

How to Cite

Cimet, N. C., Betancourt, L. A. A., Vega de la Cruz, L. O., & Monier, Y. P. R. (2026). Geopark design management based on multimodal 4.0 technology. *International Journal of Engineering and Computer Science*, 9(1), 1-9.
<https://doi.org/10.21744/ijecs.v9n1.2480>

Geopark Design Management Based on Multimodal 4.0 Technology

Norge Caseres Cimet

Sucursal Isla Azul, Cuba

Email: norgecaseres@gmail.com

<http://orcid/0000-0001-6202-9173>

Luis Aníbal Alonso Betancourt

Universidad de Holguín, Cuba

Email: alonsob@uho.edu.cu

<http://orcid/0000-0003-0989-746X>

Leudis Orlando Vega de la Cruz

Universidad de Holguín, Cuba

Email: leovega@uho.edu.cu

<http://orcid/0000-0001-7758-2561>

Yoan Pablo Rodríguez Monier

Colegio de Bachillerato Técnico “Narcisa de Jesús”, El Coca, Orellana, Ecuador

Corresponding author email: yoanpablo2283@gmail.com

<https://orcid.org/0000-0001-7200-8456>

Abstract---The growing need to integrate sustainability, technological innovation, and territorial development has driven new ways of conceiving geopark management. In this context, multimodal tourism 4.0 emerges as an integrative approach that combines advanced technologies such as artificial intelligence, data analytics, and augmented reality. The objective of this research is to propose a methodology for geopark design management based on this approach. A mixed-methods, quasi-experimental, cross-sectional study was conducted in the Moa-Baracoa region of Cuba. The sample consisted of 200 participants selected through simple random sampling (100 in Moa and 100 in Baracoa), representing 30% of potential users. The results highlight limitations in traditional management models and demonstrate the feasibility of incorporating multimodal technologies to optimize decision-making. It is concluded that the proposed methodology promotes intelligent, participatory, and sustainable geopark management.

Keywords---tourism 4.0, artificial intelligence, sustainability, multimodal technology.

Introduction

In the contemporary context of sustainable territorial development, geoparks are configured as integrated systems capable of combining the conservation of geological heritage, environmental education, and local socioeconomic development through innovative, inclusive, and technologically advanced management models. This ideal state implies not only the preservation of natural resources but also the creation of smart, personalized, and sustainable tourism experiences, in line with the transformations of the so-called Fourth Industrial Revolution (Zhang & Lu, 2021).

The concept of geoparks has been extensively developed by UNESCO, which defines them as territories with geological heritage of international significance, managed with a holistic approach that integrates conservation, education, and sustainable development (UNESCO, 2021). This concept has been further enriched by Zouros (2004),

who highlights the role of geoparks as tools for regional development, and by [McKeever & Zouros \(2005\)](#), who emphasize the importance of community participation in their management.

From a theoretical perspective, geoparks constitute complex systems where natural, cultural, social, and economic dimensions converge. Geopark design management is understood as a strategic and systemic process oriented toward the planning, organization, implementation, and evaluation of actions that allow these territories to be structured as sustainable tourism products. [Borrás \(2019\)](#) argues that design management involves the integration of interdisciplinary approaches to generate innovative solutions in territorial contexts, while [Mozota \(2003\)](#) conceives of it as a process that connects creativity with organizational strategy.

In the specific context of geoparks, design management takes on particular importance as it requires the coordination of multiple stakeholders, resources, and technologies. According to [Dowling \(2011\)](#), geopark planning should be based on principles of sustainability, education, and local economic development, which demands flexible and adaptive management models. However, traditional approaches have shown limitations in terms of technological integration, effective citizen participation, and the personalization of the tourist experience.

In this context, the concept of Tourism 4.0 emerges, derived from Industry 4.0, which incorporates advanced technologies such as artificial intelligence, the Internet of Things (IoT), big data, and virtual reality to transform how tourism experiences are designed and managed ([Gretzel et al., 2015](#)). Multimodal Tourism 4.0 expands this vision by integrating different modes of interaction—physical, digital, sensory, and cognitive—allowing for a more immersive and adaptive experience for visitors.

Artificial intelligence plays a key role in this new paradigm. According to [Davenport & Ronanki \(2018\)](#), AI enables the optimization of decision-making processes, the prediction of user behavior, and the personalization of services in real time. In the context of geoparks, this translates into the possibility of designing smart routes, automated interpretation systems, and data-driven management platforms.

Furthermore, the use of multimodal technologies facilitates the integration of different types of data (geospatial, environmental, social) and their real-time processing. [Buhalis & Amarangana \(2015\)](#) emphasize that smart tourism destinations should be based on digital ecosystems that connect stakeholders in the territory and improve the visitor experience through the use of advanced technologies.

The relevance of implementing multimodal tourism 4.0 tools in geopark management lies in their ability to address current sustainable tourism challenges, such as destination overcrowding, the need for diversification of tourism products, and the growing demand for personalized experiences. In Latin America and the Caribbean, where territories with high geological and cultural potential exist, adopting these approaches represents a strategic opportunity to boost local development ([García & Pérez, 2021](#)).

Therefore, the overall objective of this research is to propose a methodology for the design of geopark management based on multimodal tourism 4.0, which will optimize the tourist experience, strengthen the conservation of geological heritage and promote sustainable territorial development through the use of emerging technologies, with an emphasis on artificial intelligence.

Materials and Methods

This research was conducted following the methodological foundations of the mixed-methods approach proposed by [Hernández Sampieri et al. \(2014\)](#), which systematically integrates qualitative and quantitative procedures to achieve a deeper and more holistic understanding of the phenomenon under study. In accordance with this approach, a quasi-experimental, cross-sectional study was designed to evaluate the relevance and applicability of a methodology for geopark design management based on multimodal tourism 4.0 in the Moa-Baracoa region of Cuba. The study adopted a quasi-experimental pretest-posttest design with non-equivalent groups, due to the impossibility of fully controlling all intervening variables in the natural context where the proposed methodology is implemented. This type of design allowed for the analysis of the effects of introducing multimodal tourism 4.0 tools in geopark management without altering the actual conditions of the territorial environment. A simple random probability sampling method was used to select the sample, ensuring the representativeness of the participants. It was assumed that 30% of the total number of potential users of the proposed methodology would be included. The sample consisted of a total of 200 participants distributed across two municipalities: 100 in Baracoa (control group) and 100 in Moa (experimental group).

Theoretical methods were used to support the research: analysis-synthesis to break down the phenomenon into its constituent elements and integrate them into a systemic vision; systemic-structural to understand the management of geopark design as a complex system; and modeling for the construction of the proposed methodology. Empirical methods included documentary analysis of regulatory documents, previous research, and technical reports related to

geoparks and tourism 4.0; a survey applied to the 200 participants to collect information on knowledge and perceptions; and participant observation during the pilot implementation of the methodology (Siswa, 2020). For statistical analysis, descriptive statistics (measures of central tendency and dispersion, absolute and relative frequencies), hypothesis tests to evaluate significant differences between groups, and percentage analysis to interpret the level of acceptance of the participants were used. The research was conducted in accordance with established ethical principles for studies involving human participants. Informed consent was obtained from all participants, confidentiality of information was maintained, and the data were used exclusively for scientific purposes. Voluntary participation and respect for local communities were also promoted (Kress & Selander, 2012).

Analysis and Discussion of the Results

The research was conducted in the Moa-Baracoa region, located in eastern Cuba, a territory of high geological, ecological, and cultural value. This region presents favorable conditions for the development of geoparks, given its rich geodiversity, the presence of unique ecosystems, and its potential for sustainable tourism. However, it also faces challenges related to land management, limited technological integration, and the need to strengthen community participation.

Multimodal tourism 4.0 can be defined as a tourism management and experience model based on the integration of multiple technological modalities—artificial intelligence, augmented reality, the Internet of Things, data analysis, and mobile platforms—that allow for real-time personalization and immersion of the visitor with tourist destinations, within the framework of smart tourism and the digital transformation of Industry 4.0. This concept constitutes the scientific novelty of the present research.

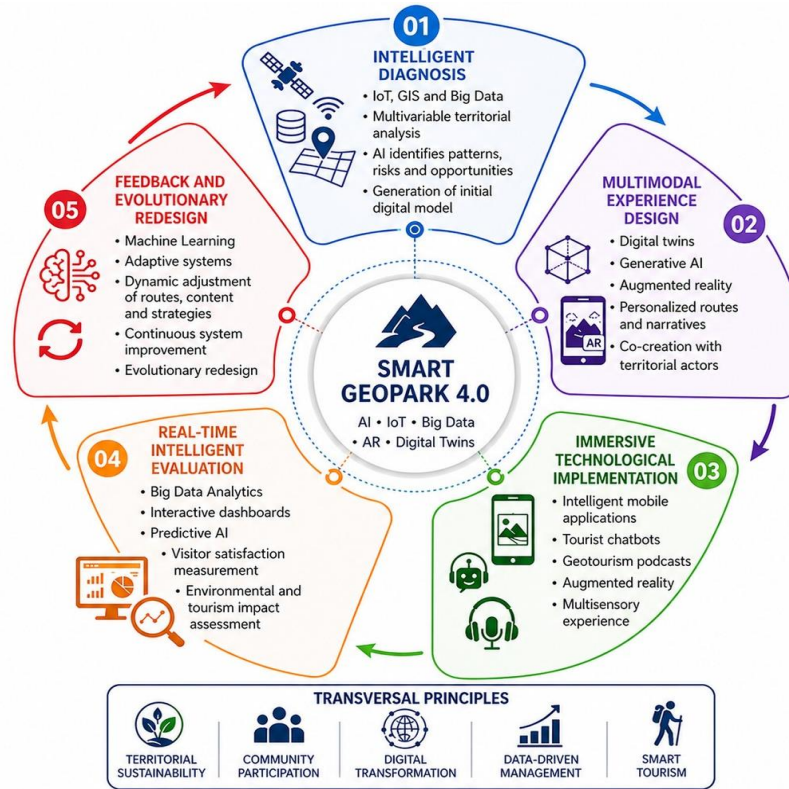
This concept is based on the convergence of smart tourism, the digitization of tourism services, and cyber-physical systems applied to user experience (Buhalis, 2020). Design management, grounded in the theories of Mozota (2003) and Borrás (2019), acts as the central axis of a complex ecosystem where technology and territorial planning co-evolve.

From an institutional perspective, the UNESCO Global Geoparks Network (McKeever et al., 2010) and the quantitative geosites assessment guidelines proposed by Brilha (2016) constitute the regulatory framework upon which this proposal is built. However, the distinctive contribution of this study lies in how Design 4.0 management transforms geological complexity into multimodal consumption experiences, facilitating heritage interpretation for a non-specialized audience through intelligent interfaces.

The Geopark Design Management Cycle (CGDG-4.0)

Based on theoretical and empirical analysis, the Geopark Design Management Cycle based on multimodal technology 4.0 (CGDG-4.0) is structured, supported by the principles of design management as a strategic process (Mozota, 2003), the management of geoparks as a sustainable territorial system (Dowling, 2011; Zouros, 2004), and the digital transformation of smart tourism (Buhalis & Amaranggana, 2015; Gretzel et al., 2015).

The proposed cycle is conceived as a cyclical, adaptive, and data-driven system, comprised of five interdependent phases that form a continuous improvement process: (1) intelligent geopark diagnosis; (2) multimodal experience design; (3) immersive technological implementation; (4) intelligent real-time evaluation; and (5) feedback and evolutionary redesign. This model is articulated with artificial intelligence, big data, IoT, digital twins, augmented reality, and advanced conversational systems. In the figure 1 shows the phases carried out.



Source: Own elaboration based on Mozota (2003), Dowling (2011), Zouros (2004), Buhalis and Amaranggana (2015) and Gretzel et al. (2015).

Figure 1. Cycle of Geopark design management passed on multimodal Technology 4.0 (CGDG-4.0)

Source: own elaboration with the help of AI

Results of the quasi-experiment

A 1-to-5 Likert scale was used to measure overall visitor satisfaction in both groups. The overall satisfaction results showed substantial differences: the experimental group in Moa (CGDG-4.0) obtained a mean of 4.62 (SD = 0.41), while the control group in Baracoa (traditional management) registered a mean of 3.78 (SD = 0.55). Table 1 presents a detailed comparison of the indicators evaluated in both groups:

Table 1
Comparison of results by the evaluated indicators

Indicator evaluated	Moa (CGDG-4.0) Media ± DE	Baracoa (Traditional) Average ± SD	Difference
Overall visitor satisfaction	4,62 ± 0,41	3,78 ± 0,55	+0,84
Quality of the tourist experience	4,70 ± 0,38	3,65 ± 0,60	+1,05
Interactivity and participation	4,75 ± 0,33	3,40 ± 0,62	+1,35
Accessibility to scientific information	4,68 ± 0,40	3,50 ± 0,58	+1,18
Perceived innovation of the destination	4,80 ± 0,35	3,30 ± 0,65	+1,50
Perceived environmental management	4,55 ± 0,44	3,90 ± 0,52	+0,65

Source: own elaboration

To compare the differences between groups, a Student's t-test for independent samples was applied. The statistical results were as follows: calculated $t = 9.87$; degrees of freedom = 198; $p < 0.001$.

The p -value < 0.001 indicates highly significant differences between the two groups, leading to the rejection of the null hypothesis (H_0 : There are no significant differences between Moa and Baracoa). This demonstrates that the implementation of the CGDG-4.0 methodology produces a statistically significant improvement in tourist user satisfaction and experience compared to traditional management methodologies.

The study's results reveal that integrating multimodal technologies into geopark management leads to significant improvements across all evaluated tourism experience indicators. These findings align with the work of [Buhalis & Amaranggana \(2015\)](#), who point out that smart tourism destinations leveraging digital ecosystems gain substantial competitive advantages over destinations with conventional management.

The most notable difference between the two groups was in the perceived innovation dimension of the destination (+1.50 points), suggesting that visitors recognize and value the incorporation of advanced technologies into the geotourism experience. This result is consistent with the findings of [Gretzel et al. \(2015\)](#), who argue that the perception of technological innovation positively influences overall tourist satisfaction.

From the perspective of the theoretical framework of design management, the CGDG-4.0 model corroborates [Mozota's \(2003\)](#) premise that design, when used as a strategic management tool, contributes to creating differential value for tourist destinations. The cyclical and adaptive structure of the model overcomes the limitations of traditional linear approaches, which [Dowling \(2011\)](#) has identified as insufficient to address the complexity of contemporary geotourism systems.

One element that deserves special attention in interpreting the results is the reconfiguration of the concept of tourist experience within the context of geoparks. Traditionally, the experience in these territories has been mediated by linear interpretive processes, focused on the transmission of geological knowledge through guides, information panels, or printed materials. However, the introduction of the multimodal 4.0 approach suggests a transition toward non-linear, adaptive, and co-created experiences, where the visitor ceases to be a passive recipient and becomes an active agent within the tourism system.

This transformation aligns with the ideas of [Xiang & Fesenmaier \(2017\)](#), who emphasize that analyzing large volumes of data allows for a better understanding of tourist behavior patterns and the design of more personalized experiences. However, while these authors approach the phenomenon from a marketing and data analytics perspective, the present study broadens this view by integrating these processes within a territorial framework, where the experience responds not only to individual preferences but also to the environmental, cultural, and social dynamics of the geopark.

Along these same lines, the CGDG-4.0 model introduces an emerging dimension that could be called "augmented territorial intelligence," understood as the capacity of a territory to self-regulate and adapt through interconnected technological systems. This concept transcends the smart destinations approach proposed by [Buhalis \(2020\)](#) by incorporating not only digital connectivity but also the territorial system's capacity for continuous learning. Unlike traditional models, where planning occurs in long cycles with limited feedback, the proposed approach allows for dynamic adjustments based on real-time data.

Another element that broadens the discussion is the educational dimension of the CGDG-4.0 model. While [UNESCO \(2021\)](#) emphasizes the role of geoparks as spaces for environmental education, the incorporation of multimodal technologies profoundly redefines learning processes. Instead of traditional didactic approaches based on the unidirectional transmission of knowledge, the proposed model favors experiential, interactive, and personalized learning. This transformation aligns with contemporary trends in digital education, where learning is conceived as an active, contextualized, and technology-mediated process.

However, this evolution also presents significant challenges. For example, reliance on technological devices could limit access for certain visitor groups, especially those with less digital familiarity. In this regard, the model must ensure the coexistence of multiple forms of heritage interpretation, combining digital resources with more traditional strategies. This hybrid approach would maintain the system's inclusivity, preventing technological innovation from becoming a factor of exclusion.

From an economic perspective, the study's findings open new avenues for reflection on value creation in geoparks. Traditionally, the economic value of these territories has been associated with direct tourism activities, such as guided tours, accommodation, and the sale of local products. However, the multimodal 4.0 approach introduces new forms of monetization based on digital services, information platforms, and personalized experiences. This shift aligns with the transformations described by [Buhalis \(2020\)](#), who points out that digitalization is redefining business models in tourism.

Despite these opportunities, questions also arise regarding the distribution of the value generated. In particular, it is necessary to analyze how the economic benefits derived from digitalization are redistributed among the different

stakeholders in the region. There is a risk that the gains will be concentrated in the hands of external technology providers, limiting the positive impact on local communities. In this regard, the CGDG-4.0 model should incorporate mechanisms that guarantee an equitable distribution of value, in line with the principles of sustainable development.

Another relevant aspect is the relationship between technology and sustainability, which has been the subject of debate in recent literature. While numerous studies highlight the potential of digital technologies to improve resource management efficiency, concerns also exist about their environmental impact, particularly in terms of energy consumption and electronic waste generation. In this regard, the CGDG-4.0 model poses a significant conceptual challenge: to what extent can intensive digitalization be considered compatible with the principles of sustainability?

The research suggests that the key lies in the strategic integration of technology, rather than its indiscriminate use. In other words, digital tools should be conceived as means to optimize environmental management, not as ends in themselves. This approach partially coincides with that of [Sigala \(2018\)](#), who warns of the need to adopt a critical perspective on technology in tourism. However, the present study goes further by proposing a concrete model where technology is linked to sustainability indicators, allowing for a systematic evaluation of its impact.

From a sociocultural perspective, the implementation of this model raises questions about the technological appropriation by local communities. In contexts like Moa-Baracoa, where there are limitations in infrastructure and digital skills, the introduction of advanced technologies could create gaps between the different stakeholders in the region. This aspect has been highlighted by [Fernández & López \(2020\)](#), who emphasize the importance of social inclusion in tourism development processes.

In this sense, one of the implicit contributions of the study is the need to conceive of technological innovation as a socially mediated process. That is, the effectiveness of the model depends not only on the availability of technologies, but also on the capacity of local actors to appropriate and use them meaningfully. This implies the need to design training, support, and knowledge transfer strategies that guarantee equitable and sustainable implementation.

Furthermore, the comparative analysis between the experimental and control groups allows us to reflect on the resistance to change in traditional management systems. The observed difference is not only due to the incorporation of technologies, but also to the break with established paradigms in tourism management. In many cases, institutional structures tend to reproduce conventional models due to organizational inertia, regulatory limitations, or a lack of incentives for innovation.

This phenomenon has been extensively documented in studies on organizational change, but it is particularly relevant in the field of geoparks, where management involves the coordination of multiple stakeholders with diverse interests. In this context, the CGDG-4.0 model could be interpreted not only as a methodological proposal, but also as a catalyst for institutional transformation.

Another element that enriches the discussion is the epistemological dimension of the concept of multimodal tourism 4.0. Unlike established categories such as sustainable tourism or smart tourism, multimodal tourism introduces an integrative logic that challenges disciplinary boundaries. In this sense, the proposed model is situated at the intersection of geography, engineering, social sciences, and design, which poses methodological and theoretical challenges.

This interdisciplinarity, while a strength, also implies the need to develop more robust conceptual frameworks to systematize the knowledge generated. In this sense, future research could delve deeper into the operationalization of the concept of multimodality, identifying its dimensions, indicators, and relationships with other variables in the tourism system.

Regarding the model evaluation, the results obtained through statistical analysis provide solid evidence of its effectiveness. However, it is important to consider that the measurement of variables such as satisfaction or the perception of innovation can be influenced by subjective, cultural, or contextual factors. Therefore, it would be advisable to complement these analyses with more in-depth qualitative methods, such as in-depth interviews or focus groups, which would allow for capturing nuances not reflected in the quantitative data.

Furthermore, the use of aggregated indicators could mask internal differences within the analyzed groups. For example, it would be pertinent to explore how variables such as age, education level, or familiarity with technology influence the perception of the model. This type of analysis would allow for the identification of specific user segments and the adaptation of design strategies based on their characteristics.

From an international comparative perspective, the CGDG-4.0 model shares similarities with initiatives developed in European and Asian geoparks, where digital technologies have been incorporated to enhance heritage interpretation. However, the main difference lies in the application context. While in Europe these initiatives are typically developed in environments with high technological availability, the Cuban case demonstrates that it is

possible to implement innovative solutions in contexts with limited resources, through adaptive and creative approaches.

This finding has important implications for other countries in Latin America and the Caribbean, where similar conditions exist. In this sense, the model could be replicated or adapted in different contexts, helping to reduce the technological gap in the tourism sector.

Another aspect to consider is the relationship between the model and public policy. Large-scale implementation of the CGDG-4.0 approach would require the support of regulatory frameworks and national digital transformation strategies. In this regard, collaboration between academia, the public sector, and the private sector emerges as a key factor for the model's sustainability.

Looking ahead, the evolution of tourism towards increasingly digital environments presents new challenges and opportunities. Emerging technologies such as the metaverse, generative artificial intelligence, and blockchain could be integrated into future versions of the model, expanding its capabilities and applications. However, this evolution also raises ethical questions related to data privacy, information security, and equitable access to technology.

It is important to emphasize that the CGDG-4.0 model should not be understood as a universal solution, but rather as a flexible framework that must be adapted to the specific characteristics of each territory. The diversity of geoparks, in terms of geological, cultural, and socioeconomic characteristics, requires differentiated approaches that respect local identities and promote balanced development.

Another point of interest is the relationship between the model and territorial resilience. In a global context marked by uncertainties, such as climate change or health crises, the adaptive capacity of tourist destinations becomes a critical factor. The cyclical and adaptive structure of the CGDG-4.0 model suggests significant potential for strengthening the resilience of geoparks by enabling rapid adjustments based on up-to-date information. This approach differs from traditional models, which often lack agile response mechanisms to unexpected changes.

In this regard, the integration of technologies such as the Internet of Things and artificial intelligence allows for real-time monitoring of environmental variables and visitor flows, facilitating risk management and proactive decision-making. This capability is especially relevant in geoparks located in vulnerable areas, where natural phenomena can affect both the heritage sites and the safety of visitors.

From a methodological standpoint, the research also raises questions about the use of mixed methods approaches in tourism studies. Following [Hernández Sampieri et al. \(2014\)](#), the combination of qualitative and quantitative methods allows for a more comprehensive understanding of the phenomenon. However, the complexity of the CGDG-4.0 model suggests the need to incorporate more advanced analytical tools, such as simulation models or network analysis, to capture the interactions between the different components of the system.

Furthermore, while the use of a quasi-experimental design is suitable for real-world contexts, future research could complement it with longitudinal designs that allow for the evaluation of the model's evolution over time. This would be particularly useful for analyzing organizational learning processes and technological adaptation.

In relation to the literature on geoparks, this study offers an innovative perspective by integrating the concept of design within territorial management. While authors such as [Zouros \(2004\)](#) and [McKeever et al. \(2010\)](#) have focused on institutional and conservation aspects, the CGDG-4.0 model introduces an operational dimension that connects these principles with concrete implementation tools. This articulation represents a significant advance in how geopark management is conceived.

However, significant differences are also evident. For example, traditional approaches tend to prioritize heritage conservation as the primary objective, while the proposed model seeks to balance this dimension with visitor experience and economic development. This duality creates tensions that must be carefully managed to avoid negative impacts on the natural environment.

In this regard, the incorporation of sustainability indicators into the model is presented as a key element to guarantee a balance between conservation and tourism. As [Brilha \(2016\)](#) points out, the quantitative assessment of geosites allows for the identification of vulnerability levels and the establishment of management priorities. Integrating these indicators into real-time analysis systems could significantly improve decision-making.

Another relevant aspect is the cultural dimension of the model. While geoparks are primarily defined by their geological heritage, in many cases this heritage is closely linked to local cultural practices and traditions. The incorporation of multimodal technologies offers new possibilities for the interpretation and enhancement of this intangible heritage. However, there is also a risk of simplifying or decontextualizing these cultural expressions in the digitization process.

Therefore, it is essential that the design of multimodal experiences be carried out in collaboration with local communities, ensuring respect for their values and knowledge. This participatory approach not only contributes to the authenticity of the experiences but also strengthens territorial identity and social cohesion.

In terms of innovation, the CGDG-4.0 model can be interpreted as a manifestation of the transition to cyber-physical systems in tourism, where the boundaries between the digital and the physical are blurring. This convergence, described by Sigala (2018), redefines the nature of tourist destinations, transforming them into hybrid environments where the experience is built from multiple layers of information.

However, this transformation also presents design challenges. Integrating different technologies requires a coherent approach that avoids fragmenting the user experience. In this sense, design management takes on a central role as an integrating discipline, capable of articulating the different components of the system into a coherent proposal.

The study of the Cuban case also contributes to the literature on sustainable tourism in Latin America. As García & Pérez (2021) point out, the region's territories possess geological and cultural conditions of high value, but face limitations in technological adoption. The experience of Moa demonstrates that it is possible to implement Tourism 4.0 systems even in contexts with developing infrastructure, through a distributed and participatory territorial governance approach. As Toselli (2019) argues, heritage management should act as an engine of socioeconomic development, a premise that this research strengthens through the use of multimodal tools.

The integration of artificial intelligence into the design of tourism experiences not only improves competitiveness but, in line with Camacho Pereira (2025), allows for greater personalization and accessibility in the consumption of cultural heritage. Regarding the study's limitations, it should be noted that the quasi-experimental design does not allow for the complete elimination of the influence of uncontrolled external variables. The sample, while representative of the studied context, may not reflect the diversity of other geotourism contexts. Future research could explore the applicability of the CGDG-4.0 model in geoparks with different levels of technological development and in other geographical and cultural contexts.

In conclusion, broadening the discussion allows us to place the study's results in a wider context, identifying not only its contributions but also its limitations and future projections. The multimodal 4.0 approach emerges as a promising path for transforming geopark management, but its effective implementation will depend on the ability of the stakeholders involved to integrate technology, knowledge, and social participation within a framework of sustainability.

Conclusions

The CGDG-4.0 methodology is highly relevant for the contemporary management of geoparks, as it responds in an integrated way to the current demands of sustainable territorial development, smart tourism, and the digitalization of tourism systems. Its cyclical, data-driven structure allows for effective integration between territorial planning, environmental management, and the visitor experience, making it a model consistent with the transformations of Industry 4.0 and the requirements of modern tourism governance.

The CGDG-4.0 methodology presents a high degree of scientific novelty by integrating emerging technologies such as artificial intelligence, big data, digital twins, and augmented reality into a single methodological system applied to the design and management of geoparks. This integration surpasses traditional approaches to tourism management and introduces a paradigm of intelligent territorial co-evolution, where the tourist experience, environmental management, and decision-making are articulated in real time through adaptive and predictive systems.

The viability of the CGDG-4.0 methodology is demonstrated through its quasi-experimental validation in the contexts of Moa and Baracoa, yielding statistically significant results ($t = 9.87$; $p < 0.001$) in favor of its implementation. Its modular, scalable, and adaptable design allows for its progressive application in different geotourism contexts, even with varying levels of technological infrastructure. Furthermore, its participatory governance approach facilitates the incorporation of local stakeholders, ensuring operational sustainability, social acceptance, and institutional feasibility.

References

- Borrás, F. (2019). *Design management: fundamentals and applications*. UOC Publishing House.
- Brilha, J. (2016). Inventory and quantitative assessment of geosites and geodiversity sites: A review. *Geoheritage*, 8(2), 119-134.
- Buhalis, D. (2020). Technology in tourism—from information communication technologies to eTourism and smart tourism towards ambient intelligence tourism: A perspective article. *Tourism Review*, 75(1), 267-272.
- Buhalis, D. y Amaranggana, A. (2015). Smart tourism destinations enhancing tourism experience. En *Information and Communication Technologies in Tourism 2015*(pp. 377-389). Springer.

- Camacho Pereira, C. (2025). Repercussions of the application of artificial intelligence in the tourism activity of people with disabilities: Regulatory advances. PASOS. *Journal of Tourism and Cultural Heritage*, 23(3).
- Collado, C. & Baptista Lucio, P. (2014). *Research Methodology* (6ta ed.). McGraw-Hill.
- Davenport, T. H. & Ronanki, R. (2018). Artificial intelligence for the real world. *Harvard Business Review*, 96(1), 108-116.
- Dowling, R. K. (2011). Geotourism's global growth. *Geoheritage*, 3(1), 1-13.
- Fernández, J. and López, R. (2020). Territorial management and tourism sustainability. *Tourism and Society Magazine*, 26, 123-140.
- García, A. and Pérez, M. (2021). Sustainable tourism and local development in Cuba. *Journal of Social Development Studies*, 9(2), 45-60.
- Gretzel, U., Sigala, M., Xiang, Z. & Koo, C. (2015). Smart tourism: Foundations and developments. *Electronic Markets*, 25(3), 179-188.
- Kress, G., & Selander, S. (2012). Multimodal design, learning and cultures of recognition. *The internet and higher education*, 15(4), 265-268. <https://doi.org/10.1016/j.iheduc.2011.12.003>
- McKeever, P., Zouros, N., & Patzak, M. (2010). The UNESCO Global Network of National Geoparks. *The George Wright Forum*, 27(1), 14-18.
- Mozota, B. B. (2003). *Design management: Using design to build brand value and corporate innovation*. Allworth Press.
- Sigala, M. (2018). New technologies in tourism: From multi-disciplinary to anti-disciplinary advances and trajectories. *Tourism management perspectives*, 25, 151-155. <https://doi.org/10.1016/j.tmp.2017.12.003>
- Siswa, T. A. Y. (2020). The effectiveness of artificial intelligence on education: learning during the pandemic and in the future. *International Journal of Engineering and Computer Science*, 3(1), 24-30. <https://doi.org/10.31295/ijecs.v3n1.195>
- Toselli, C. (2019). Tourism, cultural heritage and local development: evaluation of the tourism potential of rural villages in the province of Entre Ríos, Argentina. PASOS. *Journal of Tourism and Cultural Heritage*, 17(2), 343-361.
- UNESCO. (2021). *UNESCO Global Geoparks*. <https://www.unesco.org/en/igpp/geoparks>
- Xiang, Z. & Fesenmaier, D. R. (2017). Big data analytics, tourism design and smart tourism. *Journal of Travel Research*, 56(3), 299-307.
- Zhang, C., & Lu, Y. (2021). Study on artificial intelligence: The state of the art and future prospects. *Journal of Industrial Information Integration*, 23, 100224. <https://doi.org/10.1016/j.jii.2021.100224>
- Zouros, N. (2004). The European Geoparks Network. *Episodes*, 27(3), 165-171.