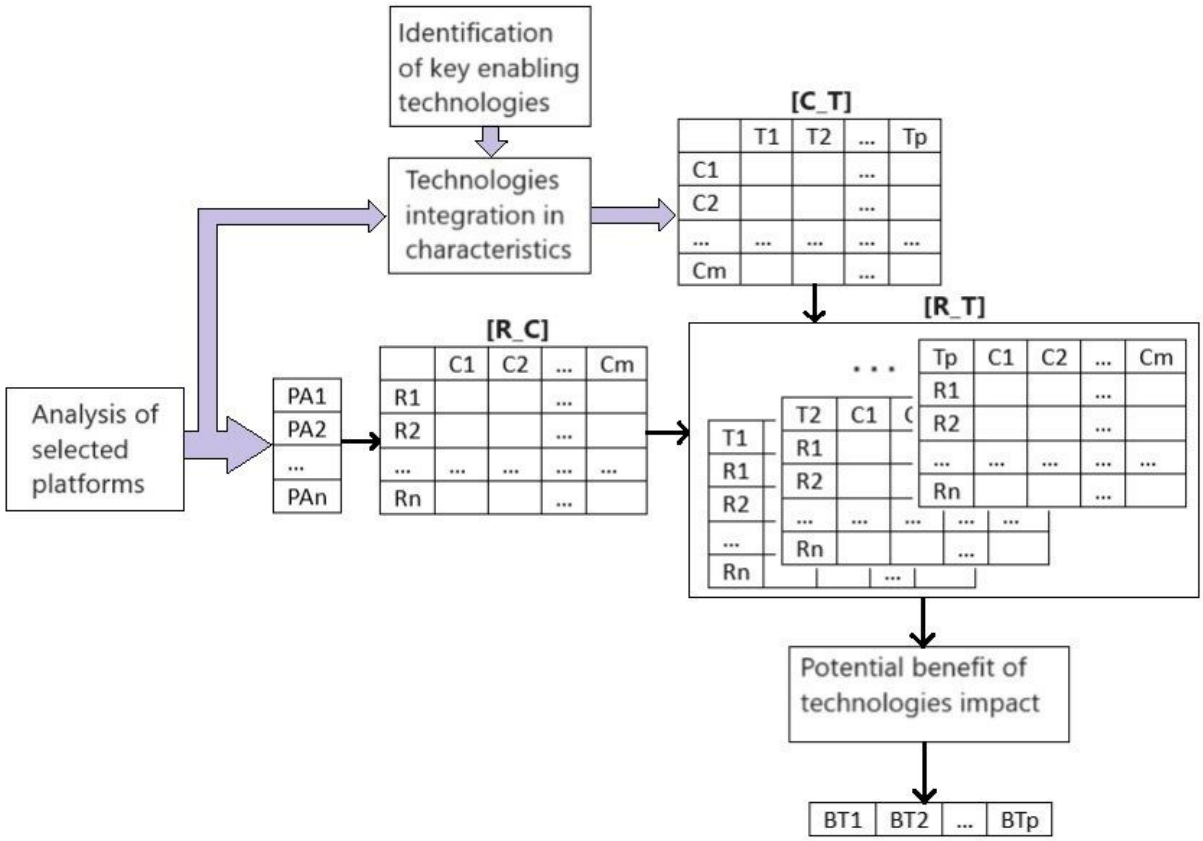
A focus group with 15 business owners/entrepreneurs from Gorj County (Romania), as participants, was used; its topic was the examination of current platforms for business development in agritourism. The moderator combined and reflected the participants' opinions into a single value (Overall value) for usefulness during the user experience (UX) research process. The criterion for choosing the platforms was to contain locations intended for agritourism. The analysis covers a range of platforms, including those that are specifically designed for tourism, as well as those that are used for other purposes but could potentially be adapted for agritourism.

According to Cheng et al (2023), the development of an open-source tourism information system requires several key features: an information management module, web and mobile services, a user-friendly interface, personalization and recommendations, multilingual support, real-time data and updates, community engagement, mobile compatibility, and security and privacy. Additionally, Lopes et al. (2019) emphasize the importance of a user-friendly booking process, advanced payment gateways, and digital tools to streamline operations, all of which enhance customer satisfaction in the context of digital transformation in hospitality.

These insights identified the following main features for further consideration: User Interface (UI) design and ease of use, features and functionality, customer support, mobile responsiveness, and payment options. Each feature was evaluated on a scale of 1 to 10, and an average score was calculated for each platform. A rank coefficient, based on perceived functionality by entrepreneurs in the agritourism context, was also

determined using values of 1, 2, or 3. This resulted in an average rank for each platform derived from focus group evaluations.

Figure 2
Methodology approach



Source: Authors

Applying the weighting rank to the average score gave the entrepreneur a clearer understanding of the overall user experience. This value aids in making informed decisions about each platform's suitability for meeting tourists' needs and supporting business objectives (see Equation 1).

where

$$Overall\ value = Score \cdot Rank$$
$$Score = \underbrace{avg}_{features}\ , Rank = \underbrace{avg}_{respondents} \quad (1)$$

The features evaluated were considered as requirements and ranked by the focus group participants.

After identifying the enabling technologies (Table1 to 9), the technologies were selected for the analysis considering the wireless connectivity (WC) as a primary preexisting condition. For determining the potential benefit of the technologies impact (BT) (equation 2), these were integrated in the identified characteristics (C) of the platform that respond to the specified requirements (R) for which the potential attraction percentage was achieved (PA), resulting the matrices [R_C], [C_T] and [R_T] (figure. 2)

$$R\_T(i,j,k) = C\_T(j,k) \cdot R\_C(i,j)$$
$$BT(k) = \sum_i \left(PA(i) \cdot \sum_j R\_T(i,j,k) \right) \quad (2)$$

where:

- PA_n = potential attraction percentage for each requirement
- $R\_C_{n \times m}$ = the correspondence matrix between requirements (R1..Rn) and characteristics (C1..Cm)
- $C\_T_{m \times p}$ = the correspondence matrix between characteristics (C1..Cm) and technologies (T1..Tp)
- $R\_T_{n \times m \times p}$ = the correspondence matrix between requirements and characteristics for each technology
- BT_p = potential benefit of each technology impact

MATLAB is used to implement the previously described calculation algorithm, which starts from the values identified in the calculation relation matrices and determines numerically and graphically the benefits of integrating each technology by determining the contribution of each characteristic to solving the requirements through the lens of each technology.

Results

The analysis of the selected platforms

A focus group analysis was conducted to address the first specific objective: to analyse the current state of the most popular tourism platforms, both general and those dedicated to agritourism. This analysis evaluated the platforms based on their relevance to the region under study for agritourism purposes. Existing similar solutions were reviewed to identify the best elements to incorporate into the new platform developed as part of this research. Table 10 presents the results of the comparative analysis of the platforms based on equation (1).

Table 10
Platform comparative analysis

Platform	Score	Rank	Overall value
Airbnb.com	9.1	2	18.2
Booking.com	8.6	2	17.2
Agriturismo.it	7.9	3	23.7
CNTraveller.com	7.9	1	7.9
Longevity-Escapes.com	8.9	1	8.9
Farmstayplanet.com	7.7	3	23.1
Agoda.com	8.6	2	17.2
Wildventure.ro	6.6	1	6.6
LaPensiuni.ro	6.9	1	6.9
RuralTourism.ro	6.9	1	6.9
Zago.ro	6.6	1	6.6
Pickatrip.ro	6.6	1	6.6
RomanianFriend.com	7.1	2	14.2
Travlocals.com	8.2	2	16.4

Source: Authors

Based on the scores provided:

- **Agriturismo.it**: This platform has the highest overall score of 23.7, indicating that it performs well across the analysed characteristics. It ranks third in terms of individual score but achieves the highest overall value due to consistency across multiple criteria.
- **Farmstayplanet.com**: While it ranks third in terms of individual score 7.7, it ties with Agriturismo.it for the highest overall value of 23.1. This suggests that despite not leading in any specific characteristic, it maintains a high level of performance across the board.
- **Airbnb.com, Booking.com, and Agoda.com**: These platforms all tie for second place with an overall value of 17.2. While they may excel in certain areas, their performance is not as consistent across all characteristics as Agriturismo.it and Farmstayplanet.com.
- **CNTraveller.com and Longevity-Escapes.com**: Although they have high individual scores (7.9 and 8.9, respectively), they have lower overall values due to their specialization in specific areas, resulting in a narrower focus compared to platforms like Airbnb and Booking.com.
- **Wildventure.ro**: This platform has the lowest overall score of 6.6, indicating that it may have weaknesses across multiple characteristics.

In conclusion, consistency across various factors is crucial for an Agritourism 4.0 platform. While platforms like Airbnb, Booking.com, and Agoda.com may excel in certain areas, Agriturismo and Farmstayplanet.com stand out for their overall performance across the analysed characteristics.

The higher overall values observed for the two platforms suggest they exemplify best practices in agritourism. This assessment serves as the basis for further analysis, wherein the key features of these platforms are adapted and evaluated within the context of the targeted region.

This suggests that a successful Agritourism 4.0 platform should prioritize user experience, booking convenience, security, and technology integration to provide a comprehensive and satisfactory experience for hosts and visitors.

Overall, agritourism platforms should have a user-friendly interface, a wide range of features and functionality, excellent customer support, mobile responsiveness, and various payment options to attract and retain users.

The Potential Attraction (PA) percentage for each requirement of the Agritourism 4.0 platform was determined by categorizing the focus group results into five percent increments. This method highlights the significance of each requirement about user preferences and prevailing market trends:

- **R1. User-Friendly Interface** (25%) - A user-friendly interface is crucial as it is the first point of interaction between the user and the platform. It greatly influences user satisfaction and continued use of the platform.
- **R2. Wide Range of Features and Functionality** (20%) - The diversity of features and functionalities can significantly enhance user engagement, catering to various user needs and preferences.
- **R3. Excellent Customer Support** (15%) - High-quality customer support is key to retaining users and maintaining a positive reputation, especially in a service-oriented sector like agritourism.
- **R4. Mobile Responsiveness** (25%) - With the increasing use of mobile devices for browsing and transactions, mobile responsiveness is critical for attracting and retaining users who prefer mobile interactions.

- **R5. Variety of Payment Options** (15%) - Offering various secure payment options is important for user convenience and trust, particularly in an international context where payment preferences vary widely.

These percentages reflect the potential attraction each requirement may have for users. A user-friendly interface and mobile responsiveness are given a higher percentage due to the growing trend of mobile usage and the importance of first impressions made by the interface. Features and functionality, as well as payment options, also play significant roles, but might be secondary considerations after the initial user interface experience and mobile compatibility.

The proposed methodology was implemented to achieve the second specific goal: to identify innovative Industry 4.0 technologies that can be integrated into a new agritourism-dedicated platform. Initially, the main characteristics of the new platform were analysed and defined (I.), guided by the previously identified requirements. Subsequently, the relationships between these platform characteristics and the technologies were delineated (II.), relying on the previous analysis of key enabling technologies. This analysis considered only those technologies deemed suitable for the current research.

The main characteristics of an Agritourism 4.0 platform

The characteristics for an Agritourism 4.0 platform, focusing on the most essential aspects and the most effective user experience, that collectively ensure that the platform is not only user-friendly and efficient but also capable of meeting the diverse needs of both agritourism providers and visitors, are:

- **C1. Integrated Booking** and Reservation System - A comprehensive system for handling online bookings for tours, accommodations, and events, including real-time availability, automated confirmations, and reminders.
- **C2. Interactive Maps and GPS Navigation**- Detailed, user-friendly maps showing locations of farms, tours, and attractions, integrated with GPS for easy navigation and planning.
- **C3. Secure and Versatile Payment Processing** - A robust payment system supporting multiple methods and currencies, ensuring secure and seamless transactions with encrypted data protection.
- **C4. User Account Management and Personalization** - Personalized user profiles with management dashboards for bookings, preferences, and history, enhancing the user experience through customization.
- **C5. Mobile Optimization and Responsiveness** - A platform optimized for all devices, particularly smartphones and tablets, ensuring fast loading times and a responsive design.
- **C6. Multilingual Support and Cultural Inclusivity** - Offering the platform in various languages to cater to a global audience, including content that respects and highlights local cultures and practices.
- **C7. Customer Engagement and Support** - Live chat, comprehensive FAQs, support resources, feedback, and survey tools for continuous improvement and customer engagement.
- **C8. Social Media Integration and Marketing Tools** - Seamless social media sharing capabilities, integrated marketing tools for promotions, and SEO optimization to enhance online visibility and engagement.
- **C9. Analytics, Reporting, and Backend Management** - An administrative dashboard providing analytics and reports on user behavior, bookings, and financials, coupled with inventory and content management tools.

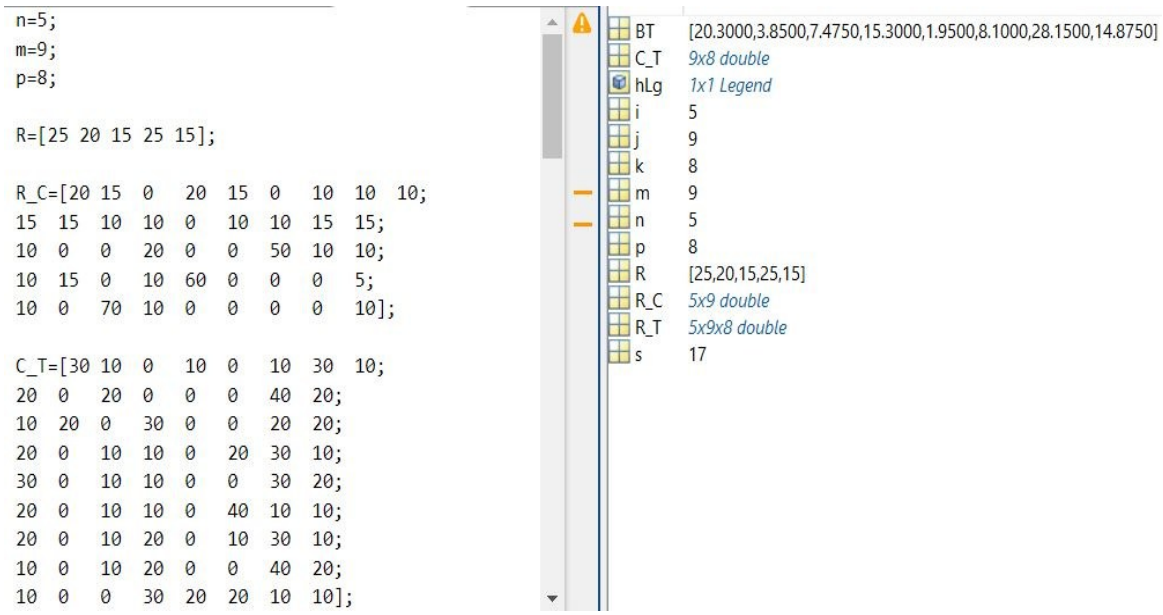
Relationship between the technologies and Agritourism 4.0 characteristics

In integrating emerging technologies within the Agritourism 4.0 platform, each technology plays a unique role, harmoniously contributing to the platform's overall functionality and user experience.

- **T1. Cloud Computing** forms the backbone of the Integrated Booking and Reservation System. It offers scalability and flexibility, which are crucial for managing fluctuating demands and large volumes of data transactions inherent in booking systems. This technology ensures that the system remains robust and responsive, regardless of user load, which is particularly valuable during peak tourism seasons.
- **T2. Blockchain** technology revolutionizes Secure and Versatile Payment Processing. Its decentralized and immutable ledger system instills high security and trust in transactions. By employing smart contracts, Blockchain automates and streamlines the payment processes, making them more efficient and reducing the likelihood of fraud.
- **T3. Internet of Things (IoT)** integrates real-time sensor data, offering users up-to-date information about various locations. This technology enriches the platform's navigational tools with accurate, live data, aiding visitors in planning their journeys more effectively.
- **T4. Cybersecurity** is a cross-cutting technology that ensures the safety and integrity of the entire platform. Advanced encryption, continuous monitoring, and robust security protocols protect against cyber threats and secure sensitive user data and financial transactions, which are paramount in maintaining user trust and platform integrity.
- **T5. High-performance computing supports the platform's extensive data processing requirements**. It is vital in managing large-scale simulations, predictive modelling, and real-time analytics, ensuring the platform's capability to process and analyse large datasets swiftly and accurately.
- **T6. Big Data** is at the forefront of Analytics, Reporting, and Backend Management. The platform generates vast amounts of data, and big data technologies are key to managing this volume. They enable sophisticated analysis, providing insights into user behaviour, operational effectiveness, and market trends that are instrumental in guiding data-driven decision-making.
- **T7. Artificial Intelligence (AI)** infuses intelligence into User Account Management and Personalization. AI can offer personalized recommendations and content by analysing user behaviour patterns and preferences through advanced machine learning algorithms. This enhances user engagement and fosters a sense of individualized service, improving customer satisfaction and loyalty.
- **T8. Augmented Reality (AR) and Virtual Reality (VR)** are used to create immersive experiences, particularly effective in showcasing destinations. They provide potential visitors with virtual tours, enhancing engagement and aiding in their decision-making process, offering a glimpse of what they can expect from their real-world experience.
- Together, these technologies weave a complex yet seamless tapestry of functionality within the Agritourism 4.0 platform. Each one is carefully integrated, not just for its own sake, but to enhance specific functionalities of the platform, ultimately aiming to create an efficient, secure, and user-friendly experience.

Using MATLAB, the implementation code of the calculation algorithm was written (Fig.3). The left side shows the initial data, i.e., the number of requirements (n), characteristics (m) and technologies (p), the matrix of potential attraction of the requirements (R), the coverage of the requirements by the characteristics (R_C) and the relationship between technologies and characteristics (C_T). On the right side, the results obtained for evaluating the potential benefit of each technology, the BT matrix, can be seen.

Figure 3
MATLAB code and numeric results



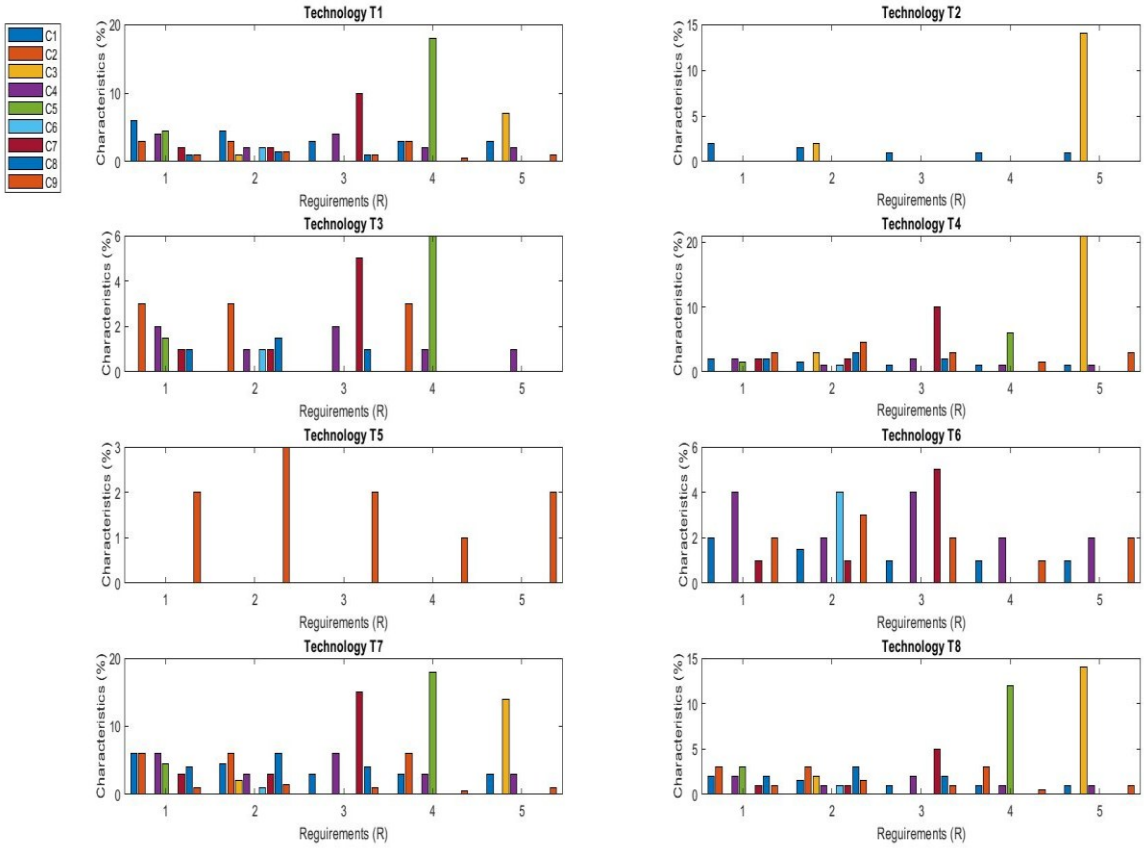
Source: Authors

The following notations *were used for the graphical presentation of the results:*

- R1. User-Friendly Interface
- R2. Wide Range of Features and Functionality
- R3. Excellent Customer Support
- R4. Mobile Responsiveness
- R5. Variety of Payment Options
- C1. Integrated Booking and Reservation System
- C2. Interactive Maps and GPS Navigation
- C3. Secure and Versatile Payment Processing
- C4. User Account Management and Personalization
- C5. Mobile Optimization and Responsiveness
- C6. Multilingual Support and Cultural Inclusivity
- C7. Customer Engagement and Support
- C8. Social Media Integration and Marketing Tools
- C9. Analytics, Reporting, and Backend Management
- T1- Cloud computing
- T2 - Blockchain
- T3 – Internet of Things (IoT)
- T4 - Cybersecurity
- T5 – High-Performance Computing

- T6 - Big Data
- T7 - Artificial Intelligence (AI)
- T8 - Augmented Reality (AR) and Virtual Reality (VR)

Figure 4
Requirements covered by characteristics for each technology



Source: Authors

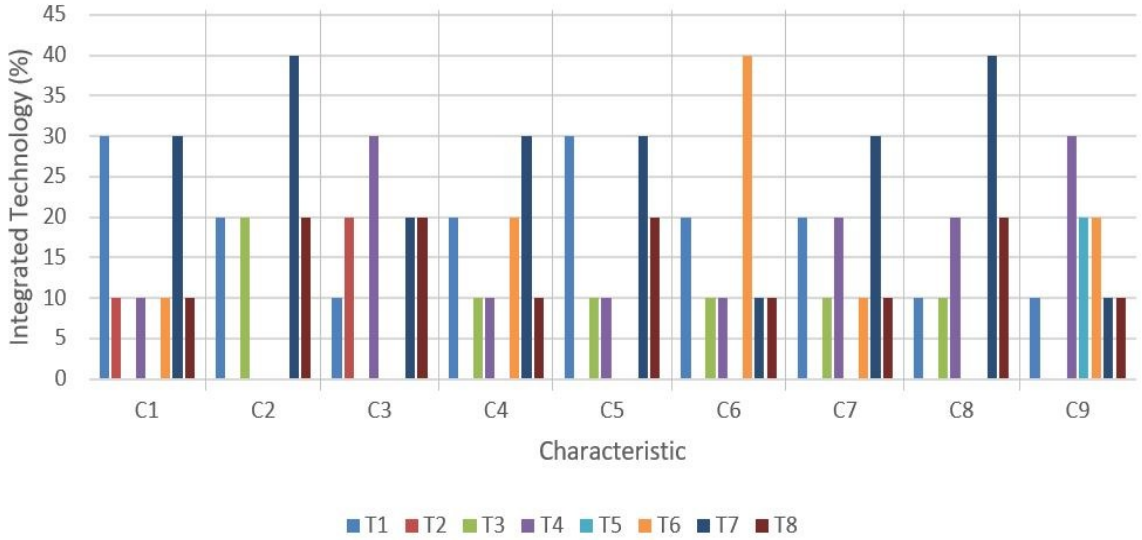
Analysing the results presented in Figure 4, the following interpretations can be considered:

- Cloud computing (T1) is the technology required to achieve the Mobile Optimization and Responsiveness (C5) characteristic, respectively, a single requirement, Mobile Responsiveness (R4) predominantly, and to a small extent on the User-Friendly Interface requirement (R1);
- Blockchain (T2) is used to a small extent in the implementation of the Integrated Booking and Reservation System (C1) and Secure and Versatile Payment Processing (C3) characteristics, except the C3 characteristic used to cover the Variety of Payment Options (R5) requirement;
- High-Performance Computing (T5) is the only technology required to cover the Analytics, Reporting, and Backend Management (C9) characteristic, impacting the fulfillment of all requirements. (Figure 4).

Figure 5 shows the percentage contribution of each technology to the realization of the platform characteristics. The graph was generated based on the values determined by the development team based on the requirements identified from the UX evaluation. It also presents design perspectives that enhance the future

functionality of agritourism platforms by properly integrating technologies into characteristics.

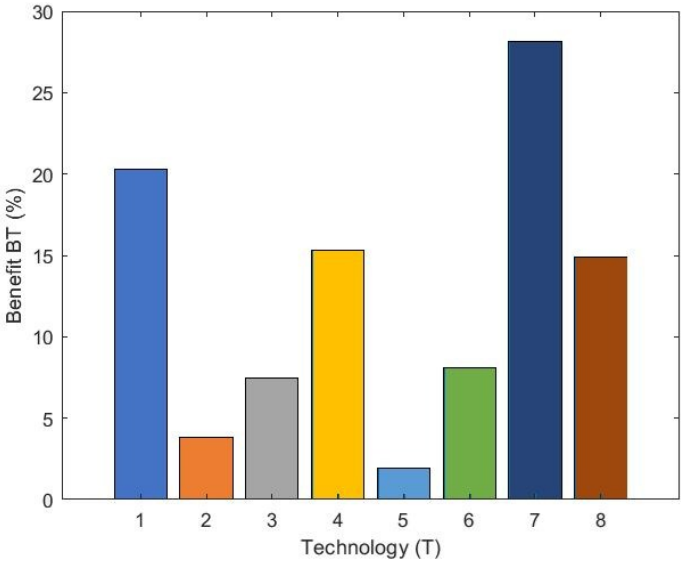
Figure 5
Technology integration in each characteristic



Source: Authors

The research shows that using Tourism 4.0 technologies can be the path towards agritourism development. These technologies constitute the premises for future development and highlight the potential benefit for entrepreneurs in the studied area.

Figure 6
Benefit of each technology



Source: Authors

Thus, they must be aware of the future steps concerning the knowledge and implementation of these technologies. Figure 6 shows that the most significant benefits could be obtained by integrating Artificial Intelligence (T7) and Cloud Computing technologies (T1) within the platform.

Discussion

The results of this study provide a comprehensive overview of the current state of tourism platforms, particularly those dedicated to agritourism, and the integration of Industry 4.0 technologies. Several key points emerge from the analysis, offering valuable insights for developing and optimizing an Agritourism 4.0 platform.

Evaluation of Existing Platforms. The comparative analysis of popular tourism platforms revealed significant findings. Agriturismo.it and Farmstayplanet.com stood out with the highest overall values, indicating their exemplary performance across various critical characteristics. Agriturismo.it, with an overall score of 23.7, and Farmstayplanet.com, with 23.1, demonstrate the importance of consistency and a balanced feature set. These platforms provide a comprehensive user experience, essential for agritourism platforms aiming to attract and retain users. While popular, platforms like Airbnb, Booking.com, and Agoda.com did not achieve the highest overall scores, suggesting that while they perform well in certain areas, they may lack the specialized features necessary for agritourism. This highlights the need for dedicated agritourism platforms to focus on specific user needs related to rural and farm tourism, which general platforms may not fully address.

Key Requirements for Agritourism 4.0 Platform. Analysing user preferences and market trends through the Potential Attraction (PA) percentage for each requirement underscores the importance of certain features. A user-friendly interface and mobile responsiveness were identified as top priorities, each accounting for 25% of the potential attraction. This reflects the growing reliance on mobile devices for travel planning and the necessity for an intuitive user experience. Other significant requirements include a wide range of features and functionality (20%), excellent customer support (15%), and a variety of payment options (15%). These findings suggest that an Agritourism 4.0 platform must prioritize ease of use, mobile compatibility, and comprehensive service offerings for success. High-quality customer support and flexible payment options are crucial for building trust and ensuring user satisfaction.

Integration of Industry 4.0 Technologies. Integrating specific Industry 4.0 technologies into the Agritourism 4.0 platform illuminates their potential to enhance user experience and operational efficiency. For instance, cloud computing and Blockchain technology facilitate secure, efficient booking systems and payment processes. Artificial intelligence and big data offer personalized user experiences and strategic insights from user data. This tailored integration bolsters the platform's functionality and enhances its security, reliability, and user engagement.

Technological Synergies and Platform Optimization. The relationships identified between the platform's characteristics and the enabling technologies underscore the synergistic potential of these integrations. Technologies such as IoT and cybersecurity play foundational roles in maintaining the integrity and enhancing the platform's functionality. For example, IoT enhances real-time data integration for navigation and location-based services, while cybersecurity protects user data and builds trust. The strategic application of these technologies is crucial in creating a resilient platform capable of adapting to evolving market needs and user expectations.

Future directions and technological Implications. The research indicates a significant trajectory for the use of Tourism 4.0 technologies in driving the future of agritourism. As detailed in the results, the potential benefits show that technologies like Artificial Intelligence and Cloud Computing meet current operational demands and set the stage for future enhancements. These technologies are instrumental in creating a functional, secure, and forward-looking platform that caters to the next generation of agritourism enthusiasts.

Conclusion

This research conclusively affirms that Tourism 4.0 technologies hold transformative potential for agritourism, answering the guiding research question affirmatively. The integration of Industry 4.0 technologies into agritourism platforms is not only feasible but also beneficial, enhancing both operational efficiency and user engagement. Through comprehensive analysis and evaluation, platforms such as Agriturismo.it and Farmstayplanet.com have demonstrated superior performance by integrating a balance of key functionalities that resonate well with entrepreneurial needs in agritourism. Furthermore, the study has highlighted the critical role of technologies such as Cloud Computing, Blockchain, and Artificial Intelligence in creating robust, secure, and user-friendly agritourism platforms. These technologies facilitate improved service delivery and operational management, which are vital for agritourism ventures' scalability and sustainability. Embracing these technologies will be essential for agritourism entrepreneurs looking to innovate and maintain a competitive edge in the rapidly evolving tourism industry.

One of the study's limitations is that it used focus group results as its primary foundation, which helps gain preliminary insights but requires additional research using quantitative techniques to support conclusions. There are difficulties with the comparison analysis, especially when comparing smaller, niche platforms with market giants like Booking.com and Airbnb. Even though these comparisons appear uneven, they are important because they point out possible areas for improvement, particularly for platforms with the .ro domain, which provides a strategic direction for creating a new agritourism platform. The present study establishes the foundation for future investigations that will further explore the evaluation of current resources and pinpoint domains that necessitate improvement from managerial and technical viewpoints. These domains include infrastructure, data management, and regulatory frameworks. A second limitation of the research stems from the selection bias in our focus group composition. Participants with access to wireless connectivity were exclusively chosen from the area under study. This criterion may limit the generalizability of the findings, as it excludes perspectives from participants without such connectivity, potentially skewing the data towards technology-adaptive individuals only. Nevertheless, the current trend is moving towards global connectivity and adopting related technologies, which could mitigate this limitation over time as broader access becomes more common.

References

1. Amiri-Zarandi, M., Dara, R. A., Duncan, E., & Fraser, E. D. G. (2022). Big Data Privacy in Smart Farming: A Review. *Sustainability, 14*(15), 9120. https://doi.org/10.3390/su14159120
2. Basile, G., Porcaro, A., De Lucia, C., & Pazienza, P. (2024). Digitalisation and development policies to enhance cultural heritage in inland and marginal areas: a pilot study on the Gargano agritourism sector. *Turistica - Italian Journal of Tourism, 32*(2), 90-119. https://doi.org/10.70732/tijt.v32i2.29
3. Bheda, R., Bhimani, D., Dharamshi, F., Sheth, S., Menon, R., Somra, R., Bhasuru, R., Mahajan, C., Gajbhiye, S., & Toradmalle, D. (2021). Educational Advancements in the Field of Augmented Reality and Virtual Reality. 2021 International Conference on Communication information and Computing Technology (ICCICT), 1-4. https://doi.org/10.1109/iccict50803.2021.9509941
4. Cheng, X., Xue, T., Yang, B., & Ma, B. (2023). A digital transformation approach in hospitality and tourism research. *International Journal of Contemporary Hospitality Management, 35*(8), 2944-2967. https://doi.org/10.1108/ijchm-06-2022-0679

5. Ferrag, M. A., Shu, L., Friha, O., & Yang, X. (2022). Cyber Security Intrusion Detection for Agriculture 4.0: Machine Learning-Based Solutions, Datasets, and Future Directions. *IEEE/CAA Journal of Automatica Sinica,* 9(3), 407-436. https://doi.org/10.1109/jas.2021.1004344
6. Georgiou, Y., Zhou, N., Zhong, L., Hoppe, D., Pospieszny, M., Papadopoulou, N., Nikas, K., Nikolos, O. L., Kranas, P., Karagiorgou, S., Pascolo, E., Mercier, M., & Velho, P. (2020). Converging HPC, Big Data and Cloud Technologies for Precision Agriculture Data Analytics on Supercomputers. *Lecture Notes in Computer Science*, 368-379. https://doi.org/10.1007/978-3-030-59851-8_25
7. Liu, L. (2022). Research on the Operation of Agricultural Products E-Commerce Platform Based on Cloud Computing. *Mathematical Problems in Engineering, 2022*, 1-8. https://doi.org/10.1155/2022/8489903
8. Lopes, P., Almeida, L., Pinto, J., de Jesus, J., Fernandes, D., Vieira, I., & Gama, R. (2019). Open Tourist Information System: a platform for touristic information management and outreach. *Information Technology & Tourism, 21*(4), 577-593. https://doi.org/10.1007/s40558-019-00159-w
9. Mhlanga, D. (2021). Artificial Intelligence in the Industry 4.0, and Its Impact on Poverty, Innovation, Infrastructure Development, and the Sustainable Development Goals: Lessons from Emerging Economies? *Sustainability, 13*(11), 5788. https://doi.org/10.3390/su13115788
10. Maquera, G., da Costa, B. B. F., Mendoza, Ó., Salinas, R. A., & Haddad, A. N. (2022). Intelligent Digital Platform for Community-Based Rural Tourism—A Novel Concept Development in Peru. *Sustainability, 14*(13), 7907. https://doi.org/10.3390/su14137907
11. Pencarelli, T. (2020). The digital revolution in the travel and tourism industry. *Information Technology & Tourism, 22*(3), 455-476. https://doi.org/10.1007/s40558-019-00160-3
12. Pilaiwan, P. & Sheau-Ru, T. (2019). Augmented Reality in the Integrative Internet of Things (AR-IoT): Application for Precision Farming. *Sustainability, 11*(9), 2658. https://doi.org/10.3390/su11092658
13. Prodanović, R., Rančić, D., Vulić, I., Zorić, N., Bogićević, D., Ostojić, G., Sarang, S., & Stankovski, S. (2020). Wireless Sensor Network in Agriculture: Model of Cyber Security. *Sensors, 20*(23), 6747. https://doi.org/10.3390/s20236747
14. Raj, M., Gupta, S., Chamola, V., Elhence, A., Garg, T., Atiquzzaman, M., & Niyato, D. (2021). A survey on the role of Internet of Things for adopting and promoting Agriculture 4.0. *Journal of Network and Computer Applications, 187*, 103107. https://doi.org/10.1016/j.jnca.2021.103107
15. Tseng, M.L., Chang, C.H., Wu, K.J., Lin, C.W.R., Kalnaovkul, B., & Tan, R.R. (2019). Sustainable agritourism in Thailand: Modeling business performance and environmental sustainability under uncertainty. *Sustainability, 11*(15), p.4087. https://doi.org/10.3390/su11154087
16. Xiong, H., Dalhaus, T., Wang, P., & Huang, J. (2020). Blockchain Technology for Agriculture: Applications and Rationale. *Frontiers in Blockchain, 3*. https://doi.org/10.3389/fbloc.2020.00007

About the authors

Elena Loredana Stăncioiu, Ph.D. student Eng. at University of Petrosani, Romania, with a thesis that approaches agritourism and implementing innovative technologies. She graduated with an Economics Engineering specialization from the Faculty of Engineering, Constantin Brâncusi University of Târgu-Jiu, Romania. She got a master's degree in modern manufacturing technologies. Her main research interests are agritourism and Tourism 4.0. The author can be contacted at e-mail: **stancioiuloredana@gmail.com**

Prof. Andreea Cristina Ionica is a Ph.D. supervisor in management and engineering and a professor of management in the management and industrial engineering department at the University of Petrosani, Romania. She holds a bachelor's degree in engineering (1992), a PhD (2004) in Industrial Engineering, a Bachelor's Degree in Economics (2002) from the University of Petrosani, and a Postgraduate Diploma (1998) from the Institut National Polytechnique de Lorraine, France. The published papers address interdisciplinary and innovative research topics. She has more than 100 refereed research papers in international journals and conferences, and international prizes for patents. The author can be contacted at e-mail: **andreeaionica@upet.ro**

Prof. Monica Leba is a Ph.D. supervisor in System Control Engineering in the Computer and Electrical Engineering Department at the University of Petrosani, Romania. She has a PhD (2002) in System Control Engineering from the University of Petrosani, a Bachelor's Degree in Applied Informatics (1998), and a Master's Degree in Computer Engineering (2007) from the University of Petrosani. She is a member of the IEEE and IFAC and the Computers for Control Technical Committee. Her research interests are applied informatics, modelling and simulation, and algorithm design. She has more than 100 refereed research articles in international journals and conferences, and international prizes for patents. The author can be contacted at e-mail: **monicaleba@upet.ro**