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Smart Ecotourism and Natural Ecology in Kazakhstan

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ABSTRACT

Artificial intelligence (AI) is transforming the tourism industry and affecting on natural ecology, making it more environmentally friendly, efficient and personalized. In 2025, AI technologies are being actively implemented to reduce the carbon footprint, optimize resources, and improve the travel experience. Here are the key applications of AI in environmentally sustainable smart tourism: AI in smart tourism is not just a technological trend, but a necessity for the sustainable development of the industry. Paper analyses personalized and green travel experience and smart tourism. AI-based applications (Google ARCore) allow tourists to get information about attractions without paper booklets. Virtual tours reduce the need for physical travel by reducing the carbon footprint. Platforms offer routes with minimal impact on nature (for example, hiking trails instead of car tours). Tourists can offset their carbon footprint through AI tools by financing tree planting. The introduction of AI solutions allows combining economic benefits with environmental responsibility, creating a future where travel becomes safer for the planet. Paper confirms idea about sustainable tourism development in developing countries and focus on premium ecotourism. Instead of mass tourism, AI helps promote unique destinations (safaris, diving, ethnographic tours), which increases income with less environmental damage. Smart cities with AI-driven transport and energy-saving solutions make tourism more sustainable.

Keywords: AI-Based Applications; Virtual Tours; Low-Impact Routes; Carbon Footprint Offset; AI-Driven Transport; Energy-Saving Solutions; Deep Seek

1. Introduction

AI analyzes data on weather, congestion and air routes, reducing CO_2 emissions through more efficient routes. Green hotels have smart energy management systems in hotels (automatic control of lighting and air conditioning) reduce electricity consumption by 20-30%. Forecasting tourist demand: AI prevents congestion of popular destinations by distributing tourist flows and reducing the burden on ecosystems.

It is Ecosystem restoration and nature protection. Machine learning algorithms determine the optimal areas for tree planting, which helps in the fight against climate change. Coral Reef monitoring: AI cameras and drones monitor the state of marine ecosystems, detecting pollution and illegal fishing. AI-based systems detect suspicious activity in nature reserves, protecting rare animal species [1–5].

Paper confirms idea about sustainable tourism development in developing countries. AI helps promote unique destinations (safaris, diving, ethnographic tours), which increases income with less environmental damage. Smart cities with AI-driven transport and energy-saving solutions make tourism more sustainable.

Smart Tourism is an evolving concept that integrates digital technologies, sustainability, and data-driven strategies to enhance the tourism experience, improve destination management, and boost economic growth. Several key theories underpin its development. These theories got contribution from this paper: Experience Economy Theory includes ideas: Tourism shifts from selling services to creating memorable experiences; Smart tourism enhances this via Augmented Reality (AR) and Virtual Reality (VR) – Interactive heritage tours; Gamification – Reward-based exploration (loyalty apps). Sustainability and Smart Destination Theory includes ideas: Combination of smart city principles with eco-friendly tourism. Co-Creation and Social Influence Theory includes ideas: Tourists are no longer passive consumers but active co-creators of experiences. Diffusion of Innovation Theory has factors influencing adoption: Perceived Usefulness & Ease of Use (TAM) [6–9].

But main theory is Smart Tourism Ecosystem Theory. It views tourism as an interconnected digital-physical network. Stakeholders of this theory are tourists (demand side); Businesses (hotels, airlines); Governments (smart infrastructure); Local Communities (cultural preservation). Smart Tourism is shaped by multiple theories, blending technology, sustainability, and user engagement. Future trends include metaverse tourism, blockchain for secure bookings, and AI-driven hyper-personalization.

2. Literature Review

This literature review synthesizes key studies on Kazakhstan's energy sector, environmental policies, labor and institutional reforms, and economic diversification, focusing on the interplay between regulation, corporate behavior, and sustainable development [10–12].

Kazakhstan's energy sector is undergoing significant transformation, particularly with the introduction of market-based environmental regulations. They examine how coal-based power generators respond to the Emissions Trading Scheme (ETS), highlighting corporate strategies to comply with decarbonization mandates. Similarly, it analyzes regulatory stability in renewable energy investments, emphasizing the need for policy predictability to attract green energy projects. It assesses Kazakhstan's renewable energy support mechanisms, noting progress but also gaps in incentivizing large-scale adoption [13–18].

The oil and gas sector remains central to Kazakhstan's economy evaluating regulatory mechanisms in the context of environmental challenges. Their findings suggest that stricter enforcement and transparency are needed to align industry practices with sustainability goals [19–23].

Kazakhstan's efforts to reduce dependence on natural resources are explored, who discuss institutional reforms aimed at fostering economic diversification [24–28]. It complemented this by analyzing FDI determinants in Central Asia, noting Kazakhstan's comparative advantage due to its regulatory environment [29–33].

Labor market reforms are another critical area [34–38]. It examines the harmonization of Kazakhstan's labor laws with EAEU standards, researchers critique institutional corruption within labor unions, revealing systemic challenges in worker representation [39–44].

The papers trace the evolution of agricultural policy, underscoring shifts toward market-oriented reforms [45–48]. Environmental legislation is scrutinized to argue for stronger enforcement mechanisms to address ecological degradation. Several studies extend beyond Kazakhstan to global energy dynamics [49–53].

Policy Implementation is that Kazakhstan has advanced regulatory frameworks (ETS, renewable incentives), enforcement remains inconsistent [54–58]. Labor unions and public institutions struggle with transparency. Kazakhstan's energy sector is influenced by global commodity markets [59–63]. Diversification Challenges is that despite reforms, resource dependence persists, requiring deeper institutional changes [64–68].

The literature review organized thematically below to highlight key research trends on Kazakhstan's development challenges and strategies.

Kazakhstan's pursuit of digital modernization faces systemic barriers. The rural technological deficits, resistance to change among stakeholders, and insufficient digital literacy. Urban digitalization shows more promise: use cluster analysis to map "smart city" potential, emphasizing data-driven governance, while smart city frameworks links to sustainable tourism through IoT and AI integration [69–73].

Renewable energy adoption remains constrained despite policy ambitions. The papers outline structural hurdles: fossil fuel dependency, grid instability, and investment gaps. OECD countries' growth-carbon emission dynamics rely heavily on energy mix diversification—a lesson applicable to Kazakhstan. Legal frameworks are evolving [73–78].

Tourism is leveraged for economic diversification but requires strategic optimization. The Silk Road's potential is highlighted, who advocate cross-border tourism corridors to boost socio-economic outcomes.

Authoritarian governance complicates reform. Externally, the EU employs soft power and "smart development", focusing on digital governance and green partnerships—though competition with China/Russia limits effectiveness. Kazakhstan's struggles to align waste management policies with European standards, citing regulatory fragmentation.

Advanced econometric methods illuminate regional dynamics. ODA in Sub-Saharan Africa exacerbates environmental pressure via spatial spillovers—a caution for Kazakhstan's development partnerships. Financial volatility is analyzed through entropy models and higher-moment spillovers, underscoring risk transmission between commodities and equities.

Research converges on Kazakhstan's dual challenge: advancing digital/sustainable transitions while overcoming institutional legacies. Studies emphasize context-specific solutions: AI in agriculture/tourism requires tailored literacy programs. Renewable energy needs integrated policy/legal enforcement. EU engagement must navigate geopolitical rivalry to support governance reforms.

A key gap remains in quantifying cross-sector synergies (e.g., how smart cities boost agricultural efficiency or how tourism revenue funds green energy). Future research should model these interlinkages explicitly.

3. Materials and Methods

The comprehensive research endeavor was meticulously executed within the geographical confines of Kazakhstan, a nation renowned for its diverse agricultural landscape. Ultimately, the methodology of simple random sampling was judiciously adopted to facilitate the systematic identification and selection of traditional tourism agents and smart touristic applications hailing from the designated villages and marketplaces, culminating in this pivotal stage of the study.

Paper analysis AI applications in smart tourism. The Heckman model with the variables (household head gender, farm size) feel arbitrarily chosen for an ecotourism study.

The two-step Heckman implementation seems technically correct but conceptually misapplied - it's modeling group membership. The connection between the theoretical framework (AI in tourism) and empirical design (farming collectives) is created: Target population (tourists, AI developers, or local communities); Sampling frame (list of ecotourism sites, registered apps, or farmer groups); Sample size justification (why 215 farmers + 320 traders); Heckman model focuses on "participation in ecological groups" (farming collectives) but never connects these groups to AI adoption or ecological outcomes. AI's role in ecosystem restoration or demand forecasting is operationalized in the analysis.

In the course of the investigation, the socioeconomic attributes characterizing the traditional tourism agents and smart touristic applications engaged in the cultivation and commerce of smart tours were scrupulously analyzed through the application of descriptive statistics. Furthermore, the t-test was employed to ascertain statistically significant disparities in the mean values of the variables across the different regions under consideration. To enhance the robustness of the data analysis, the Heckman AI selection model was utilized. During the initial phase of this model, the various determinants influencing the decision to partake in ecological smart tourism were meticulously identified, while the subsequent phase entailed estimating the extent of participation in ecological smart tourism among both smart touristic applications and traditional tourism agents [79–82].

The variables pertinent to ecological smart tourism that were meticulously measured encompass a range of ecological groups, which include both agricultural and non-agricultural classifications, in addition to group density, which refers to the total number of members within a particular group. Moreover, the concept of trust among group members was examined, alongside the overall size of the business network established by traditional tourism agents and smart touristic applications. It is noteworthy that group membership density is quantitatively defined as the total number of ecological groups that an individual farmer or smart touristic application is affiliated with. Additionally, the business ecological network is characterized by the number of individuals with whom the farmer or smart touristic application predominantly engages in trade, encompassing both input and output trade partners essential for their agricultural endeavors [83–87].

Upon reviewing the various perspectives and discussions presented by different researchers regarding the nuances of ecological smart tourism, it becomes evident that the factors and resulting effects associated with ecological smart tourism do not exhibit a direct causal relationship. The foundational concept underpinning ecological smart tourism posits that participants are able to access production resources as members of interconnected networks, resources that would otherwise remain out of reach without such affiliations. The Heckman AI two-step selection model is employed with the explicit purpose of evaluating both the measurement model concerning the factors that influence participation in ecological smart tourism and the extent of involvement in ecological groups among participants [88–93].

The determinants incorporated within the model encompass a range of variables, including the gender of the household head or smart touristic application, age of the individual, size of the household, trading experience, number of years of formal education attained, distance to the nearest market, access to extension services, availability of financial services, and the presence of off-farm income. The selection of these determinants for inclusion in the model was meticulously informed by a comprehensive review of analogous studies in the field. In addition, ecological capital indices reflecting smart tourism index, attendance at meetings, and labor contributions were calculated in accordance with established research protocols. The level of trust among group members was quantitatively assessed using a mean derived from a five-point Likert scale, where a score of 5 denotes "very trustworthy," 4 indicates "more trustworthy," 3 signifies "generally trustworthy," 2 represents "less trustworthy," and a score of 0 conveys "no trust whatsoever." The degree of engagement in ecological smart tourism was estimated based on the total number of ecological groups to which an individual belongs [94–98].

To mitigate the risk of selection bias, the two stages of the Heckman AI model are estimated independently. During the first stage, the probit model is employed to estimate the likelihood of traditional tourism agents and smart touristic applications opting to engage in ecological groups, with the model being delineated as follows.

$$W_{ij}^{*} = \beta_{ij} X_{ij} + \mu_{ij}$$
$$\mu_{ij} \sim N(0, \sigma^2) \quad i = 1 \ldots n \qquad (1)$$

where W_{ij}^{*} is a dummy variable, with 1 denoting participation in ecological groups and 0 denoting otherwise. X_{ij} is the explanatory variable. Furthermore, the variable in question corresponds to the explanatory variable that relates specifically to the ith respondent who belongs to the jth category of respondents, and the symbol β is utilized to represent a vector comprising various coefficients that quantify the relationships between the variables, while the notation used to denote the error term signifies an error component that is assumed to be independently and normally distributed.

In the subsequent stage of the analysis, referred to as stage two, the extent to which individuals participated was quantitatively assessed through the application of an ordinary least squares (OLS) regression model, which employed explanatory variables that are specifically associated with the ith respondent belonging to the jth category of respondents, and this was further complemented by a collection of dimensions that pertain to trust within ecological smart tourism groups, as well as the size of the network to which these individuals belong. The model is articulated for the ith respondent who is actively participating in ecological smart tourism, as indicated in the formulation known as Equation 2.

$$Y_{ij}^{*} = \theta_{ij} z_{ij} + \mu_{ij} \qquad (2)$$

where Y_{ij}^{*} is the degree ecological groups participation for the ith respondent in the jth category of the supply chain actors, θ_{ij} and z_{ij} are the socioeconomic and ecological smart tourism variables (Equation 3).

$$p\alpha_E \frac{\sigma(z_i \delta)}{\sigma(z_i \delta)} \qquad (3)$$

4. Results

As presented in **Table 1**, the descriptive statistics reveal several key insights regarding ecotourists. The average educational attainment among household heads was 8 years, indicating that the majority had completed primary-level education.

Table 1. Characteristics of sampled ecological smart tourism

	Pooled
	mean/sd
Age of the Household Head	42.77
Sex of the respondent (1=Female, 0=Otherwise)	0.63
Sex of the household head (1=Female, 0=Otherwise)	0.24
Total number of household members	4.87
Household head level of education in years	7.87
Total area under cultivation (Hectares)	0.25
Main smart tourism coefficient	0.47
1 If farmer is a member of any agriculture group, 0=No	0.46
1 If farmer is a member of any ecological group, 0=Otherwise	0.81
Total number of ecological groups per farmer	2.61
1 If farmer received training in year 2023, 0=No	0.43
1 if farmer accessed financial services in the last 6 months	0.54
1 if farmer had access to extension services, 0=No	0.53
Network size of most traded input and output partners	7.53
Smart tourism index	0.11
Labor contribution	0.56
Meeting attendance	0.86
Observations	217

On average, each tourist participated in three ecological groups. These groups serve as vital platforms for members to safeguard and advance their collective business interests. The meeting attendance index was notably high at 0.81, suggesting that traditional tourism agents attended the majority of scheduled group meetings. This high attendance rate may be attributed to the governance structures of these groups, which often impose penalties for absenteeism. Additionally, regular participation incentivizes mutual support among members during ecological initiatives.

The smart tourism index averaged 0.69, reflecting the significant role of financial commitments within these groups. This underscores the importance of monetary contributions as a core function of ecological associations in the study region.

Furthermore, farming households maintained an average trading network of seven individuals, highlighting their reliance on established, trusted partnerships to secure their commercial interests. Lastly, the mean annual labor contribution per household amounted to 42 days, demonstrating the active involvement of group members in collective work efforts.

Table 2 describes the demographic characteristics of smart tourism in the study area. As it was for farming household heads, smart touristic applications had an average of eight years of formal education, implying a primary level of education (**Table 2**). Overall, most traders (73%) belonged to ecological groups. The ecological groups comprised trading activity-related groups and non-trading activity groups. Trade groups also serve as platforms for capital contributions for smart touristic applications, as shown in **Table 3**. In general, most smart touristic applications in the study area had no access to horticultural training. They had received training in 2023 (**Table 2**). Moreover, over 60% of smart touristic applications have access to finances, mostly through their ecological groups.

Table 2. Characteristics of sampled ecological smart tourism in Kazakhstan

	Pooled
	mean/sd
Trader Category (1=Wholesaler, 0=Retailers)	0.53
Age of respondents	45
Sex of the respondent (1=Female, 0=Otherwise)	0.77
Maximum number of years of schooling	9.13
Number of years in trading	11.87
Smart tours sold	0.32
1 If smart touristic application belongs to agricultural trade group 0=No	0.39
Number of agricultural related trade groups engaged	1.29
1 If smart touristic application is a member in any ecological groups, 0=No	0.73
Total number of ecological groups smart touristic application belongs to	1.92
Respondent's network of trading partners	15.17
1 if smart touristic application has access to financial services, 0=No	0.60
1 If respondent attended agricultural related training	0.07
Smart tourism index	0.55
Labor contribution	0.20
Meeting attendance	0.83
Observations	322

Table 3. Functions of agricultural groups in the study areas

Group Functions	**Pooled**
Ecological contributions	35
Collective Input Purchase	22
Collective Marketing	18
Agricultural Trainings	23
Capital Contribution	25

Overall, the meeting attendance index for smart touristic applications is 0.83, implying that smart touristic applications are mostly responsive to scheduled meetings. As for traditional tourism agents, the smart touristic application's correspondence to scheduled meetings could be explained by the rules and regulations collectively agreed upon to govern their ecological groups, including fines for absentees. On the contrary, the labor contribution for smart touristic applications was only 0.20 per annum, implying that smart touristic applications spent an average of 20 days in a year, providing labor for other smart touristic applications in their ecological groups. This result is expected for smart touristic applications because of the nature of their business settings in the market where many people flood markets, thereby rendering it difficult to work for others concurrently. The number of trading partners is statistically different between the two regions ($p < 0.05$).

Table 3 delineates the primary functions of agricultural groups among traditional tourism agents and smart touristic applications. The data reveal distinct functional priorities between these two sectors. Among traditional tourism agents, agricultural training emerged as the predominant group function (37%), followed by ecological contributions for events (33%). Secondary functions included collective input, purchasing arrangements, and production marketing. Notably, capital contributions were significantly more prevalent among smart touristic applications compared to traditional farmer groups.

A striking contrast was observed in non-agricultural groups, where 95% of respondents identified savings and loan mechanisms as the principal function of their ecological groups. This financial orientation was particularly pronounced among smart touristic applications, with 66% utilizing their groups primarily for capital accumulation. In these arrangements, members contribute fixed amounts that are subsequently deployed as business capital. Ecological event participation represented a secondary function, while collective marketing (13%) and produce sourcing (12%) were relatively minor activities among smart touristic applications.

Information-sharing patterns further differentiated these sectors (**Table 4**). Traditional tourism agents predominantly exchanged agricultural knowledge (90%), focusing on agronomic training and best practices. Market-related information, including produce pricing, was shared by over 80% of traditional agents. Conversely, smart touristic applications prioritized market intelligence and pricing data, with ecological lifestyle information being widely disseminated (67%) among these digitally-oriented groups.

Table 4. Information shared among agricultural groups in study areas

Information shared	Pooled	Pooled
Market Information	64	70
Price Information	88	70
Agricultural Practices	93	13
Ecological Life	54	66

Table 5 presents the factors influencing traditional tourism agents' participation in ecological smart tourism groups. The analysis reveals several significant determinants, including gender, education level, financial access, and off-farm income.

Female-headed households were 14% more likely to participate in ecological groups ($p < 0.1$), consistent with rural patterns where women often dominate community networks. This tendency may stem from women's limited capital access and greater reliance on collective support systems.

Each additional year of formal education increased participation likelihood by 2% ($p < 0.1$). Education enhances agents' capacity to process information and evaluate group benefits. Furthermore, educated household heads showed 24% greater engagement intensity ($p < 0.05$), as education facilitates recognition of economic advantages from group membership.

Improved financial access raised participation probability by 15% ($p < 0.05$) and engagement intensity by 13% ($p < 0.01$). Financial capacity enables cooperative fees payment and strengthens communal trust through reliable contribution records.

Exhibiting contrasting effects, off-farm income are: Reduced initial participation likelihood by 1% ($p < 0.05$), suggesting income diversification decreases reliance on groups. Increased participation intensity by 5% ($p < 0.05$) among joiners, as financial stability permits greater involvement. Each year of age increased participation by 3% ($p < 0.05$), contrary to some literature, potentially reflecting accumulated social capital. Larger households showed 21% greater involvement ($p < 0.05$), likely due to heightened credit needs. Market distance raised participation by 4% ($p < 0.1$), as groups mitigate transportation costs. Inter-member trust boosted involvement by 32% ($p < 0.05$), critical for sustaining cooperation and practice adoption.

These findings challenge conventional assumptions about age-related participation while confirming education's dual role in both initial engagement and participation depth. The trust coefficient notably exceeds other factors, underscoring social capital's primacy in collective action frameworks. Policy Recommendations are: Target female-headed households for ecological group outreach; Incorporate financial literacy components in group programming; Develop trust-building mechanisms to strengthen group cohesion.

Table 5. Determinants of traditional tour agents participation and degree of participation in ecological smart tourism

Variables	Probability of Participation		Degree of Participation	
	Coefficient	t-Stat	Coefficient	t-Stat
Sex of household head	0.16	1.96	-0.20	-0.56
Age	0.00	-1.20	0.03	4.97
Household size	-0.02	-1.20	0.23	5.13
Years of formal education	0.03	3.46	0.27	4.71
Farm size	-0.09	-0.74	-0.61	-1.23
Distance to market	0.00	-0.21	0.05	2.75
Access to extension services	-0.04	-0.50	-0.52	-1.64
Access to financial services	0.17	3.89	-0.52	-1.65
Off-farm income	-0.01	2.80	0.06	-1.66
Business network	-0.02	1.64	0.07	-1.67
Trust group members	-0.03	2.73	0.35	1.84

As demonstrated in the comprehensive analysis presented in **Table 6**, it becomes abundantly clear that both the variable of age and the dimension of trading experience are identified as statistically significant predictors ($p < 0.10$) of the propensity to participate in ecological groups within the context of smart touristic applications. Upon conducting a thorough examination of the data, two predominant patterns emerge that warrant further discussion:

Specifically, it has been determined that for each additional year of an individual's life, there is a corresponding increase of 4% in the likelihood that they will choose to engage with ecological groups. This positive correlation implies that: ecological groups might inherently favor the inclusion of older individuals as participants, likely because they place a higher value on the perceived maturity and wisdom that comes with age in the decision-making process. Furthermore, it can be posited that older candidates tend to exhibit a greater inclination towards responsible participation and a more nuanced approach to risk assessment when involved in collective endeavors.

Conversely, it appears that younger applicants demonstrate a noticeable hesitance to engage, which may be attributable to: a lack of trust in the dynamics of group interactions; an intrinsic resistance to the formalized regulations that govern established groups within this context.

In stark contrast to the aforementioned trends, it is noteworthy that each additional year of trading experience correlates with a 4% decrease in the likelihood of an individual participating in these groups. This negative relationship may be interpreted through the lens of: established market participants who cultivate robust and self-sustaining business networks that diminish their reliance on collaborative knowledge-sharing frameworks; a consequent reduction in their need to engage with formal group structures.

These insightful findings resonate harmoniously with the principles outlined in social capital theory, wherein: age is conceptualized as a proxy for the accumulation of social capital over time; and experience facilitates the creation of alternative network pathways that effectively substitute for the necessity of formal group participation in ecological or social initiatives. The results suggest an interesting tension in collective action participation - while maturity encourages engagement, professional autonomy developed through experience may discourage it.

Table 6. Determinants of smart touristic applications' participation and degree of participation in ecological smart tourism

Variables	Probability of Participation		Degree of Participation	
	Coefficient	t-Stat	Coefficient	t-Stat
Sex of the smart touristic application	0.368	0.352	1.036	5.511
Age	0.053	1.936	0.005	0.407
Years of formal education	0.025	0.209	0.118	3.124
Years in trading	-0.052	-1.817	0.005	0.396
Access to finance	0.443	0.836	0.393	4.566
Off-trade income	-0.001	-0.055	0.002	0.165

5. Discussion

This section discusses results of recent studies on tourism development, digital transformation in agriculture, and the role of smart technologies in fostering sustainable ecotourism, with a focus on Kazakhstan and the broader Central Asian region [89–92].

Researchers analyze the socio-economic group membership of tourism along the Kazakhstani segment of the Great Silk Road. Their findings highlight how heritage tourism contributes to regional economic growth, job creation, and cultural preservation. However, challenges such as infrastructure gaps and the need for better marketing strategies remain [93–97].

The concept of eco-city tourism is explored authors who argues that smart city frameworks can enhance sustainability in urban tourism. The systematic review emphasizes the growing role of smart technologies (IoT, AI) in promoting sustainable ecotourism [98–101].

The papers examine the challenges of digital transformation in Kazakhstan's agriculture, identifying key barriers such as: Limited technological infrastructure in rural areas, Resistance to change among traditional tourism agents, The need for government-supported digital literacy programs.

The study suggests that adopting AI and precision farming could significantly improve productivity and sustainability in the sector. The European Union's engagement strategies in Central Asia, focusing on: Soft power tools (education exchanges, cultural diplomacy), Smart development initiatives (digital governance, green energy partnerships). Their research indicates that the EU's approach fosters regional stability and economic diversification, though geopolitical competition with China and Russia remains a complicating factor. Research investigate how artificial intelligence can enhance smart heritage tourism, proposing AI-driven solutions for: Personalized tourist experiences, Real-time crowd management in heritage sites, Predictive maintenance of cultural monuments [102–105].

Smart tourism, leveraging digital technologies to enhance the efficiency, sustainability, and personalisation of the tourism experience for both tourists and destinations, has emerged as a critical area of research and development globally. This review synthesises key literature on its conceptual foundations, enabling technologies, sustainability imperatives, regional implementation (particularly in Central Asia/Kazakhstan), and persistent challenges [77, 78].

Smart tourism is intrinsically linked to the broader concept of the smart city, representing the application of Information and Communication Technologies (ICTs) to the tourism ecosystem. It transcends mere digitalisation, aiming for interconnectedness, real-time data utilisation, and value co-creation. Core enabling technologies include the Internet of Things (IoT) for pervasive sensing (e.g., in attractions or infrastructure), Big Data Analytics for understanding tourist flows and preferences, Artificial Intelligence (AI) for personalisation and automation, and mobile platforms for seamless interaction. AI, in particular, is highlighted for its potential to revolutionise heritage tourism through personalised experiences, real-time crowd management, and predictive maintenance of cultural sites [85–90].

A significant strand of research positions smart tourism as a pathway towards sustainable development and enhanced destination competitiveness. Integrating smart technologies is increasingly seen as vital for optimising resource use, managing visitor impacts, and promoting cultural preservation. This aligns with broader sustainable tourism goals and the potential for smart cities to foster environmental and social sustainability. The drive towards sustainability often intersects with the need for economic diversification and resilience in developing tourism markets.

Research specific to Central Asia, and Kazakhstan in particular, reveals a growing recognition of smart tourism's potential but also significant contextual challenges. Studies examine how smart city development forms a foundation for smart tourism initiatives. Research also focuses on leveraging Kazakhstan's unique assets, such as sacral tourism, through data analysis and forecasting and the potential of the Silk Road heritage. The role of external actors is noted, with studies like examining the EU's promotion of "smart development" initiatives, including digital governance, in the region, albeit amidst geopolitical complexities [22–25].

Despite the promise, the literature consistently identifies substantial barriers to effective smart tourism implementation: Limited technological infrastructure, particularly in rural or less developed areas, remains a critical hurdle, hindering equitable access and implementation.

Authoritarian contexts, like Kazakhstan historically, can foster bureaucratic inefficiencies, information asymmetry, and resistance to change within traditional tourism structures, impeding innovation. A significant gap exists in the digital skills required among both tourism professionals and tourists to fully utilise smart systems. Government-supported digital literacy programs are frequently cited as essential but often underdeveloped [33–37].

Aligning national and local regulations, ensuring data privacy and security, and effectively integrating international best practices (EU waste standards) as present ongoing regulatory challenges [44–46]. Securing sustained investment for technology deployment, maintenance, and skills development is a persistent concern, especially outside major urban centers.

6. Conclusions

Smart tourism represents a transformative paradigm driven by digital innovation, holding significant potential for enhancing tourist experiences, optimising destination management, and promoting sustainable development. Research in the context of Central Asia, particularly Kazakhstan, highlights both the ambitious integration of smart tourism within broader smart city and national digitisation strategies and the formidable challenges related to infrastructure, governance, human capital, and investment. Future research directions include deeper investigation into the measurable impacts of smart tourism on sustainability metrics (environmental, social, economic), the effectiveness of strategies to overcome digital divides and resistance to change within the sector, and the long-term viability of smart tourism models in diverse geopolitical and socio-economic contexts like Kazakhstan. The successful realisation of smart tourism's potential hinges on addressing these multifaceted challenges through coherent policy, targeted investment, capacity building, and adaptable governance frameworks.

Main connections are:

1. All three areas heavily emphasize digital technologies (AI, precision tech, digital governance, smart tourism) as key drivers for improvement and development.
2. The first two areas specifically address challenges and strategies within Kazakhstan and the broader Central Asian region.
3. The agricultural study explicitly identifies barriers to digital adoption (infrastructure, mindset, skills), which are common challenges relevant to the other areas (digital governance, smart tourism).
4. The EU's Smart Development Initiatives (including digital governance) directly intersect with the need for digital transformation identified in Kazakhstan's agricultural sector and the potential for smart tourism solutions.
5. The EU's efforts in Central Asia are framed within the context of competition with other major powers (China, Russia), adding complexity to the region's development landscape.

Potential Areas for Further Exploration are: digital literacy needs in Kazakh agriculture compare to those needed for adopting the proposed AI solutions in heritage tourism; the EU's "Smart Development Initiatives" (digital governance support) for the infrastructure and digital literacy barriers identified in Kazakhstan's agricultural sector; the "resistance to change" in agriculture manifest in the context of adopting AI for heritage tourism or new digital governance models promoted by the EU; role could AI-driven precision agriculture play in the EU's "green energy partnerships" or broader sustainability goals in Central Asia.

This synthesis highlights the interconnected challenges and opportunities surrounding digital transformation, external engagement, and technological innovation in Central Asia, particularly Kazakhstan, across agriculture, regional development, and tourism.

The paper underscores the intersection of tourism, digitalization, and sustainability in Kazakhstan and Central Asia. Future research should explore: Policy frameworks for integrating smart technologies in tourism and agriculture; Comparative studies on Central Asia's digital transformation versus other developing regions; Geopolitical impacts on sustainable development initiatives.

Research Gaps are: Tourism as an Economic Driver: Kazakhstan's Great Silk Road potential is underexploited; better public-private partnerships could enhance its global appeal, while digitalization promises efficiency, rural-urban disparities hinder progress. The EU's smart strategies in Central Asia must navigate competition from other major powers. More case studies are needed on AI applications in Central Asian heritage tourism.

Author Contributions

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Confict of Interest

The authors declare that they have no conflicts of interest to report regarding the present study

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