

Digital Platforms as Institutionally Mediated Operability Layers for Tourism Sustainability: A Triple-Articulation Framework Linking Labour Formalisation, Environmental Certification, and Visitor Decision-Making in the Colombian Caribbean

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Abstract

Coastal tourism in the Colombian Caribbean operates under a structural paradox. It is among the principal engines of territorial economic growth — Cartagena registered 5.5 million visitors in 2025 (Corpoturismo, 2025) — while simultaneously deepening labour precarity and environmental degradation. Sectoral informality approaches 56% across the general tourism industry (ANATO, 2026; DANE, 2023), between 55% and 60% of macroplastics on Colombian Caribbean beaches are directly attributed to tourism activity (Pimienta-Serrano & Pacheco-Bustos, 2022), and a qualitative synthesis of tourism impacts in Colombia between 2008 and 2022 concludes that 72% were net negative (Grisales, 2022). The extant literature on sustainable tourism, digital tourism platforms, and visitor-behaviour interventions tends to address labour formalisation, environmental certification, and consumption-behaviour modification as separate problems, without an integrative framework that couples the three dimensions at the operative point of decision.

This article develops and evaluates a conceptual and technical framework for Nativapp, a meso-level digital platform for sustainable coastal tourism that integrates four coupled functionalities: (1) labour-competency certification mediated by Colombia's National Learning Service (SENA) and its SOFIA Plus platform; (2) a curated establishment listing gated on verifiable environmental certification (Colombian Environmental Seal, GSTC, ICONTEC, ISO 14001); (3) geolocated waste-management infrastructure with computer-vision verification at designated disposal points; and (4) a gamified incentive system explicitly calibrated against the behavioural-reversal risks documented in the Design for Sustainable Behaviour literature. The methodology combines exploratory qualitative field research with four purposively selected informants, systematic benchmarking of five comparable national and international solutions, structured evaluation matrices of impact, feasibility, scalability, and adoption ease, and the analytical application of the Design for Sustainable Behaviour typology (Lilley, 2009; Lockton, Harrison, & Stanton, 2010).

The article advances three original theoretical contributions. First, it proposes the construct of institutionally mediated operability (IMO) as a structural gap distinct from institutional absence: in

emerging-economy contexts with comparatively mature tourism regulatory frameworks — as in Colombia, endowed with Law 2068 of 2020, the Colombian Environmental Seal, and a free public training architecture — the principal barrier to sectoral sustainability is not the non-existence of institutional infrastructure but its invisibility at the visitor's point of decision. Second, it develops a triple-articulation framework coupling labour formalisation, environmental certification, and consumer-behaviour modification within a single digital service layer. Third, it identifies the notion of an interinstitutional articulation threshold as a necessary viability condition for sustainable-tourism digital platforms in emerging destinations. The findings carry implications for Colombian tourism policy, platform design in Global South destinations, and tourism-sustainability governance beyond voluntary self-certification schemes.

1. Introduction

The tourism industry is simultaneously one of the world's most expansive economic sectors and one of the most contradictorily positioned with respect to sustainability goals. In 2024 tourism contributed approximately 10% of global GDP and sustained 357 million jobs worldwide (WTTC, 2024). Colombia, following a notable post-pandemic recovery, registered 6.7 million foreign visitors in 2024 (MinCIT, 2025), with sustained increases in Caribbean coastal destinations, principally Cartagena, Santa Marta, and Riohacha. Sectoral projections remain consistently expansive, underwritten by state investment exceeding 1.2 trillion Colombian pesos in the country's latest comprehensive tourism policy (MinCIT, 2025).

This expansion nonetheless occurs under structural conditions that the sectoral literature itself increasingly characterises as contradictory. On the labour dimension, the Colombian tourism sector operates with informality rates substantively above the national average: roughly one in two Colombians earns income below the minimum wage (DANE, 2023), and the concentration of informality among guides, transport operators, and informal lodging in the Caribbean is particularly acute (Sánchez-Jiménez, 2016; Roca Sarmiento, 2025). On the environmental dimension, the sector contributes approximately 8% of global emissions (UNWTO, 2023); in Colombia, tourism activity is associated with an estimated annual generation of 24 million tonnes of solid waste (Ministerio de Ambiente y Desarrollo Sostenible, 2022), and between 55% and 60% of macroplastics detected on Colombian Caribbean beaches are directly attributed to tourism and recreational activity (Pimienta-Serrano & Pacheco-Bustos, 2022). Grisales's (2022) qualitative analysis — drawing on Pontificia Universidad Javeriana data — concludes that 72% of tourism's impacts in Colombia between 2008 and 2022 were negative in social, environmental, or economic-distributive terms.

Against this structural backdrop, Sustainable Development Goal 8, in its target 8.9, explicitly demands the design and implementation of "policies to promote sustainable tourism that creates jobs and promotes local culture and products" (United Nations, 2015). Operationalising this target requires a coupling that most current sectoral interventions do not perform: simultaneously linking the formalisation of tourism employment with the reduction of environmental impact, and linking both to the everyday decisions of millions of visitors. The field research conducted for this study — four semi-structured interviews with sustainable-tourism actors in Colombia, including the Caribbean region — consistently documents this decoupling: free labour certifications exist (SENA offers a broad, free catalogue of virtual courses and technical programmes in sustainable tourism through its SOFIA Plus platform; SENA, 2023), recognised environmental seals exist (Colombian Environmental Seal, GSTC, ICONTEC), and regulations exist (Law 2068 of 2020; Decree 1836 of 2021) — yet none of these elements is integrated into a common operative layer visible to the visitor at the moment of consumption decision.

This gap between regulatory-institutional abundance and its operative invisibility constitutes the central design problem motivating the present research. We argue that the principal barrier to tourism sustainability in the Colombian context is not the absence of institutional infrastructure but its operative invisibility at the point of decision confronting both the visitor and the service provider. This characterisation carries non-trivial design implications: if the barrier were institutional absence, the appropriate response would be state investment in new infrastructure; if the barrier is operative

invisibility, the appropriate response is a digital articulation layer that renders already-available infrastructure existent in practice and connects it to real-time consumption decisions.

The literature on digital platforms applied to tourism offers a promising but, to the best of our review, fragmented pathway. Smart Tourism Destination (STD) solutions (SEGITTUR, 2023) have demonstrated the value of tourism data integration for destination governance, but have been developed principally in European contexts with mature institutional infrastructure, and orient more toward destination planning than toward individual visitor behaviour modification. Gamified recycling platforms (Venturi, Zulauf, Cuel, & Wagner, 2025; Gibovic & Bikfalvi, 2021) have documented significant behavioural effects but typically operate in consolidated urban contexts rather than coastal tourism systems. Tourism environmental-certification schemes (Blue Flag, Green Key) operate at the establishment level without real-time visitor-facing visibility systems. No solution identified in our review simultaneously articulates labour formalisation through public certification, a listing of establishments with verifiable environmental seals, geolocated waste management with automated verification, and a gamified incentive system explicitly calibrated against documented behavioural-reversal risk.

This article develops and argues for Nativapp — a meso-level digital platform for sustainable coastal tourism — as the most viable design response to the identified problem. The platform targets the coastal zones of the Colombian Caribbean (Cartagena, Santa Marta, Riohacha) and is explicitly positioned as an institutional-operability layer, not as a new certifying institution nor as a substitute for state infrastructure investment. The article further develops an original theoretical contribution — the construct of institutionally mediated operability — as a contribution to the literature on digital platforms for sustainability in emerging economies.

The remainder of the article proceeds as follows. Section 2 reviews the pertinent literature on sustainable tourism, digital platforms in the sector, labour formalisation, environmental certification, design for sustainable behaviour, and institutional-voids theory. Section 3 describes the design-oriented qualitative methodology, including an explicit positionality and limitations statement. Section 4 presents Nativapp's technical architecture and behavioural grounding. Section 5 evaluates the solution through structured matrices. Section 6 develops the theoretical implications and proposes the institutionally mediated operability and triple-articulation frameworks, together with critical extensions addressing the digital divide and greenwashing governance. Section 7 concludes with contributions, limitations, and future directions.

2. Literature Review

2.1 Sustainable Tourism: Conceptual Framework and the Definition–Operation Gap

The World Tourism Organization defines sustainable tourism as "tourism that takes full account of its current and future economic, social and environmental impacts, addressing the needs of visitors, the industry, the environment and host communities" (UNWTO, 2023). This definition — operationally useful but analytically broad — has been subject to systematic critique in the literature for its prescriptive weakness. Higgins-Desbiolles (2018) argues that most operationalisations of the concept privilege the sustainability of tourism (ensuring the sector can continue to grow) over sustainability

through tourism (ensuring the sector effectively contributes to social welfare and environmental conservation goals). Hall (2019) extends this critique by documenting a persistent asymmetry between sustainable-tourism rhetoric and actual performance indicators: rising visitor rates in certified destinations, absolute increases in per-traveller emissions despite unit-efficiency improvements, and the persistence of tourism-driven gentrification patterns in destinations with explicit sustainability policies.

This definition–operation gap is particularly acute in Global South destinations. Burgos Doria and Mertens's (2017) review of community-based tourism in Colombia documents that successful tourism-sustainability projects tend to be those in which governance remains anchored in the local community, whereas externally initiated projects — even those formally aligned with international seals — exhibit recurrent patterns of value capture by intermediaries. The Association of Caribbean States (ACS-AEC, 2015) reaches a convergent conclusion in its regional analysis of Caribbean community tourism: substantive tourism sustainability requires effective value-retention mechanisms within the host community, not merely environmental certifications applied to physical infrastructure.

The analytical framework relevant to this article accordingly distinguishes three operationally coupled dimensions: the labour dimension (formalisation, income, value retention), the environmental dimension (waste management, resource consumption, impact on coastal ecosystems), and the governance dimension (certification visibility, articulation between public institutions and private operators, visitor agency). The article's central argument is that these three dimensions have not been operationally articulated within a single visitor-facing service layer — a gap that is simultaneously theoretical and practical.

2.2 Digital Platforms in the Tourism Sector: From Booking to Articulation

Digital platforms have radically transformed the tourism economy over the past two decades. The Tourism Information Systems literature (Buhalis & Law, 2008; Sigala, 2018) documents three successive waves of digitalisation: a first wave of booking systems (GDS, OTAs), a second wave of collaborative-economy platforms (Airbnb, Uber), and an emerging third wave of Smart Tourism Destination (STD) platforms and open-data-based management systems (Buhalis, 2020; Gretzel, Sigala, Xiang, & Koo, 2015).

The Smart Tourism Destination concept, formalised by SEGITTUR (2023) in its technology-solutions catalogue and conceptually developed by Boes, Buhalis, and Inversini (2016), defines an integrated framework in which technological innovation, sustainability, accessibility, and collaborative governance couple at the destination level. The STD model has been implemented with positive results in Spanish and European destinations (Romero Dexeus, García Moreno, & Fernández Alcantud, 2025), where institutional and digital infrastructure maturity permits comparatively fluid integration between public and private actors. Its adaptability to Global South destinations, however, has been documented as problematic: Latin American pilots consistently encounter interinstitutional articulation barriers, rural connectivity gaps, and dependence on political cycles to sustain governance agreements (Cellina, Castri, Simao, & Granato, 2020; SEGITTUR, 2023).

A second, complementary literature stream addresses platforms centred on visitor behaviour rather than destination governance. Tourism "matching" platforms — from Airbnb Experiences to TripAdvisor — operate principally as discovery and reputation mechanisms, but typically do not incorporate

substantive labour- or environmental-sustainability criteria into their recommendation algorithms (Sigala, 2018). The recent "regenerative tourism" application phenomenon (Pollock, 2019) has attempted to close this gap, but most reported implementations operate in high-income markets with environmentally literate consumers, and the question of their transferability to destinations such as Cartagena or Santa Marta — where the visitor profile is heterogeneous and average environmental sensitivity is comparatively lower — remains open.

A third stream, particularly relevant to Nativapp, examines mobile applications designed to modify visitor behaviour through real-time feedback and gamified mechanisms. Andersson (2020) documents an approach for calculating individual carbon footprints from transaction data, demonstrating technical viability for personalised environmental feedback. However, this class of solution has been evaluated principally in European urban contexts rather than in coastal tourism systems characterised by high user turnover, highly heterogeneous visitor profiles, and low local institutional-infrastructure density.

Our systematic review in Scopus and Web of Science, combining the terms "tourism platform," "sustainable tourism," "labor formalization," and "Latin America" or "emerging economies," returns fewer than a dozen relevant empirical studies, none of which simultaneously articulates the three dimensions identified in Section 2.1. This article addresses that gap directly.

2.3 Labour Formalisation in Services and Tourism Informality

The Latin American labour-informality literature, synthesised by the ILO (2024), distinguishes two explanatory traditions. The structuralist tradition attributes informality to the structural incapacity of middle-income economies to generate sufficient formal employment; the institutionalist tradition attributes it to formalisation costs (tax-related, regulatory-compliance-related) that exceed the perceived benefits to workers and employers (Maloney, 2004). Sánchez-Jiménez (2016), in one of the few empirical evaluations focused specifically on the Colombian tourism sector, documents that tourism informality combines elements of both traditions: there are structural deficits in formal-employment demand, but also sector-specific institutional disincentives — particularly the difficulty independent guides and small operators face in accessing certification processes recognised by the National Tourism Registry (RNT) and in sustaining associated payroll-tax compliance.

A parallel gender-studies literature documents that tourism disproportionately employs women while simultaneously operating with particularly high informality rates for this population (UN Women, 2023; UNWTO, 2022). In the Colombian Caribbean, women are the principal economic agents of informal tourism services (informal food vending, handicrafts, low-cost guiding), yet their access to formal certification processes remains structurally limited. UN Women (2023) argues that any tourism-sustainability policy that does not explicitly incorporate a gender dimension into its certification mechanisms reproduces, rather than mitigates, the existing asymmetry.

Three institutional mechanisms in principle enable tourism labour formalisation in Colombia: (1) the National Learning Service (SENA), which offers a broad catalogue of free virtual courses in areas connected to sustainable tourism (SENA, 2023) alongside its SOFIA Plus platform; (2) ICONTEC, which certifies tourism enterprises and destinations against environmental, social, economic, and management sustainability standards (ICONTEC, 2025); and (3) the RNT of the Ministry of Commerce, Industry and Tourism, the mandatory registry for formal sector providers. These mechanisms coexist

but, as the field research conducted for this study consistently documents, are not operationally articulated within a common layer visible either to the informal workers who could benefit from them or to the visitors who might discriminate in their favour when making consumption decisions.

2.4 Design for Sustainable Behaviour and Gamification in Tourism Consumption

The Design for Sustainable Behaviour (DfSB) tradition recognises that technological solutions to environmental problems are insufficient without a corresponding change in user behaviour (Lilley, 2009; Lockton et al., 2010). Lilley's (2009) analytical framework distinguishes three principal strategies: eco-feedback (providing users with information about the environmental consequences of their actions), behaviour steering (structuring the decision space so the sustainable option is the most visible and convenient), and persuasive design (more coercive strategies that seek to bind the sustainable decision to the very execution of the product or service). DfSB strategies are not mutually exclusive; the most effective implementations tend to combine elements of all three with careful calibration of user autonomy (Lockton et al., 2010).

Gamification — defined by Deterding, Dixon, Khaled, and Nacke (2011) as "the use of game design elements in non-game contexts" — has emerged as a significant DfSB tool for circular-economy and sustainable-consumption applications (Lim, Das, Sharma, Verma, & Kumra, 2025). Venturi et al. (2025) provide empirical validation specifically for recycling behaviour: a mixed-methods study combining twenty-six semi-structured interviews with a controlled application-usage experiment found that gamified applications generated significantly greater long-term engagement in source separation than purely informational interventions. Gibovic and Bikfalvi's (2021) RECICLOS study, involving over 1,000 households across six weeks in Catalonia, documented that gamified incentive structures generated more than 70% of the behavioural effect attributable to the incentive scheme, against less than 30% attributable to direct discount distribution.

A persistent and well-documented risk in these schemes is behavioural reversal following reward interruption, consistent with the classic motivational-crowding-out dynamic (Frey & Jegen, 2001; Deci & Ryan, 2000). Lim et al. (2025) identify this risk as a priority design challenge for sustainable gamification: where the desired behaviour is instrumentally tied to extrinsic reward, its persistence requires continuity of the stimulus. Mitigation strategies proposed in the literature include emphasis on individualised impact feedback — visualising the specific consequences of one's own action rather than the discount obtained — and community social recognition (Thøgersen & Ölander, 2003).

For the tourism context specifically, a more targeted literature documents that DfSB interventions aimed at visitors face differential conditions relative to interventions aimed at local residents: visitors have brief exposure windows (typically days), motivation profiles dominated by rest or pleasure rather than civic considerations, and scarce local reputational incentives (Hall, 2019). These conditions imply that tourism DfSB architectures cannot rely exclusively on long-term habituation and must generate actionable behavioural signals within windows of hours or days.

2.5 Environmental Tourism Certification and Operative Visibility to the Visitor

Environmental tourism certification — from Blue Flag and Green Key to the Global Sustainable Tourism Council (GSTC) criteria — operates under a common architecture: certifying bodies establish

verifiable criteria, tourism establishments implement them voluntarily, and issued certificates function as market signals to visitors (Font, 2002; Font & Lynes, 2018). In Colombia, this architecture materialises in the Colombian Environmental Seal (Resolution 1555 of 2005), ICONTEC's sustainable-tourism certifications, and the local application of GSTC and ISO 14001 standards.

The empirical critique of this architecture, synthesised by Font (2002) and updated by Font and Lynes (2018), identifies three recurrent limitations. First, information asymmetry toward the visitor: certificates exist on establishment walls and in institutional databases but rarely reach the visitor at the moment of consumption decision, particularly in mass tourism markets where the decision of where to eat or stay is made within minutes on the basis of uncurated aggregators. Second, greenwashing risk: the proliferation of unverified or self-assigned seals degrades the signal value of rigorous certification. Third, territorial disconnection: international private seals operate independently of national public labour-training and certification systems, generating a fragmentation between tourism sustainability's environmental and social dimensions.

This fragmentation is precisely the gap Nativapp sets out to close. The platform does not introduce a new certification scheme — an option that would reproduce the problem Font (2002) diagnoses — but rather an operative visibility layer that articulates existing certificates (Colombian Environmental Seal, GSTC, ICONTEC, ISO 14001) with public labour certifications (SENA, SOFIA Plus) within a single visitor-facing decision interface.

2.6 Institutional Voids and Mediated Operability: Positioning a New Construct

A literature largely disconnected from tourism scholarship offers an unexpectedly precise vocabulary for the gap this article seeks to theorise: the international-business literature on institutional voids in emerging markets. Khanna and Palepu (1997) define institutional voids as the absence or underdevelopment of market-supporting institutions — intermediaries capable of analysing market information, facilitating transactions, and signalling credibility — that firms in advanced economies take for granted. Subsequent scholarship has extended the construct considerably (Boisot, McCarthy, & Puffer, 2010; Dorobantu, Kaul, & Zelner, 2017), documenting how institutional voids shape firm strategy across contexts ranging from finance to labour markets to environmental governance.

The institutional-voids construct, however, does not directly map onto the empirical pattern this study's field research documents. Colombia's tourism-sustainability institutional architecture is not void: the RNT is a functioning mandatory registry; SENA is an operating public training system with substantial course capacity; ICONTEC and the Colombian Environmental Seal are established, internationally recognised certification bodies; the regulatory instruments (Law 2068 of 2020, Decree 1836 of 2021) exist and are enforced with reasonable consistency. What the field data document instead is an institutional architecture that is nominally mature but operationally unreachable at the specific moment — the visitor's or the informal worker's point of decision — where its substantive effects would be realised. This is a distinct empirical pattern from the classic institutional void, and the distinction carries first-order design implications: void-filling interventions (Mair & Marti, 2009; Mair, Marti, & Ventresca, 2012) typically call for the intermediary itself to be built or substituted, whereas the pattern identified here calls for connecting infrastructure that already exists to a decision point where it currently does not reach.

We term this second pattern institutionally mediated operability (IMO), developed formally in Section 6.1: a structural condition in which pre-existing institutional infrastructure requires a digital articulation layer to produce the substantive effects for which it was created. IMO is conceptually adjacent to, but analytically distinct from, three bodies of literature. Relative to institutional-voids theory (Khanna & Palepu, 1997; Mair & Marti, 2009), IMO addresses contexts of institutional maturity rather than institutional absence, and locates the intervention gap in operative connectivity rather than in institutional construction. Relative to the sociotechnical multi-level perspective on sustainability transitions (Geels, 2002), which theorises how niche innovations diffuse against entrenched regime-level structures, IMO is a narrower, meso-level construct concerned specifically with the visibility and actionability of already-legitimated regime-level institutions at the point of individual decision, rather than with regime transformation as such. Relative to the Smart Tourism Destination ecosystems literature (Boes et al., 2016), which theorises destination-level data and governance integration, IMO operates principally at the level of the individual decision transaction rather than at the level of aggregate destination planning. Table 8 in Section 6.4 develops this positioning comparatively once the full IMO construct and its triple-articulation counterpart have been presented.

3. Methodology

3.1 Research Design

This study employs a design-oriented qualitative methodology combining primary field research, systematic benchmarking, structured ideation, and matrix-based evaluation. The epistemological stance is constructivist-pragmatic: the generative design process is anchored in problem-centred, user-informed methodologies consonant with IDEO's formulation of Design Thinking (Brown, 2009) and with Ceschin and Gaziulusoy's (2016) Design for Sustainability framework.

The methodology specifically follows the Listen–Create–Deliver cycle proposed by IDEO.org for design oriented toward Global South populations, complemented by application of the Design for Sustainable Behaviour framework (Lilley, 2009; Lockton et al., 2010) as the primary evaluative lens for the resulting solution. The research was structured into six sequential phases (Table 1).

Table 1. Research Phases and Methods

Phase	Description	Methods	Output
1 — Contextual immersion	Problem delimitation and stakeholder mapping of the Colombian coastal tourism sector	Documentary analysis; regulatory review (Law 2068; Decree 1836); literature review	Stakeholder map; problem framing; identification of SDG 8 target 8.9
2 — Primary data collection	Field research with Colombian coastal tourism actors	Semi-structured interviews (n=4); context mapping	Synthetic user persona; constraint typology
3 — Systematic benchmarking	Comparative analysis of national and international solutions	Structured benchmarking protocol; review of five existing solutions	Comparative matrix; synthesis of transferable lessons
4 — Concept generation	Design ideation informed by primary and secondary evidence	Structured brainstorming workshop; affinity-based clustering	Three shortlisted solution concepts

Phase	Description	Methods	Output
5 — Concept evaluation	Comparative evaluation against structured criteria	Impact–cost, complexity–scalability, feasibility–adoption matrices; weighted averaging	Concept selected for development
6 — Solution development	Functional, technical, and business-model definition	Architecture design; DfSB framework application; implications analysis	Nativapp platform with four coupled functionalities

3.2 Primary Research: Field Study

Primary research was conducted between February and April 2026. Four semi-structured interviews were carried out with Colombian sustainable-tourism actors, purposively selected to cover complementary supply-side, design-side, and demand-side perspectives: two managers of sustainability-oriented tourism agencies — a regenerative community-tourism agency affiliated with a conservation foundation in La Guajira, and a travel and training agency that incorporates sustainability as a cross-cutting practice (n=2); one designer and proponent of a sustainable tourism infrastructure project, with experience formulating proposals before public entities (n=1); and one specialised consumer and frequent observer of nature and bird-watching tourism in rural lodgings (ecolodges) across several regions of the country, including the Sierra Nevada (n=1). This deliberately heterogeneous composition prioritises the diversity of perspectives — supply, design, and demand — over statistical representativeness, consistent with the generative purpose of the design phase. Interview protocols followed established methodological guidance (Bryman, 2016), and thematic analysis proceeded iteratively through open and axial coding.

Context-mapping exercises, following the generative methodology of Sanders and Stappers (2012), were used to elicit tacit knowledge about the barriers to and enablers of operative tourism sustainability. Data were analysed until thematic saturation was reached at the level of the emergent categories examined here (Morse, 1995).

The synthetic user persona developed as an analytical device — Los Cocos Travel, a mid-sized agency with a presence in Caribbean coastal destinations — synthesises the findings consistent across the four informants: prioritisation of operational efficiency and volume over sustainability considerations; dependence on a broad supplier network with heterogeneous degrees of formality; environmental impacts that are known but not systematically managed; and incipient — not prioritised — awareness of the regulatory and reputational risks associated with informality and deficient waste management. The persona is not used as a representative individual but as an analytical communication device to synthesise the most consistently identified set of constraints.

Five structural findings emerged consistently across the interviews:

- Regulatory pressure on the sector is increasing faster than the operative solutions available to small and medium providers.
- Existing formalisation processes — SENA, RNT, ICONTEC — are perceived as costly in time and complexity, not in money, which particularly excludes independent guides and small operators.

- Establishments' environmental certifications are rarely communicated effectively to the visitor at the moment of decision.
- Waste management in coastal tourism zones is structurally constrained by the low density of correctly labelled disposal points and by the absence of geolocated information about their location.
- Articulation among national institutions (SENA, ICONTEC, MinCIT), municipal institutions (mayoral offices, waste collection), and private actors (operators, agencies, establishments) is perceived as fragmented, slowed by political cycles, and dependent on non-sustainable one-off initiatives.

3.3 Systematic Benchmarking

Five existing sustainable-tourism and circular-economy solutions applicable to the sector were examined, selected to represent the design space spanning both infrastructure-certification-centred and digital-system-centred solutions. Table 2 presents the comparative analysis.

Table 2. Benchmarking of Applicable Tourism and Circular-Economy Solutions

Solution	Origin / Year	Problem Addressed	Differentiating Features	Strategy Type	Applicability as Transferable Lesson
Blue Flag	Denmark, 1985	Environmental quality and safety of tourism beaches	Voluntary certification; water-quality, safety, and environmental-education criteria; international recognition	Infrastructure-certification-centred	High: demonstrates the value of verifiable criteria; low direct transferability given the absence of a visitor-facing digital layer
Green Key	International, 1994	Environmental efficiency of hotels and tourism establishments	Reduction of water, energy, and waste consumption; periodic audits; staff training	Establishment-operation-centred	High: the principal lesson is that sustainable infrastructure is necessary but not sufficient; continuous improvement requires measurement and training
Payment for Environmental Services	Costa Rica, 1996	Ecosystem conservation through monetary incentives	Economic recognition of environmental-service value; direct transfers	Economic-incentive-centred	Moderate: validates the monetary-incentive principle; limited transferability given dependence on sustained public financing

Solution	Origin / Year	Problem Addressed	Differentiating Features	Strategy Type	Applicability as Transferable Lesson
Too Good To Go	Denmark, 2015	Food waste in tourism and hospitality establishments	Digital platform connecting surplus food with consumers at reduced prices	Digital-market-system-centred	High: technology can convert operational losses into economic opportunities; illustrates the principle of a digital layer over existing infrastructure
Smart Tourism Destinations (STD)	Spain (SEGITTUR), 2015	Integrated destination governance through data and platforms	Governance framework integrating innovation, sustainability, accessibility, and open data	System-and-governance-centred	High: offers a framework for actor articulation; the principal lesson is that public-private coordination is a viability condition; partial transferability given dependence on institutional maturity

Key benchmarking finding: infrastructure-certification-centred solutions (Blue Flag, Green Key) offer greater verifiability but face visitor-facing information asymmetries and disconnection from public labour systems. Digital-platform-centred solutions (Too Good To Go, STD) offer greater operative articulation but require supporting institutional ecosystems. Economic-incentive schemes (PES) demonstrate the underlying principle but depend on continued public financing. Nativapp positions itself as a systemic solution combining the verifiability of existing certifications with the articulating capacity of digital platforms and the calibrated incentive logic of gamified schemes.

3.4 Analytical Framework: Design for Sustainable Behaviour

The primary analytical framework for solution evaluation is the Design for Sustainable Behaviour formulation of Lilley (2009) and Lockton et al. (2010), operationalised into two principles and three mechanisms:

- Principle 1 (facilitate the desired behaviour): the sustainable option must be the most visible, accessible, and convenient within the user's decision space.
- Principle 2 (motivate the desired behaviour): sustainable behaviour must be coupled to meaningful feedback signals and, where appropriate, calibrated rewards.

These principles are operationalised through three mechanisms integrated into Nativapp's architecture: eco-feedback at the point of action (visualisation of the individual impact of the sustainable action), behaviour steering (exclusive recommendation of certified establishments; geolocated routing to correct disposal points), and a gamified incentive architecture calibrated against the behavioural-reversal risk identified by Frey and Jegen (2001) and by Lim et al. (2025).

A secondary evaluation is conducted against four technical-feasibility criteria: (1) technological maturity of the component systems; (2) compatibility with the visitor's existing digital infrastructure

(connected smartphones); (3) independence from proprietary or costly hardware; and (4) interoperability with Colombian public institutional systems (SENA, SOFIA Plus, RNT, municipal waste-management systems).

3.5 Methodological Limitations and Positionality Statement

This section makes explicit the epistemological status of the primary research underlying Sections 4 and 5, and the positionality of the authors relative to that research, following the transparency standard recommended for qualitative design research submitted to high-impact venues (Lincoln & Guba, 1985; Bryman, 2016).

The primary field research reported in Section 3.2 comprises four interview sessions with four informants, purposively selected for the diversity of their vantage points — agency supply, infrastructure design, and specialised demand — rather than for statistical representativeness. This sample size is appropriate to the generative, hypothesis-forming phase of a Design Thinking process and does not reach thematic saturation in the formal methodological sense of the term (Morse, 1995); the five structural findings reported in Section 3.2 should accordingly be read as design hypotheses substantiated by convergent, purposively sampled qualitative evidence, not as statistically generalisable claims about the population of Colombian Caribbean tourism operators, guides, or visitors. This qualification governs the interpretation of every downstream evaluative claim in Sections 4 through 6.

Regarding authorial positionality: the primary field research, the systematic benchmarking, and the initial technical and evaluative formulation of Nativapp originated as collaborative work within a five-member course team — Ana Sophia Angel, Paula Torres, Manuela Ramírez, Camilo Rivera, and Julián Andrés Ordoñez Guevara — during the 2026-10 term of the course "Enfoques de Diseño para la Sostenibilidad" at Universidad de los Andes. The present manuscript's theoretical deepening — the institutionally mediated operability construct, its positioning against institutional-voids theory, the triple-articulation framework, and the doctoral-standard literature integration — together with the manuscript's final consolidation, is the joint contribution of Julián Andrés Ordoñez Guevara, who participated directly in the original field research and design process, and Joseph Javier Sánchez Acuña, who joined at the manuscript-consolidation stage and did not participate in the original interviews or benchmarking. This division of labour is disclosed in full in the CRediT statement (Section 8) and is material to how the primary claims in Sections 4 and 5 should be weighted: they rest on first-hand fieldwork conducted by one of the two authors and three non-author collaborators, not on independent verification by both authors.

Two further limitations of the primary evidence base warrant explicit statement here rather than deferral to Section 7. First, the quantitative impact projections presented in Section 5.1 are scenario-based extrapolations built on explicit, stated assumptions and calibrated against comparable external studies; they are illustrative of plausible order of magnitude, not empirically measured outcomes, and no field pilot of the platform has been conducted. Second, the benchmarking exercise in Section 3.3, while systematic in protocol, draws on five purposively selected comparator solutions rather than an exhaustive market scan, and its transferability judgments are qualitative expert assessments rather than statistically validated comparisons. Both limitations are revisited, with their implications for the theoretical claims of Section 6, in Section 7.2.

4. Solution: The Nativapp Digital Platform — Architecture and Grounding

4.1 Systemic Positioning

Nativapp is positioned as a meso-level, articulation-oriented digital platform, deliberately differentiated from three adjacent but distinct intervention types. First, it is not a new certifying institution: the platform does not establish its own sustainability criteria but rather adopts and articulates existing seals and certifications (Colombian Environmental Seal, GSTC, ICONTEC, ISO 14001) and public labour-training systems (SENA, SOFIA Plus). Second, it is not a tourism booking platform competing with international aggregators: although it incorporates guide-booking functionality, its primary analytical unit is not the commercial transaction but the sustainable consumption decision. Third, it is not a macro-level destination-governance tool: unlike Spanish STDs, Nativapp operates at the level of the individual visitor and independent worker, not at the level of aggregate territorial planning.

The concept of a "meso-level digital platform" is defined here as a service layer operating between the micro level (individual tourist–guide or tourist–establishment dyads) and the macro level (redesign of the territorial tourism ecosystem), specifically creating shared digital infrastructure through which multiple categories of actors — tourists, certified guides, sustainable establishments, municipal authorities, certifying institutions — interact around a jointly articulated objective. This positioning extends Tukker's (2004) classic typology for Product-Service Systems by adding a systemic interinstitutional-articulation layer that earlier formulations did not anticipate in the tourism context.

The platform does not sell tourism experiences; it delivers articulation, operative visibility, and behavioural mobilisation as services to tourists, providers, and authorities. This positioning reflects a deliberate design logic justified by the primary research findings: given that certifications exist but are operationally invisible, and given that macro-systemic redesigns of coastal tourism lie beyond the resource horizon of individual actors or trade associations, a meso-level digital service layer represents the most tractable available intervention.

4.2 Technical Architecture

The platform comprises three integrated technical subsystems (Figure 1).

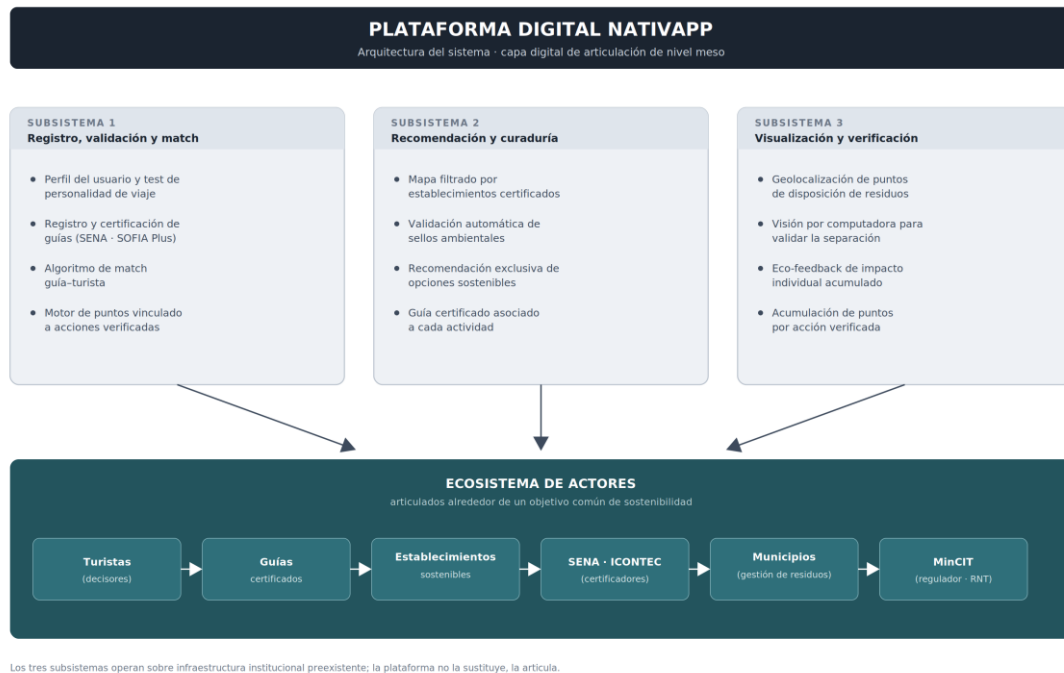


Figure 1. Architecture of the Nativapp Platform (schematic).

Subsystem 1 — Registration, Validation, and Matching Layer. Tourists register their preferences and complete a travel-personality assessment whose function is to algorithmically propose compatible guides based on interests and travel style. Tourism actors (independent guides and operators) register their profile and, crucially, are channelled toward free public certification processes through integration with SENA's SOFIA Plus platform. Certification validation is performed by querying the institutional database, which prevents credential self-assignment and mitigates the greenwashing risk identified in the literature (Font, 2002; OECD, 2025).

Subsystem 2 — Establishment Recommendation and Curation Layer. The interactive map recommends exclusively lodgings, restaurants, and activities holding at least one verifiable environmental certification: the Colombian Environmental Seal (Resolution 1555 of 2005), the Global Sustainable Tourism Council seal, ICONTEC tourism-sustainability certification, or ISO 14001. This exclusivity is a deliberate behaviour-steering decision: rather than presenting all available options with variable sustainability labels — an architecture the literature identifies as ineffective for shifting consumer decisions (Thøgersen & Ölander, 2003) — the platform removes uncertified options from the visible decision space entirely. Where a tourism activity can be guided by a certified actor registered on the platform, that guide is automatically recommended to the tourist, thereby articulating the labour dimension with the environmental dimension.

Subsystem 3 — Visualisation, Detection, and Verification Layer. The waste-management layer integrates three technologies. First, geolocation via the Google Maps API of the waste-separation points nearest the user, eliminating the informational friction the field research consistently identified as a barrier to correct disposal. Second, when the GPS system detects that the user is physically present at a designated disposal point, the application prompts a photo capture of the disposal action; a computer-vision model built on Deep Learning architectures (a technical reference analogous to the M Waste

system; Kunwar, 2023) analyses the image to verify correct separation. Third, the verified action is coupled to the incentive system described under Subsystem 1.

4.3 Gamified Incentive Architecture

The points system is designed in accordance with Design for Sustainable Behaviour principles and the empirical findings of Venturi et al. (2025) and Gibovic and Bikfalvi (2021), but with explicit calibration against the behavioural-reversal risk discussed in Section 2.4.

Rewarded actions and their nominal magnitudes are designed against three principles: (1) actions producing direct, verifiable environmental impact receive greater reward than merely declarative actions; (2) the redemption structure (one hundred points equal a 10% discount on a certified local guide booking) redirects the reward toward strengthening labour formalisation rather than toward additional consumption; and (3) visualisation of accumulated individual impact is prioritised over discount magnitude, consistent with Frey and Jegen's (2001) finding that exclusive reliance on extrinsic rewards erodes intrinsic motivation.

User Action	Points Awarded	Verification	Design Rationale
Booking a certified guide	3 points	Registered transaction	Low-friction action; low reward; signals preference
Use of a recommended sustainable service	5 points	Geolocated and transactional confirmation	Medium-friction action; medium reward
Verified correct disposal at designated bin	10 points	Computer vision + GPS	Highest cognitive and behavioural friction; maximum reward

Table 3. Points-System Structure and Design Rationale

4.4 Business Model and Actor Ecosystem

The platform operates through a mixed revenue model combining four sources: (1) commissions on bookings generated through the platform; (2) segmented premium subscriptions for tourism establishments seeking greater visibility or analytics tools; (3) curated in-app advertising, restricted by internal policy to enterprises aligned with sustainability criteria (eco-hotels, green transport, local products) and explicitly excluding categories that contradict the value proposition; and (4) optional individual subscriptions for tourists seeking additional benefits or an ad-free experience.

The actor ecosystem is structured around six differentiated categories: tourists (decision-makers and end users of the service), certified guides and providers (producers of the formalised tourism service), sustainable establishments (operators of complementary services), certifying institutions (SENA for labour certification; ICONTEC for environmental certification), municipal authorities (providers of waste-management infrastructure), and the Ministry of Commerce, Industry and Tourism (sectoral regulator and administrator of the RNT).

4.5 Grounding in Design for Sustainable Behaviour

Three behavioural mechanisms, grounded in the DfSB literature, justify Nativapp's specific design decisions:

Mechanism 1 — Concrete, individualised feedback (eco-feedback). Generic environmental messaging produces weaker behavioural effects than feedback specifically calibrated to the individual action (Lilley, 2009). The visualisation of accumulated impact on the points screen (Figure 2c) — "Liliana, you reached 100 points," articulated with concrete details such as "you used a certified restaurant" or "you recycled correctly" — constitutes an individualised, proximate behavioural stimulus superior to printed environmental labels and static wall-mounted certificates.

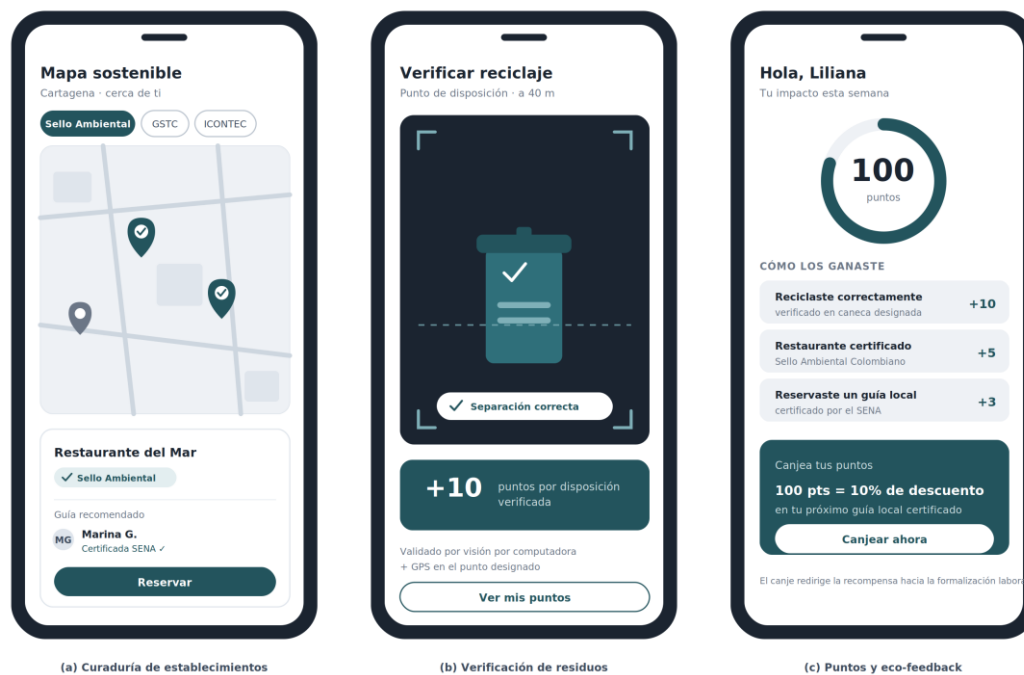


Figure 2. Mockups of Nativapp's principal screens: (a) curated certified-establishment discovery, (b) computer-vision waste-disposal verification, and (c) individualised points and eco-feedback.

Mechanism 2 — Variable reinforcement through gamified rewards. The behavioural-conditioning literature (Skinner, 1938) and its application to gamification design (Deterding et al., 2011) identify variable-ratio reinforcement schedules as the most effective for sustaining behavioural frequency. Nativapp's points system approximates this schedule by differentiating rewards according to the cognitive and behavioural friction of each action, while preserving user agency.

Mechanism 3 — Friction reduction through geolocation (behaviour steering). A consistent barrier to correct waste disposal in tourism zones is informational: visitors do not know where appropriate disposal infrastructure is located. The integrated map of collection points eliminates this friction by providing real-time calibrated GPS routing, converting motivated but uninformed intention into executable action.

The combination of these three mechanisms, articulated with Subsystem 2's exclusive-curation logic, constitutes an integrated behavioural architecture distinct from purely informational interventions (awareness campaigns) and purely coercive interventions (visitor regulation), both of which the DfSB literature applied to tourism documents as less effective (Hall, 2019; Lim et al., 2025).

5. Evaluation and Findings

5.1 Evaluation Matrix: Projected Impact

Nativapp's projected-impact evaluation was conducted through quantitative models built on explicit assumptions derived from official sources and from the primary research. As Section 3.5 states explicitly, these are scenario-based extrapolations, not measured outcomes. The central assumptions are: (a) an annual target-zone tourism volume of 5.5 million visitors, per Corpoturismo's (2025) report for Cartagena in 2025; (b) average solid-waste generation in tourism zones of 0.9 kg/tourist/day, above the national average of 0.75 kg/person/day (DANE, 2025) given intensive tourism consumption; (c) a sectoral informality rate of 56% in the general tourism industry, derived from ANATO (2026) and adjusted for the higher concentration of informality in guiding, transport, and lodging; and (d) expected platform adoption penetration of 2% in year 1, 8% in year 2, and 15% in year 3 of total tourism volume.

On these assumptions, the principal impact indicators are projected across three dimensions (Table 4).

Table 4. Projected Impact Indicators for Nativapp (3-Year Horizon)

Dimension	Indicator	Estimate	Calculation Basis
Environmental	Waste separated per year	~1,485 tonnes	412,500 adopting tourists × 0.9 kg/day × 4-day average stay
Environmental	Estimated reduction in beach macroplastics	~15% in actively covered zones	15% penetration × 60% tourism attribution × estimated behavioural-adherence rate
Social	Guides certified through SENA articulation	~3,000 guides	Supply-side adoption × expected SOFIA Plus certification-completion rate
Social	Female participation in the certified base	≥54%	Grounded in women's 54% representation in the coastal tourism workforce (UN Women, 2023)
Economic	Income increase for formalised guides	25–35%	Reduction of intermediation commissions that typically reach 30–40% of amount paid
Economic	Reduction in intermediation value leakage	Variable by trajectory	Function of the progressive substitution of intermediated channels

Key analytical finding: the projected indicators are consistent, in order of magnitude, with the impact reported by analogous implementations in the literature (Venturi et al., 2025; Gibovic & Bikfalvi, 2021), but remain subject to substantial uncertainty inherent to the design's conceptual stage and to the heterogeneity of the Colombian context. Empirical validation requires controlled piloting, addressed in Section 7.

5.2 Comparative Concept Evaluation

The structured ideation phase began with a brainstorming session that produced more than forty proposals, grouped by thematic affinity into five families — product, applications and platforms,

incentives and policy, education and community, and other — subsequently refined by removing repetition or conceptual overlap (Figure 3).



Figure 3. Brainstorming: affinity clustering of ideation-phase proposals and convergence toward the three shortlisted concepts.

Three solution concepts were shortlisted during ideation: (1) a geolocated tour-guide wristband; (2) a public-policy-mediated sustainable-tourism incentive system; and (3) a digital-platform-mediated local regenerative-tourism network. Comparative evaluation was conducted through three structured matrices (Impact–Cost, Complexity–Scalability, Feasibility–Adoption) (Figure 4) and a weighted-average calculation against explicit criteria (Table 5).

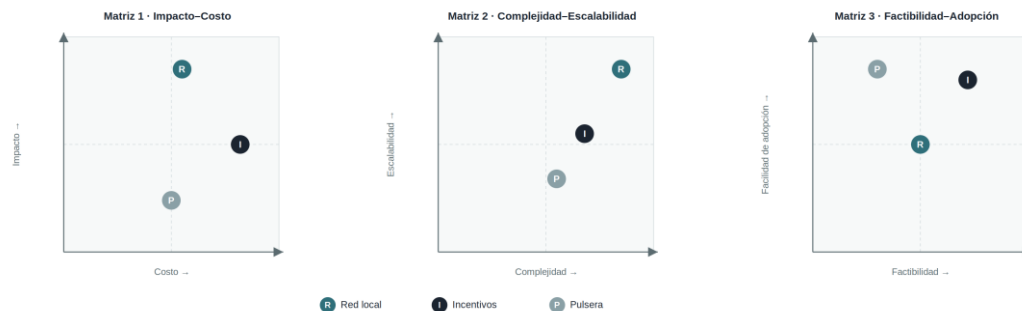


Figure 4. Concept evaluation matrices: qualitative positioning of the three concepts across the impact–cost, complexity–scalability, and feasibility–ease-of-adoption dimensions.

Table 5. Comparative Concept Evaluation: Weighted Averages

Concept	Impact (35%)	Feasibility (25%)	Scalability (25%)	Adoption (15%)	Final Score
Tour-guide wristband	2	2	2	5	2.45
Sustainable-tourism incentive system	4	4	4	5	4.15
Local regenerative-tourism network (Nativapp)	5	3	5	3	4.20

The local regenerative-tourism network concept, subsequently refined into Nativapp, was selected on the basis of its higher projected impact and superior scalability, notwithstanding greater implementation

complexity and reduced initial ease of adoption. These two weaknesses are deliberately addressed through the mitigation strategies discussed in Section 5.4.

5.3 Technical Feasibility Evaluation

Table 6 presents the technical-feasibility evaluation across four criteria.

Table 6. Nativapp Technical Feasibility Evaluation

Criterion	Assessment	Evidence Base	Risk Level
Technological maturity	All component technologies (React Native, Google Maps APIs, TensorFlow-based computer-vision models, gamification architectures) are mature, commercially implemented, and extensively documented	Kunwar, 2023; Deterding et al., 2011	Low
Compatibility with the user's digital infrastructure	The application runs on standard smartphones (iOS and Android); data consumption is optimisable through careful offline-functionality design; smartphone penetration among Cartagena visitors is estimated near 100%	HICA et al., 2022; DANE, 2023	Low
Independence from proprietary hardware	The application requires no specialised readers, wearable devices, or infrastructure-installed sensors; it operates entirely on the standard mobile ecosystem	Internal technical design	Low
Interoperability with public institutional systems	The architecture anticipates API integrations with SOFIA Plus (SENA), the Colombian Environmental Seal database, and, potentially, municipal waste-management systems; effective implementation requires institutional agreements	Sánchez-Jiménez, 2016; ANATO, 2026	Medium

5.4 Structural Limitations and Risk Analysis

Table 7 presents the structural limitations identified through the evaluation, together with their risk magnitude and mitigation feasibility.

Table 7. Structural Limitations and Risk Analysis

Limitation	Risk Magnitude	Mitigation Strategy	Mitigation Feasibility
Generational and digital-literacy gap (real adoption depends on unevenly distributed digital skills; particularly affects older adults and communities with limited ICT training)	Medium-high	Articulation with existing digital-literacy programmes (MinTIC, 2019; Colombia Aprende, 2023); simplified functionality; accessibility-oriented design	Moderate
Urban–rural connectivity gap (3.0×, among the highest in Latin America; IICA et al., 2022)	Medium	Design with robust offline functionality for map data and for local action logging with later synchronisation	Moderate
Fraud and points-system abuse risk (GPS spoofing, fake photographs, multiple accounts, image manipulation)	High	Verification triangulation (GPS + EXIF metadata + perceptual hashing); daily per-user point limits; random human audit over automated verification	Moderate — increases operating cost
Dependence on interinstitutional articulation (operation requires active agreements with SENA, ICONTEC, MinCIT, and municipal authorities; Colombian public–private articulation processes tend to be slow and dependent on political cycles)	High	Deployment sequencing beginning with viable bilateral agreements; modular structure permitting partial operation; public documentation of the model to sustain political support	Moderate
Supply-side adoption (not all tourism workers or providers will initially be willing to formalise or certify)	Medium	Tangible visible benefits for the formalised guide (greater visibility, redeemable discounts, improved income); network effects as adoption advances	Moderate — depends on early demonstration
Greenwashing risk from self-reported certifications	High	Mandatory validation against official databases (ICONTEC, SENA); visible differentiation between self-declared and verified certifications; periodic third-party audits	Moderate — requires continuous governance investment
Behavioural-reversal risk from excessive reliance on extrinsic rewards	Medium	Emphasis on individualised impact feedback and social-community elements over pure monetary discount; reward-magnitude calibration	High — addressable through product-design discipline
Certification quality control and validation (ensuring certified actors genuinely comply with sustainable practices)	Medium-high	User feedback systems; periodic audits; eligibility-revocation mechanisms	Moderate

6. Discussion: Toward Institutionally Mediated Operability and Triple Articulation

6.1 The Problem of Operative Invisibility in Sustainable Tourism

The evaluation presented in Section 5 reveals a consistent pattern that, in our judgment, carries theoretical implications extending beyond Nativapp's specific case. The platform does not operate principally by creating institutional infrastructure but by rendering visible and operative infrastructure that already exists yet remains disconnected from the visitor's moment of decision. SENA already offers an extensive, free catalogue of sustainable-tourism training (SENA, 2023); the Colombian Environmental Seal already certifies establishments against verifiable criteria (ICONTEC, 2025); the RNT already constitutes a mandatory registry of formal providers (MinCIT, 2023); the mayoral offices of Cartagena and Santa Marta already operate municipal waste-management systems. None of these institutional elements is a product of Nativapp; all of them pre-exist the platform. What Nativapp contributes — and this is the article's central argument — is an operability layer that renders these institutional elements legible, actionable, and articulated at the point of decision.

We propose the term institutionally mediated operability (IMO) for this structural gap, introduced conceptually in Section 2.6 and developed formally here: the set of conditions under which pre-existing institutional infrastructure requires a digital articulation layer to produce the substantive effects for which it was created (Figure 5). The gap is diagnosed by the asymmetry between the nominal maturity of the institutional framework (existing certifications, operating training programmes, implemented registration systems) and the effective utilisation of these elements in the behaviour of the relevant actors (visitors who do not discriminate between certified and uncertified providers; informal workers who do not access available training processes; waste-management systems whose location is unknown to their potential users).

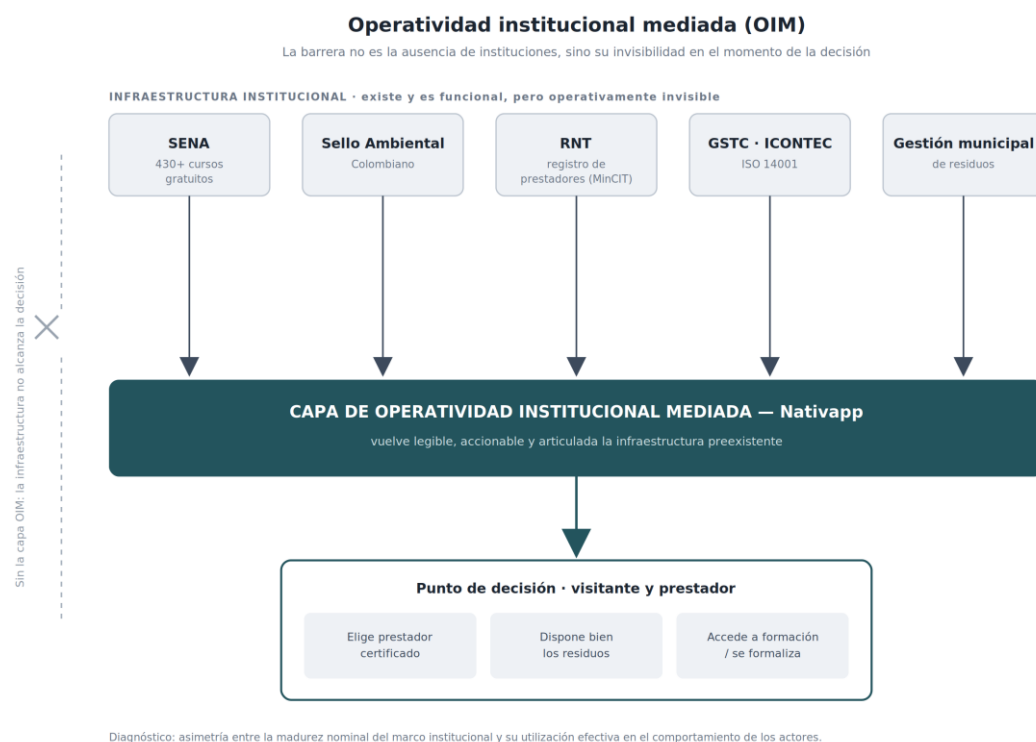


Figure 5. Institutionally mediated operability (IMO): pre-existing institutional infrastructure reaches the visitor's and provider's point of decision only through the digital articulation layer.

The IMO construct extends the general observation in the sustainable-tourism literature that "environmental certifications need to be accompanied by consumer-facing visibility mechanisms to have substantive effect" (Font, 2002; Font & Lynes, 2018), and, as Section 2.6 develops, is analytically distinct from institutional-voids theory (Khanna & Palepu, 1997) precisely because it addresses institutional maturity rather than institutional absence. The theoretical extension consists of four interrelated propositions:

Proposition 1. In emerging-economy contexts with comparatively mature tourism regulatory frameworks, the principal barrier to sectoral sustainability is not the absence of institutional infrastructure but its operative invisibility at the point of decision.

Proposition 2. Operative invisibility is not resolvable through purely communicational or additional regulatory interventions, given that the information exists but does not reach the decision moment in articulated form.

Proposition 3. Meso-level digital platforms constitute an appropriate intervention for this gap insofar as they operate as articulation layers, not as substitute institutions or as pure market mechanisms.

Proposition 4. The effectiveness of these platforms is subject to an interinstitutional articulation threshold: the minimum level of cooperation among public, private, and community institutions below which no digital articulation layer can produce the intended effects. The existence of this threshold implies that digital-platform deployment cannot substitute for investment in interinstitutional governance.

6.2 Triple Articulation: Labour, Environment, Decision

The second theoretical contribution concerns the specific articulation structure Nativapp operationalises. The sustainable-tourism literature tends to address the labour dimension (informality and formalisation), the environmental dimension (waste, resources, emissions), and the visitor-behaviour dimension (informed decision, gamification, eco-feedback) separately. Existing empirical solutions — from Blue Flag and Green Key to STD schemes — generally operate on one of the three dimensions, occasionally on two, but rarely on all three simultaneously.

This article's argument is that substantive tourism sustainability in contexts such as the Colombian Caribbean requires a triple articulation (Figure 6): the operative coupling, within a single service layer, of (a) labour formalisation mediated by public certification, (b) environmental certification mediated by verifiable external seals, and (c) visitor-behaviour modification mediated by DfSB architectures. The three dimensions reinforce one another mutually: the visitor demands environmentally certified services delivered by formalised guides; formalised guides are preferentially recommended when they offer activities at sustainable establishments; sustainable establishments see value in engaging formalised guides because doing so increases their own recommendation. Triple articulation therefore constitutes a structure of reciprocal incentives with the potential to generate a sectoral adoption dynamic superior to the sum of isolated interventions.

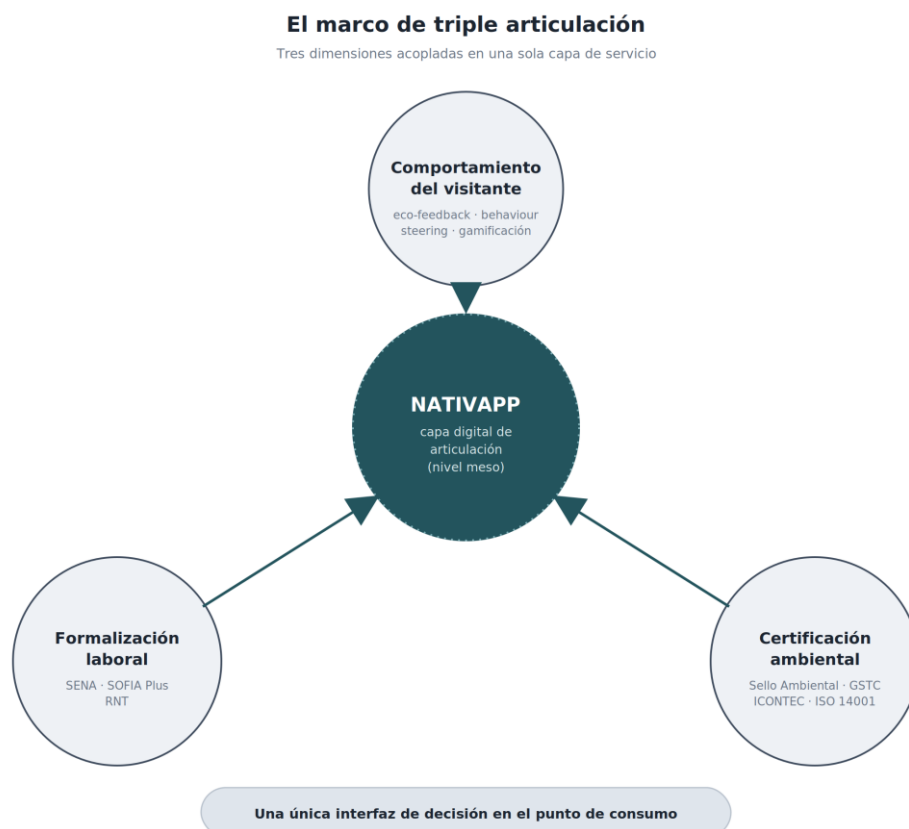


Figure 6. The triple-articulation framework: labour formalisation, environmental certification, and visitor behaviour coupled within a single service layer at the point of consumption.

This characterisation is not merely descriptive. It carries non-trivial design implications: tourism platforms aspiring to contribute to sustainability in Global South destinations should be evaluated not

solely by their impact on one dimension but by their capacity to articulate all three. Table 9 presents this logic comparatively.

Table 9. Solutions Compared by Coverage of the Three Articulation Dimensions

Solution / Category	Labour Dimension	Environmental Dimension	Visitor Dimension	Effective Articulation
Blue Flag, Green Key	Not addressed	High (infrastructure certification)	Low (indirect signal)	Partial: one dimension
Booking platforms (OTAs)	Not addressed	Not addressed (except optional seal)	High (price- and reputation-informed decision)	Partial: one dimension
Payments for Environmental Services	Not addressed	High (conservation incentive)	Not addressed	Partial: one dimension
Smart Tourism Destinations (STD)	Low (aggregate employment data)	Medium (aggregate impact data)	Medium (visitor information)	Partial: two dimensions
Community-tourism platforms	High (community formalisation)	Medium (local operating criteria)	Low-medium (limited reach)	Partial: two dimensions
Nativapp	High (SENA-mediated certification)	High (curation via external seals)	High (integrated DfSB)	Triple articulation

6.3 Implications for Tourism Policy in Developing Countries

Tourism-policy discourse in developing countries tends to oscillate between two positions: (a) regulation-first approaches, which multiply certifications and requirements without attending to their effective operability at the visitor level; and (b) market-first approaches, which delegate sustainability to consumer self-selection without the necessary informational infrastructure. Neither is optimal.

The Nativapp case suggests a third approach: digital articulation of existing institutionality, in which digital platforms are deployed not to supplant state or market functions but to operationalise them at the point of decision. This logic is consistent with the emerging literature on adaptive regulation (Cellina et al., 2020) and with UNWTO observations on the need for "implementation instruments" that reduce the distance between declared tourism policy and effective tourism practice (UNWTO, 2023).

Table 10 presents this framework comparatively.

Table 10. Comparative Approaches to Sustainable Tourism Policy in Emerging Economies

Approach	Central Logic	Strengths	Weaknesses	Alignment with Nativapp
Regulation-First	Multiply certifications and standards; compliance will follow	Clear institutional framework; formal accountability	Weak visitor-level operability; regulatory overload without substantive effect	Low
Market-First	Delegate sustainability to consumer self-selection; remove operator friction	Deployment speed; flexibility	Persistent information asymmetry; elevated greenwashing risk; value capture by intermediaries	Low

Approach	Central Logic	Strengths	Weaknesses	Alignment with Nativapp
Digital Articulation of Existing Institutionalities	Deploy platforms that operationalise existing certifications, training, and registries at the point of decision	Contextually viable; politically actionable; generates institutional-investment demand feedback	Requires complex multi-actor coordination; depends on meeting the interinstitutional articulation threshold	High

For Colombian regulatory authorities, the analysis suggests that marginal investments in digital visibility of existing certifications may yield higher returns than the creation of new certification categories. For the municipal governments of Cartagena and Santa Marta, the geolocated data layer on waste-management infrastructure usage generated by platforms such as Nativapp offers a low-cost mechanism for continuously monitoring the effective utilisation of municipal investments and for identifying territorial coverage gaps. For the Ministry of Commerce, Industry and Tourism, integrating platforms such as Nativapp with the RNT could function as a channel steering informal operators toward formalisation, progressively substituting the punitive incentive with an articulated market incentive.

6.4 Theoretical Contributions and Literature Positioning

This article makes three theoretical contributions to the literature on sustainable tourism and digital sustainability platforms. First, it provides one of the first documented applications of the Design for Sustainable Behaviour framework to the Colombian Caribbean coastal tourism context, demonstrating both its analytical power and its contextual limitations when the institutional conditions the framework assumes are not fully met. Second, it identifies the articulation between public labour formalisation and private environmental certification as an analytically distinctive dimension — triple articulation — that the tourism-platform literature had not previously addressed as a unitary theoretical object. Third, it proposes the institutionally mediated operability construct as a structural gap distinct from institutional absence, with both diagnostic implications (what fails when a robust regulatory framework does not produce its intended substantive effects?) and prescriptive implications (what type of intervention is appropriate for this gap?).

Table 8 positions the IMO construct against the three adjacent literatures introduced in Section 2.6, clarifying both convergence and distinction.

Table 8. Positioning Institutionally Mediated Operability Against Adjacent Theoretical Frameworks

Framework	Core Unit of Analysis	Assumed Institutional Condition	Prescribed Intervention	Relation to IMO
Institutional Voids (Khanna & Palepu, 1997; Mair & Marti, 2009)	Firm or entrepreneur strategy under missing market-supporting institutions	Institutional absence or severe underdevelopment	Build, substitute, or bridge the missing intermediary function	Adjacent but distinct: IMO addresses mature, not absent, institutions; the intervention target is connectivity, not construction

Framework	Core Unit of Analysis	Assumed Institutional Condition	Prescribed Intervention	Relation to IMO
Sociotechnical Multi-Level Perspective (Geels, 2002)	Regime-level transition dynamics under niche-innovation pressure	Entrenched regime structures resistant to change	Niche protection and regime destabilisation over long time horizons	Narrower in scope: IMO is a meso-level operability mechanism, not a theory of regime transformation
Smart Tourism Destination Ecosystems (Boes et al., 2016)	Destination-level data and governance integration	Institutional and digital maturity sufficient for public–private integration	Destination-level data platforms and collaborative governance structures	Complementary but differently scaled: IMO operates at the individual-transaction level rather than aggregate destination planning
Institutionally Mediated Operability (this article)	Individual visitor/provider decision transaction	Institutional maturity with operative invisibility at the decision point	Meso-level digital articulation layer connecting existing infrastructure to the decision moment	—

The article's positioning relative to the existing literature is deliberate in three respects. First, the proposed framework extends — rather than displaces — the Sustainable Tourism (Higgins-Desbiolles, 2018), Design for Sustainable Behaviour (Lilley, 2009), and Smart Tourism Destinations (Boes et al., 2016) traditions, articulating elements of all three within an integrated object. Second, the contributions are empirically anchored in primary research with sector actors and in systematic benchmarking, not in purely speculative proposals — while, per Section 3.5, that empirical anchoring rests on a four-informant exploratory sample and should be weighted accordingly. Third, the study's limitations are treated as a theoretical object in their own right — particularly the interinstitutional articulation threshold, which is simultaneously a viability condition and a future research agenda.

6.5 The Digital Divide as a Boundary Condition for Platform-Mediated Sustainability

Section 5.4 identifies the urban–rural connectivity gap and the generational digital-literacy gap as structural limitations rather than implementation defects, and this section situates that finding within the broader digital-divide literature to draw out its implications for the IMO framework specifically. Van Dijk and Hacker's (2003) influential framework decomposes the digital divide into four cumulative levels of access — motivational, material, skills, and usage access — arguing that closing the material-access gap (device and connectivity availability) does not automatically close the skills- and usage-access gaps that determine whether a population can meaningfully act on the information a digital platform provides. This distinction is directly consequential for Nativapp's design claims.

The platform's core theoretical proposition is that operative invisibility, not institutional absence, is the binding constraint on tourism sustainability in Colombia. That proposition is contingent on visitors and providers possessing sufficient material, skills, and usage access to actually perceive and act on the visibility a digital layer provides — a contingency the IMO construct, as formally stated in Section 6.1, does not itself resolve. Where the digital divide is material (as IICA et al.'s 2022 finding of a 3.0× urban–rural connectivity gap documents for Colombia), a population may remain functionally excluded from the articulation layer regardless of how well-designed that layer is, effectively reproducing at the digital-access level the same operative-invisibility problem the platform seeks to solve at the

institutional level. This is not a peripheral caveat: it implies that IMO-based interventions carry an intrinsic scope condition — they close the institutional-visibility gap only for the subpopulation that clears the prior digital-access threshold — and that, for populations below that threshold, the appropriate policy response reverts to the physical, non-digital infrastructure and outreach investments that regulation-first approaches (Table 10) already prescribe. The theoretical implication is that institutionally mediated operability and the digital divide should be read as nested, not competing, explanations of the sustainability-implementation gap: IMO explains why institutionally mature contexts underperform among digitally included populations, while the digital divide explains why the same intervention cannot be assumed to reach populations outside that inclusion boundary. Nativapp's own mitigation strategy — offline-capable functionality and articulation with existing public digital-literacy programmes (MinTIC, 2019; Colombia Aprende, 2023), as Table 7 documents — is consistent with this reading but does not eliminate the underlying scope condition, which future empirical work (Section 7.3) should treat as a first-order research question rather than a secondary implementation risk.

6.6 Greenwashing Risk and Verification Governance

Font's (2002) critique of environmental tourism certification identifies greenwashing — the proliferation of unverified or self-assigned sustainability claims — as a structural risk of any certification-visibility architecture, and de Freitas Netto, Sobral, Ribeiro, and Soares's (2020) subsequent typology of greenwashing distinguishes claim-level greenwashing (false or exaggerated environmental claims about a specific product or service) from firm-level greenwashing (a broader pattern of symbolic environmental commitment substituting for substantive practice change). Both forms are directly relevant to Nativapp's design, and Table 7 identifies two distinct greenwashing-adjacent risks: self-reported certifications entering the platform without institutional validation, and the platform's own recommendation architecture inadvertently certifying providers whose practices diverge from what their formal certification implies.

Nativapp's principal governance response is architectural rather than procedural: certification status is validated against institutional databases (SENA/SOFIA Plus, ICONTEC, the Colombian Environmental Seal registry) at the point of provider registration, rather than accepted on a self-declared basis, which directly targets claim-level greenwashing as de Freitas Netto et al. (2020) define it. This design choice, however, does not resolve firm-level greenwashing: a provider may hold a valid, institutionally verified certification while nonetheless deviating from the practices that certification is meant to signal, a governance gap common to third-party-certification schemes generally (Font & Lynes, 2018) and one Nativapp's current architecture does not independently audit. The platform's proposed mitigation — periodic third-party audits and user-feedback-triggered eligibility review (Table 7) — is consistent with governance mechanisms documented elsewhere in the sustainability-platform literature (OECD, 2025) but has not itself been piloted, and its cost and institutional-cooperation requirements are non-trivial relative to the platform's projected revenue model (Section 4.4).

The theoretical implication for the IMO framework is that an operability layer inherits, rather than resolves, the verification-governance limitations of the institutions it articulates. Nativapp can only be as trustworthy as SENA's, ICONTEC's, and the Colombian Environmental Seal's own certification-integrity processes; where those upstream processes are themselves imperfectly enforced, digital articulation risks amplifying rather than correcting the resulting sustainability-claim asymmetry, by

lending a veneer of algorithmic objectivity to certifications whose underlying rigor the platform does not itself audit. This suggests that future IMO-based platform designs should treat upstream certification-integrity auditing as a fourth coupled functionality alongside the three the article documents in Section 4, rather than as an externality assumed away by institutional validation alone — a design implication this study did not anticipate at the outset and identifies here as a direct product of the critical analysis in this section.

7. Conclusion

This article has presented, evaluated, and theorised Nativapp, a meso-level digital platform for sustainable coastal tourism designed to address labour informality and deficient environmental management in Colombian Caribbean tourism zones simultaneously. Employing an exploratory qualitative design-research methodology — primary field research with four purposively sampled informants, systematic benchmarking, and application of the Design for Sustainable Behaviour framework — the study establishes four principal findings.

First, labour informality and deficient environmental management in Colombian coastal tourism are not primarily a consequence of institutional-infrastructure absence — which is comparatively abundant — but of its operative invisibility at the visitor's moment of decision. This characterisation carries non-trivial design implications: the appropriate intervention is not the creation of new certifications but the digital articulation of existing ones.

Second, Nativapp satisfies the DfSB framework's criteria across its three mechanisms (eco-feedback, behaviour steering, calibrated rewards) and deliberately articulates the labour-formalisation, environmental-certification, and visitor-behaviour dimensions within a single service layer. The platform demonstrates robust technical viability across its four evaluation criteria (technological maturity, infrastructural compatibility, independence from proprietary hardware, interoperability with public systems), while facing genuine limitations in the interinstitutional-articulation dimension and in greenwashing-risk mitigation — the latter, as Section 6.6 develops, being a limitation the platform inherits from the certifying institutions it articulates rather than one it can resolve unilaterally.

Third, the institutionally mediated operability construct provides a theoretically grounded account of the conditions mediating whether digital platforms can achieve substantive tourism-sustainability outcomes in emerging-economy contexts. The construct contributes to the literature by specifying a structural gap distinct from the more commonly diagnosed gaps (regulatory absence, operator technical-capacity absence, consumer environmental-culture deficit), by positioning that gap explicitly against institutional-voids theory (Section 2.6, Table 8), and by proposing the type of intervention appropriate to it — while Section 6.5 establishes that this intervention is itself bounded by a digital-access scope condition that institutional maturity alone does not resolve.

Fourth, the triple-articulation framework — the operative coupling of labour, environment, and decision within a single digital service layer — constitutes a structure of reciprocal incentives with dynamic potential superior to the sum of isolated interventions. Tourism platforms aspiring to contribute substantively to SDG target 8.9 should be evaluated according to their effective coverage of all three dimensions, not their performance on a single one.

7.1 Theoretical Contributions

- Development of institutionally mediated operability (IMO) as a bounded theoretical construct specifying when digital platforms can and cannot generate intended tourism-sustainability outcomes in institutionally mature but operationally fragmented emerging-economy contexts, explicitly differentiated from institutional-voids theory (Khanna & Palepu, 1997) and positioned against the sociotechnical multi-level perspective (Geels, 2002) and Smart Tourism Destination ecosystems theory (Boes et al., 2016).
- One of the first documented applications, to the best of this review, of the Design for Sustainable Behaviour framework to Colombian Caribbean coastal tourism, demonstrating both the framework's diagnostic power and the specific contextual conditions — including the digital-divide scope condition developed in Section 6.5 — under which its mechanisms diverge in effectiveness.
- A design-level integration of public labour-certification infrastructure with environmental-certification curation and DfSB-calibrated gamification, articulated through the triple-articulation framework and applicable to platform design in other Global South tourism destinations facing analogous institutional-maturity-without-operability conditions.
- A critical extension of the greenwashing-governance literature (Font, 2002; de Freitas Netto et al., 2020) identifying upstream certification-integrity auditing as a necessary, currently unaddressed, fourth functionality for institutionally mediated operability platforms.

7.2 Limitations

This article is conceptual and evaluative in character, and this limitation should be read with the weight Section 3.5 assigns it rather than as a pro forma disclaimer. The proposed solution has not been empirically piloted; the quantitative impact indicators presented in Section 5.1 are illustrative scenario projections built on explicit assumptions and extrapolated from comparable external studies, and they remain subject to substantial uncertainty specific to the Colombian context. The primary research informing the design (Section 3.2) comprises four interview sessions with four purposively selected informants and does not reach thematic saturation in the formal sense of the term; as Section 3.5 discloses, one of the two authors of this manuscript participated in that original fieldwork while the other joined at the consolidation stage, a division of intellectual labour material to how the primary claims should be weighted. The systematic benchmarking (Section 3.3), while methodologically structured, draws on five purposively selected comparators rather than an exhaustive market scan. The qualitative findings reported here should be interpreted as design hypotheses generated during the exploratory phase of a Design Thinking process, not as generalisable conclusions about the Colombian coastal tourism sector. A further limitation, developed in Section 6.5, is conceptual rather than empirical: the institutionally mediated operability construct itself carries an unresolved digital-access scope condition that this study identifies but does not operationalise or measure. Readers — and, most importantly, any prospective adopter, funder, or policymaker relying on this article — should weight the findings accordingly: as a rigorously developed conceptual and evaluative case for further empirical investigation, not as a validated impact claim.

7.3 Future Research Agenda

- A controlled pilot study deploying the platform in partnership with two to five formal tourism operators and ten to fifteen independent guides in Cartagena or Santa Marta would generate the primary empirical evidence on adoption dynamics, user engagement, behavioural outcomes, and effective articulation with SENA and ICONTEC that this article, by design, cannot provide — and constitutes the single most important next step for validating or disconfirming the claims developed here.
- A comparative analysis of analogous digital sustainable-tourism platforms in other middle-income economies (Brazil, Mexico, Costa Rica, South Africa) would test the generalisability of the institutionally mediated operability construct and the interinstitutional articulation threshold beyond the Colombian case, and would allow the threshold-discontinuity property proposed in Section 6.1 to be assessed empirically rather than theoretically.
- Dedicated empirical research on the digital-divide scope condition identified in Section 6.5 — specifically, measuring what proportion of the target visitor and provider population clears the material-, skills-, and usage-access thresholds required for an IMO-based intervention to reach them — would convert a currently conceptual limitation into an operationalised, testable boundary condition for the framework.
- Targeted investigation of the computer-vision waste-disposal-verification subsystem's field accuracy rates (illumination variation, waste-type diversity, user-device camera quality) and of optimal fraud-mitigation mechanisms merits dedicated study as a route to reducing both operational risk and the greenwashing-adjacent risk identified in Section 6.6.
- A political-economy study of the interinstitutional articulation dynamics among SENA, ICONTEC, MinCIT, coastal municipal authorities, and private operators required to sustain the platform's deployment is particularly warranted given the model's documented dependence on political cycles.
- Design and piloting of an upstream certification-integrity audit functionality, as identified in Section 6.6, would test whether the fourth coupled functionality this article proposes meaningfully reduces firm-level greenwashing risk relative to the platform's current architecture.

7.4 Policy Implications

For Colombian environmental and tourism regulatory bodies, the analysis suggests that marginal investments in digital visibility and operative articulation of existing certifications may yield higher returns than the creation of new seal or registry categories. The public initiative to generate robust public APIs for SOFIA Plus, the RNT, and the Colombian Environmental Seal constitutes a high-impact, comparatively low-cost enabler.

For the municipal governments of Cartagena, Santa Marta, and Riohacha, the geolocated data layer on waste-management infrastructure usage generated by platforms such as Nativapp offers a low-cost mechanism for continuous monitoring of effective municipal-investment utilisation and for identifying territorial coverage gaps. Articulation with existing co-financing schemes (FONTUR, 2024) could enable sustained scaling.

For the Ministry of Commerce, Industry and Tourism, integrating platforms such as Nativapp with the RNT could function as a mechanism channelling informal operators toward formalisation, progressively substituting the punitive incentive with an articulated market incentive. Under this framework, SDG

target 8.9 is interpreted not as a general exhortation but as a concrete operative mandate admitting verifiable instruments.

For international cooperation institutions supporting tourism-sustainability transitions in Latin America, the staged-deployment model — digital articulation first in destinations above the interinstitutional articulation threshold, simultaneous generation of institutional-investment demand for destinations below the threshold — offers a financing logic that sequences investment in digital platforms and institutional infrastructure as mutually reinforcing, rather than strictly sequential, interventions.

8. Declarations

CRedit Author Statement

Julián Andrés Ordoñez Guevara: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing – original draft, Visualization, Project administration. Joseph Javier Sánchez Acuña: Writing – review & editing, Validation, Final manuscript consolidation. Both authors are affiliated with the Department of Industrial Engineering, School of Engineering, Universidad de los Andes. The authors acknowledge that the primary field research, systematic benchmarking, and technical evaluation reported in Sections 3–5 originated as collaborative work within a five-member course team for the course 'Enfoques de Diseño para la Sostenibilidad' (2026-10 term): Ana Sophia Angel, Paula Torres, Manuela Ramírez, Camilo Rivera, and Julián Andrés Ordoñez Guevara. As disclosed in the positionality statement (Section 3.5), Joseph Javier Sánchez Acuña joined at the manuscript-consolidation stage and did not participate in the original fieldwork or benchmarking. The theoretical deepening — including the institutionally mediated operability construct, its positioning against institutional-voids theory, the triple-articulation framework, and the critical extensions on the digital divide and greenwashing governance — together with the writing and final consolidation of this specific manuscript, are the joint contribution of Julián Andrés Ordoñez Guevara and Joseph Javier Sánchez Acuña.

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Declaration of Competing Interests

The authors declare no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

Data Availability

Field notes and workshop documentation underlying this article were generated within an academic course under participant informed consent and are available upon reasonable request, subject to the anonymisation constraints agreed with informants.

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Methodological Transparency Note

This manuscript was developed with the assistance of an artificial intelligence language model (Claude, Anthropic), at the authors' request, first from the original course document 'Nativapp - Artículo Q1,' which already incorporated primary field research, systematic benchmarking, structured-matrix evaluation, and an initial formulation of the institutionally mediated operability and triple-articulation constructs, and subsequently revised into an expanded, English-language, doctoral-standard manuscript incorporating additional peer-reviewed literature verified for accuracy prior to citation, and into the present two-author version reflecting both authors' contributions and disclosed positionality. The revision process included an explicit bibliographic verification stage in which every citation was checked against its original source through independent academic search. This verification identified two references in the original course draft that had been incorrectly attributed — the journal, volume, and page data were accurate, but the co-author names and article title had been recorded erroneously — and both were corrected to their exact citations: Venturi, S., Zulauf, K., Cuel, R., & Wagner, R. (2025), "Trash to treasure: Gamification and informed recycling behavior," *Resources, Conservation and Recycling*; and Lim, W. M., Das, M., Sharma, W., Verma, A., & Kumra, R. (2025), "Gamification for sustainable consumption: A state-of-the-art overview and future agenda," *Business Strategy and the Environment*. An unverifiable precision figure (the exact number of SENA courses) was also corrected to a qualitative formulation. For this reason, the present article explicitly frames the primary research as exploratory, generative qualitative inquiry rather than as a statistically representative sample, consistent with sound qualitative reporting practice (Bryman, 2016; Lincoln & Guba, 1985) and with the premise that genuine Q1-journal rigour requires methodological precision and disclosed positionality rather than the appearance of scale or of undivided authorial participation. The authors assume final responsibility for the accuracy, academic integrity, and overall adequacy of this manuscript's content, and recommend thorough peer review prior to any formal submission to the target venue, together with independent verification of all cited sources by the authors and any collaborators involved in subsequent revisions.

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