

BEYOND PHYSICAL BOUNDARIES: A COMPARATIVE ANALYSIS OF SUSTAINABLE AND DIGITAL TOURISM INFRASTRUCTURE IN INDONESIA, THAILAND, AND SINGAPORE

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ABSTRACT

Sustainable tourism demands infrastructure that is not only physically adequate, but also environmentally friendly and digitally connected. This study compares sustainable tourism infrastructure and digital infrastructure in Indonesia with Thailand and Singapore, and examines the integration of the two. The study uses a qualitative approach with a descriptive comparative design, based on secondary data from policy documents, official statistics, and scientific literature equipped with supporting primary data. The results show that Indonesia has a diversity of natural and cultural resources and a large potential of local communities, but still faces overtourism, development inequalities, weak cross-sector coordination, and gaps in connectivity and human resource capacity. Singapore provides lessons on an integrated digital ecosystem and the association of data center growth with energy efficiency standards, while Thailand shows how investment incentives can be required on energy performance and workforce development. The two dimensions of infrastructure reinforce each other, and their integration is determined by policies, cross-actor collaboration, and community readiness. Based on these findings, this study developed a conceptual model consisting of integration drivers, two infrastructure dimensions, an eco-smart destination layer, outputs, and feedback mechanisms. This model is conceptual and not a formal ranking of the three countries, so its application needs to be adjusted to the characteristics of each destination.

Keywords: sustainable tourism, digital infrastructure, eco-smart destination, southeast asia comparative study, tourism policy integration

1. INTRODUCTION

Sustainable tourism has become the dominant paradigm in global destination development in response to environmental degradation, social inequality, and destination overcapacity. The sector accounts for about 10% of the world's gross domestic product, but also nearly 8% of global carbon emissions (Hutagalung et al., 2025). In Indonesia, the massive growth of tourism poses ecological and social pressures, ranging from *overtourism* that damages marine ecosystems in coastal areas such as Bali, Lombok, and Labuan Bajo to the construction of unplanned facilities in mountainous areas (Hutagalung et al., 2025). Poor infrastructure, weak cross-sectoral policies, and low local community involvement remain major obstacles to the implementation of sustainable tourism (Hutagalung et al., 2025).

In this context, tourism infrastructure can no longer be understood merely as physical facilities. While transportation, parking areas, and tourist routes remain determinants of service quality, infrastructure based on the **eco-smart tourism** concept—which is environmentally friendly and technology-driven—is now viewed as a necessity (Firdasari et al., 2025). For instance, the implementation of QR code-based information boards at Kuala Leuge Beach, East Aceh, has expanded access to tourism information while enhancing the community's ability to market flagship products via social media (Firdasari et al., 2025). At a more advanced level, the integration of the **Internet of Things** (IoT) and **smart destinations** enables managers to monitor visitor density, energy consumption, and air quality in real-time, thereby facilitating more responsive decision-making (Nugroho et al., 2024). However, implementation faces various challenges, such as data privacy and security concerns, technological compatibility issues, and the need for substantial investment (Nugroho et al., 2024). Success also hinges on collaboration among the government, tourism operators, and the community, given that knowledge gaps regarding information technology-based tourism management remain a major obstacle (Firdasari et al., 2025). Tourism infrastructure must be planned and managed by diverse stakeholders within a collaborative framework, reflecting the close interconnection between physical development and the destination's socio-economic goals (Kuntariningsih, 2026:22).

The COVID-19 pandemic has emphasized the importance of resilience and digitalization. Jang et al. (2021) found that the performance of *peer-to-peer accommodation* based on digital platforms is affected differently in urban and rural areas, depending on the attributes of the destination, so that the resilience of destinations to crises is influenced by the characteristics of locations and tourist segments. The pandemic has also accelerated remote work and given birth to *digital nomads*, i.e. knowledgeable workers who stay for weeks to months so that their consumption patterns resemble temporary residents (Rahmad & Amir, 2026). This segment demands digital infrastructure and accommodations that support remote work, as well as sustainable governance that protects local communities from the risk of gentrification (Rahmad & Amir, 2026).

Digital readiness between regions in Indonesia is still uneven. Aryapranata et al. (2025) show that in three tourism villages, namely Nglanggeran, Penglipuran, and Sade, online booking platforms, social media marketing, and digital literacy strengthen destination visibility, market access, and community participation, but digital infrastructure gaps, financial limitations, and low digital awareness still hinder equitable development. The government has shown commitment through the *100 Smart Tourism*

Villages program, but the benefits of digital adoption have not been evenly distributed due to poor internet connectivity and limited training (Aryapranata et al., 2025). Digital transformation therefore needs to be seen as a socio-cultural evolution, not just a technological shift (Aryapranata et al., 2025). On the other hand, Canggu is developing organically into a *digital nomad* center with significant sustainability challenges, while Labuan Bajo and Mandalika do not have a structured strategy (Rahmad & Amir, 2026). This condition shows that the development of sustainable physical infrastructure and digital infrastructure has not been balanced, so Indonesia's position needs to be studied *beyond physical boundaries* by comparing it to Thailand and Singapore.

Previous studies show three gaps. First, research in Indonesia tends to be fragmented and micro-scale, for example assistance in one region (Firdasari et al., 2025), a study of three tourist villages (Aryapranata et al., 2025), secondary data analysis for the period 2012–2023 in two North Sumatra ecoregions (Hutagalung et al., 2025), or conceptual studies of IoT and *smart destinations* (Nugroho et al., 2024). Aryapranata et al. (2025) also noted that the literature so far has focused more on urban destinations or those that have advanced digitally. Second, comparative studies are still limited so that cross-context learning has not been optimally utilized (Rahmad & Amir, 2026), and existing comparative studies only compare Lisbon and Canggu with a focus on *digital nomads*. Third, the dimensions of sustainability and digitalization tend to be studied separately. Rahmad and Amir (2026) said that sustainability is often treated as a footnote and the integration of infrastructure, policies, marketing, and sustainability has not been formulated holistically, while Hutagalung et al. (2025) noted that cross-sector integration and alignment with green investment still need to be strengthened. In the literature reviewed, no studies have been found that compare Indonesia's sustainable and digital tourism infrastructure with Thailand and Singapore in an integrated manner.

This research is important for three reasons. First, competition between destinations is getting tighter. The *global digital nomad* population is estimated at around 40 million by early 2025 with an annual growth of 12–17% until 2030, and its economic contribution could reach 1.5–2.5 times that of conventional tourists, so many countries are racing to prepare special policies and infrastructure (Rahmad & Amir, 2026). Without systematic comparison, efforts to improve Indonesia's competitiveness risk stopping at improving physical facilities without considering digital readiness and environmental sustainability. Second, digital infrastructure investments are expensive (Nugroho et al., 2024), while policy recommendations such as expanding *broadband connectivity*, digital tourism funds, and public-private partnerships demand a strong benchmark base (Aryapranata et al., 2025). Third, vulnerability due to crises and environmental degradation demands ecosystem-based policies that are adaptive to local conditions (Hutagalung et al., 2025; Jang et al., 2021).

Theoretically, this study expands the literature by combining two dimensions that have been studied separately, namely sustainability and digitalization of infrastructure, in a comparative framework across Southeast Asian countries. Practically, the results are expected to be a reference for governments, destination managers, and business actors in compiling an inclusive, environmentally friendly, and digitally connected tourism infrastructure roadmap. Indonesia is positioned as the main case, while Thailand and Singapore are comparators. This study answers four questions:

- (1) How does the state of sustainable tourism infrastructure in Indonesia compare to Thailand and Singapore?
- (2) How does the state of digital tourism infrastructure in Indonesia compare to Thailand and

Singapore?

- (3) To what extent are sustainable infrastructure and digital infrastructure integrated in all three countries?
- (4) What strategic lessons and recommendations can Indonesia adopt from the results of the comparison?

2. LITERATURE REVIEW / THEORETICAL FRAMEWORK

1.1 Sustainable Tourism

Sustainable tourism is defined as tourism that takes into account current and future economic, social, and environmental impacts, and meets the needs of visitors, industries, the environment, and host communities (UNWTO, 2023, in Hutagalung et al., 2025). This definition rests on a balance of

ecological sustainability, socio-cultural inclusivity, and economic feasibility (Gössling & Hall, 2021, in Hutagalung et al., 2025). Sharpley (2020, in Hutagalung et al., 2025) emphasizes that sustainable tourism must prioritize the long-term interests of local communities, including access to economic benefits and involvement in decision-making. Its success is highly dependent on local contexts, institutional adaptation, and participatory governance (Lane & Kastenholz, 2023, in Hutagalung et al., 2025), so empirically measurable indicators, such as the carbon footprint of tourists and environmental carrying capacity indices, are increasingly recommended (Becken, 2022, in Hutagalung et al., 2025).

A community-based approach is the main instrument in this framework. Hutagalung et al. (2025) found that *community-based tourism* effectively encourages community participation and strengthens local economic resilience, both in coastal and mountainous areas. Firdasari et al. (2025) added that active community involvement in destination management maintains environmental sustainability while ensuring that economic benefits are directly felt by the community.

1.2 Tourism Infrastructure: from Physical to Eco-Smart

Tourism infrastructure traditionally includes basic facilities such as transportation, parking lots, and tourist routes that determine the quality of services to tourists (Firdasari et al., 2025). Within the framework of sustainability, these facilities need to be designed to be environmentally friendly. The concept of *eco-smart tourism* combines the principles of ecotourism with information technology, for example QR-Code-based information boards and village information systems, so that management is more efficient, information is more accessible, and the tourist experience is improved (Firdasari et al., 2025). Thus, infrastructure is understood as a system that involves physical devices, technology, and the human capacity to manage it.

1.3 Digital Transformation and Smart Destinations

The digital transformation of tourism is the integration of advanced technology into service delivery, tourist engagement, and operational models (Aryapranata et al., 2025). Online booking platforms and social media have transformed marketing and interaction between destinations and visitors. The idea of *Tourism 4.0* emphasizes *big data*, artificial intelligence, and virtual reality, which have been more observed in urban and high-tech destinations (Aryapranata et al., 2025).

Smart destinations are destinations that utilize digital technology to improve operational efficiency, visitor experience, and quality of life for local communities (Nugroho et al., 2024). IoT is the backbone through environmental, security, and visitor sensors that collect data in *real-time*. This data is used to manage capacity, optimize energy and water, manage waste, and respond quickly to crises and maintain facilities (Nugroho et al., 2024). Its implementation faces obstacles in the form of data privacy and security, technological compatibility, and large investment needs (Nugroho et al., 2024). Conceptually, IoT and *smart destinations* connect the digital dimension with sustainability goals because they allow monitoring of the impact of tourism on ecosystems.

1.4 Digital Infrastructure, Digital Nomad, and Destination Resilience

The COVID-19 pandemic turned remote work into a permanent option and gave birth to the *digital nomad* segment, namely knowledgeable workers who travel long distances by relying on digital technology (Cook, 2023, in Rahmad & Amir, 2026). Because they settle for weeks to months, their consumption patterns resemble temporary residents (Rahmad & Amir, 2026). Their needs can be

mapped into three levels: basic infrastructure (high-speed internet and work-supporting accommodation), supporting infrastructure (*co-working* and *co-living spaces*), and experience and well-being (Rahmad & Amir, 2026). Rahmad and Amir (2026) formulated four pillars of destination strategy, namely digital infrastructure and accommodation, policy and visa frameworks, community-based

marketing, and sustainability governance that protects local communities from gentrification. These four pillars reinforce each other and cannot be implemented partially.

In terms of resilience, Jang et al. (2021) show that the relationship between destination attributes and the performance of digital platform-based accommodation varies spatially. Revenue losses differ between urban and rural areas, and threat perceptions affect tourist interest. These findings underlie the need for location-based destination management to build crisis-resilient environments.

1.5 The Digital Divide and Community Empowerment

Information and communication technologies can empower communities because digital literacy allows citizens to manage websites, create local content, and run booking systems (Aryapranata et al., 2025). However, unreliable connectivity and electricity, financial limitations, intergenerational gaps, and reliance on third-party platforms can weaken local autonomy (Aryapranata et al., 2025). A similar pattern can be seen in the knowledge gap of the community in managing information technology-based tourism that demands assistance and collaboration from the government, managers, and the community (Firdasari et al., 2025).

1.6 Conceptual framework

Based on the study, this study positions tourism infrastructure in two interrelated dimensions. The first dimension is sustainable infrastructure, which includes environmentally friendly physical facilities, participatory governance, and ecological-socio-economic balance. The second dimension is digital infrastructure, which includes connectivity, platforms, IoT, and digital literacy. The integration of the two is determined by policies, cross-actor collaboration, and community readiness. This framework is the basis for comparing Indonesia with Thailand and Singapore.

3. RESEARCH METHOD

1.1 Research Design

This study uses a qualitative approach with a descriptive-comparative design. The qualitative approach was chosen because sustainable and digital tourism infrastructure is multidimensional, including aspects of policy, technology, and social dynamics that require in-depth exploration (Rahmad & Amir, 2026). The descriptive aspect is used to map the infrastructure condition in each country, while the comparative aspect is used to compare patterns, similarities, and differences. This strategy is in line with Hutagalung et al. (2025) which combines qualitative descriptive and comparative analysis to compare the two regions. Indonesia is the main case, while Thailand and Singapore are the comparative cases. The orientation is analytical generalization, which is a deep contextual understanding, not statistical generalization (Ragin, 2014, in Hutagalung et al., 2025).

1.2 Units of Analysis

The research analysis unit is national tourism infrastructure in two dimensions as a result of the literature review, namely sustainable infrastructure (environmentally friendly physical facilities, participatory governance, and ecological, social, and economic balance) and digital infrastructure (connectivity, digital platforms, IoT, and digital literacy). Each dimension is studied at the national policy level and its application in the destination, so that the comparison does not stop at the availability of facilities, but also includes the readiness of the community and its governance. The integration of



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the two dimensions is the third focus. This structure answers the first to third research questions, while the fourth question is answered through a synthesis of learning for Indonesia.



1.3 Data Sources

The data consisted of secondary data and supporting primary data. Secondary data was collected from policy documents, official reports, and tourism statistics, namely the Ministry of Tourism and Creative Economy and the Central Statistics Agency for Indonesia (Hutagalung et al., 2025), as well as tourism authorities and statistical institutions of each country for Thailand and Singapore. This data is complemented by a study of peer-reviewed journal articles published in 2020–2026 that are directly related to tourism infrastructure, digitalization, or sustainability, while non-academic blogs are excluded (Rahmad & Amir, 2026). For the backbone digital infrastructure, namely submarine cables and data centers, this study also uses official government releases, digital authority policy documents, and industry research reports published by trusted business media. These sources are treated as contextual data because their development is too recent to be covered in the journal literature, and each figure is compared with other sources before use. Primary data are in the form of semi-structured interviews with key informants in Indonesia, namely tourism agencies, destination managers, business actors, and local communities, which were purposively selected based on the involvement and digital readiness of the destination (Aryapranata et al., 2025; Nugroho et al., 2024). The interviews were used to explore the conditions and barriers to implementation in the field.

1.4 Data Analysis and Validity

The analysis was carried out in four stages following the order practiced by Rahmad and Amir (2026): (1) thematic extraction to identify the main themes of the documents and interview transcripts; (2) categorization of findings based on the dimensions of sustainable infrastructure, digital infrastructure, and their integration; (3) cross-case comparative synthesis through *cross-case analysis* to find gaps and superior practices; and (4) critical interpretation to formulate strategic recommendations for Indonesia.

The validity of the data is maintained through triangulation of sources, i.e. comparing findings from policy documents, statistics, scientific literature, and interviews on each key argument (Rahmad & Amir, 2026). Credibility and transferability are strengthened by cross-case analysis and verification by informants (Maxwell, 2021, in Hutagalung et al., 2025). The main limitation is the reliance on secondary data whose definitions and scope of indicators can differ between countries, so that the results represent the consensus of the latest documents and literature, rather than empirical verification in all three countries.

4. RESULTS

1.1. Sustainable Tourism Infrastructure

Sustainable tourism infrastructure in Indonesia has developed, but its implementation has not been evenly distributed and has not been fully aligned with social, economic, and environmental needs. Infrastructure has tended to be understood in physical form, such as transportation access, parking lots, tourist routes, sanitation facilities, and other supporting facilities. From the perspective of sustainable development, infrastructure should be judged not only by its function and completeness, but also by its ability to maintain a balance between the interests of tourists, local communities, economic activities, and environmental sustainability.

These challenges can be seen from environmental pressures due to rapid tourism growth. Some areas experience *overtourism*, unplanned facility development, and weak cross-sector coordination

(Hutagalung et al., 2025). The increasing number of physical developments, in other words, are not necessarily synonymous with increasingly sustainable destinations. Good infrastructure should make it.

easier for tourists to come and do activities while maintaining the carrying capacity of destinations in the long term.

The approach that is starting to develop is *eco-smart tourism*, which is the combination of environmentally friendly principles with the use of technology. QR-Code-based information boards, destination information systems, more efficient management of facilities, and the use of technology for environmental management show that physical infrastructure is starting to shift towards smarter systems (Firdasari et al., 2025; Nugroho et al., 2024). Sustainability does not stop at the construction of "green" facilities, but also concerns how these facilities are used and managed effectively.

Another important finding is the involvement of local communities. Sustainable tourism is not only about buildings, roads, technology, or tourist facilities, but also about the people who live within the destination. Local communities need to reap economic benefits while also having space in decision-making. Community-based approaches strengthen local economic resilience and maintain the relationship between tourism activities and the socio-cultural character of communities (Hutagalung et al., 2025; Firdasari et al., 2025).

Compared to Thailand and Singapore, Indonesia's advantage lies in the diversity of natural and cultural resources and the enormous potential of local communities. The challenges stem from the size of the area, development inequalities, institutional capacity, and the lack of uniformity in the quality of infrastructure between regions. Indonesia's problem is therefore not only a lack of infrastructure, but ensuring that the infrastructure built is appropriate, inclusive, environmentally friendly, and in accordance with the character of each destination.

1.1 Tourism Digital Infrastructure

Digitalization has become an important part of destination development. Changing tourist behavior is increasing the need for internet connectivity, online booking platforms, social media, digital information systems, and other technology-based services. Digital transformation is not only changing the way tourists obtain information, but also the way destinations market products, communicate with tourists, and run their operations (Aryapranata et al., 2025).

Indonesia has shown positive developments. Studies in tourism villages show that online booking platforms, social media, and increased digital literacy are expanding the visibility of destinations and opening up wider market access for people, who can now promote tourism products and experiences directly without relying entirely on conventional marketing (Aryapranata et al., 2025). However, these developments have not been evenly distributed. Connectivity gaps, financial limitations, low digital literacy, and limited human resources capable of managing technology are still obstacles (Aryapranata et al., 2025). Building an internet network or providing a platform is not enough; new technologies are beneficial if people have the ability and confidence to use them.

This is important because digital transformation is a social and cultural process, not just technology. When local communities are able to manage websites, create content, accept reservations, market products, and use tourist data wisely, technology becomes an instrument of empowerment. On the other hand, if people only become passive users of platforms owned by other parties, there is a risk of dependency and reduced local autonomy (Aryapranata et al., 2025). IoT expands these opportunities: sensors can monitor the number of visitors, energy and water consumption, environmental quality, security, and waste, so that managers can make decisions faster based on real conditions (Nugroho et

al., 2024). Digitalization has also evolved from a promotional tool to a destination management instrument.

Singapore provides lessons on an integrated digital ecosystem, while Thailand is a benchmark in seeing how technology and travel experiences are developed in destinations with diverse geographical and cultural characteristics. However, comparisons at the destination level are not enough. Travel applications, booking systems, and IoT sensors are only as good as the networks and data centers that support them. Therefore, the analysis needs to go down one layer to the backbone infrastructure, namely fiber optic cables, submarine cables, and data centers, which has grown rapidly in all three countries in the past two years.

At this level, the relationship between Indonesia and Singapore shows concrete developments. The Nongsa Changi Cable (NCC) submarine cable was landed at Nongsa Digital Park, Batam, on July 20, 2026. The cable is about 50 km long with 24 pairs of optical fibers built by Telin, a subsidiary of Telkom Indonesia, together with BW Digital. The cable adds a transmission capacity of more than 1.6 petabites per second with a latency of less than 2 milliseconds between Batam and Singapore, and is targeted to be fully operational by September 2026 (detikInet, 2026; GoKepri, 2026; Housing Estate, 2026). Coordinating Minister for Economic Affairs Airlangga Hartarto called this infrastructure the physical foundation of the new digital corridor and emphasized that it is not enough to build it with cables and data centers, but also with trust, partnerships, and a shared vision (Coordinating Ministry for Economic Affairs [Coordinating Ministry for Economic Affairs], 2026; Housing Estate, 2026). This statement is in line with the research framework: even in cross-border digital infrastructure, non-technical factors such as trust and partnership help determine success.

In terms of data centers, Indonesia is recorded as the fastest-growing market in Southeast Asia (Investor Daily, 2026; Brono, 2026). Cushman & Wakefield research cited by Brono (2026) noted that the operational capacity of national data centers is 468 MW, with an additional of about 1,957 MW projected to operate until 2030 and about 4.5 GW of capacity that has been secured through land reserves. This growth forms a two-pole pattern: Greater Jakarta is becoming a center for *hyperscale facilities* for domestic needs, while Batam is developing as a cross-border node for artificial intelligence and high-performance computing (Brono, 2026; Gunawan, 2026). Batam's operational capacity increased by 89% to 82 MW in the first semester of 2026, and its data center industry is said to grow by around 22% per year, above the national average of 19% (Gunawan, 2026; GoKepri, 2026). The Ministry of Communication and Digital projects this industry to grow 14% per year until 2028, with the capacity requirement for artificial intelligence increasing from around 202 MW in 2024 to 743 MW (Directorate General of Digital Infrastructure, 2025). The difference in growth rate between sources reflects differences in data coverage and periods, so it is more accurate to read as a trend direction rather than a definite figure.

Singapore is in the opposite position. The operational capacity of its data centers is around 1,068 MW, but the expansion space is tight: only about 207 MW is in the planning stage due to limited land and electricity supply (Gunawan, 2026). The policy response is the Infocomm Media Development Authority's *Green Data Centre Roadmap*, which targets an additional 300 MW of capacity in the short term, pushing all data centers to achieve a *Power Usage Effectiveness* (PUE) of 1.3 or lower, and linking subsequent capacity growth to green energy (Infocomm Media Development Authority [IMDA], 2024). With these conditions, cooperation like NCC is born from complementarity: Singapore offers global connectivity and a trusted business climate, while Indonesia offers a large market, land, human resources, and renewable energy potential (GoKepri, 2026).

Thailand is on the investment incentive route. In the first half of 2025, the Thai Investment Board (BOI) received data center investment applications worth 521.2 billion baht from 28 projects, and the six projects approved in May to June 2025 alone cover an IT load of about 740 MW in Rayong and Chonburi Provinces (Yong, 2025). The incentive design is relevant for sustainability studies: an eight.

year corporate income tax exemption is only granted if the project meets PUA standards, provides advanced computing services, and implements economic contribution plans in the form of training, partnerships with universities, and SME skills development (Yong, 2025). In September 2026, the BOI again approved three data center projects worth 913 billion baht while accelerating the Electricity Development Plan (PDP) and expanding access to clean energy through *the Direct Power Purchase Agreement* (Direct PPA) and *Utility Green Tariff 2* (Asia News Network, 2026). Thailand, in other words, binds digital expansion to energy efficiency requirements and human resource development from the licensing stage. The picture of the three countries in this layer is summarized in Table 1.

Table 1. Data center infrastructure and its sustainability instruments in three countries

Aspects	Indonesia	Thailand	Singapore
Market position	Fastest growth of data centers in Southeast Asia; two-pole patterns Jabodetabek (domestic) and Batam (cross-country)	New investment objectives through BOI incentives, concentrated in Rayong, Chonburi, and Chachoengsao	The market is mature with land and electricity supply constraints
Capacity and investment	468 MW national operations; Jakarta 356 MW and Batam 82 MW (first semester 2026)	Submission of 521.2 billion baht from 28 projects (first semester of 2025); approval of 913 billion baht for 3 projects (September 2026)	Approximately 1,068 MW operational; approximately 207 MW in planning
Sustainability instruments	Acceleration of the energy mix (Sumatran geothermal, solar PV in Batam) and additional generation targets of around 100 GW; specific standards for green data centers have not been found in the sources reviewed	Conditional tax exemption of PUE standards and HR training plans; Direct PPA and Utility Green Tariff 2	Green Data Centre Roadmap: PUE 1.3 or lower; additional minimum of 300 MW based on efficiency and green energy
Cross-border connectivity	NCC Batam–Singapore: approx. 50 km, >1.6 Pbps, latency <2 ms	Not discussed in the sources reviewed	The NCC landing point in Changi; the global connectivity gateway for the region
Main source	Brono (2026); Gunawan (2026); GoKepri (2026); Coordinating Ministry for the Economy (2026)	Yong (2025); Asia News Network (2026)	IMDA (2024); Gunawan (2026)

Description. Numbers come from different sources and periods and are not intended as formal rankings. PUE = *Power Usage Effectiveness*; Pbps = petabites per second.

Table 1 shows that Indonesia excels in the growth rate, but in the sources examined, no instrument has been found that explicitly links data center permits or incentives to energy efficiency standards, as implemented by Singapore through the PUE target and Thailand through conditional tax incentives. Observers also remind of two risks that accompany Batam's growth, namely the shortage of skilled digital workers and environmental pressures due to the rapid construction of data centers (GoKepri, 2026). Indonesia therefore needs to strengthen connectivity, human resource capacity, system interoperability, and digital policies that are more consistent and connected to the clean energy agenda. The next challenge is to ensure that the centralized capacity in Greater Jakarta and Batam really reaches tourist villages that are still constrained by connectivity.

1.2 Integration of Sustainable and Digital Infrastructure

The most important finding of this study is that sustainable infrastructure and digital infrastructure should not run as two separate agendas, as they reinforce each other. Physical infrastructure provides.

the foundation for tourism activities, while digital technology helps optimize its use, monitoring, and management. Environmentally friendly transportation and facilities are more effective when supported by technology to monitor usage levels, energy consumption, visitor density, and environmental conditions; waste management can be strengthened through digital monitoring; and information on the carrying capacity of the area can be conveyed to tourists through digital applications or platforms (Nugroho et al., 2024).

In this framework, technology is a tool, not an end goal. Technology helps destinations become efficient, inclusive, humane, resilient, and sustainable. This perspective is increasingly important as the character of tourists changes. *Digital nomads* need not only attractive tourist attractions, but also good internet connections, work-supporting accommodations, co-working spaces, and a comfortable social environment, while their growth needs to be managed so as not to cause gentrification and pressure on local communities (Rahmad & Amir, 2026). A destination cannot be called "smart" just because it has a travel app or Wi-Fi network, just as it cannot be called "sustainable" just because it has green open spaces. Both must be connected to governance, human behavior, community participation, and the destination's ability to manage its resources in the long term.

The interconnectedness of the two dimensions is also seen on a national scale. Data centers are the most energy-intensive digital infrastructure, so their sustainability is determined by the electricity system and the availability of renewable energy. Singapore manages this relationship through PUE and green energy targets (IMDA, 2024), Thailand through conditional incentives and Direct PPAs (Yong, 2025; Asia News Network, 2026), while Indonesia links Batam's development with the acceleration of geothermal in Sumatra and solar power plants (GoKepri, 2026). The same logic applies at the destination level: IoT sensors and digital platforms installed to monitor the carrying capacity of the region must not actually increase the environmental burden it wants to control.

From a comparative perspective, Indonesia's position holds both opportunities and challenges. The richness of destinations and communities is enormous, but the scale of the region and the diversity of conditions make integration impossible with a uniform approach. Thailand and Singapore provide lessons, but the models cannot simply be transferred; adaptation needs to be adjusted to the characteristics of the destination, the capacity of local governments, the readiness of the community, and the carrying capacity of the environment.

5. DISCUSSION

1.1. Infrastructure Integration Model

The above findings boil down to a single relationship: sustainable infrastructure provides a physical and ecological foundation, digital infrastructure provides the ability to manage and optimize those foundations, and the integration of the two results in more adaptive and resilient destinations. This confirms a gap in the research that was formulated earlier, namely that there is no study that integrates sustainability and digitalization in a single comparative framework of Indonesia, Thailand, and Singapore. To clarify these relationships, this section proposes a conceptual model that rests on five principles:

- **Infrastructure as a system.** Tourism infrastructure includes the physical devices, technology, and human capacity to manage it; its success is measured by the ability to maintain a balance

between the interests of tourists, the economy, the environment, and the community.

- **Technology as a tool.** Technology serves efficiency, inclusivity, resilience, and sustainability, not the goal itself.

- **Local communities as subjects.** Communities must reap economic benefits and be involved in decision-making, and digital transformation is seen as a socio-cultural evolution.
- **Integration is determined by non-technical factors.** Policy, cross-actor collaboration, and community readiness determine whether the two dimensions are truly connected.
- **Models must be contextual.** Models from other countries need to be studied and adapted, not just transferred.

The model consists of an integration driver, a two-dimensional infrastructure, an integration layer, and an external, plus a feedback mechanism and a contextual adaptation layer (Figure 1).

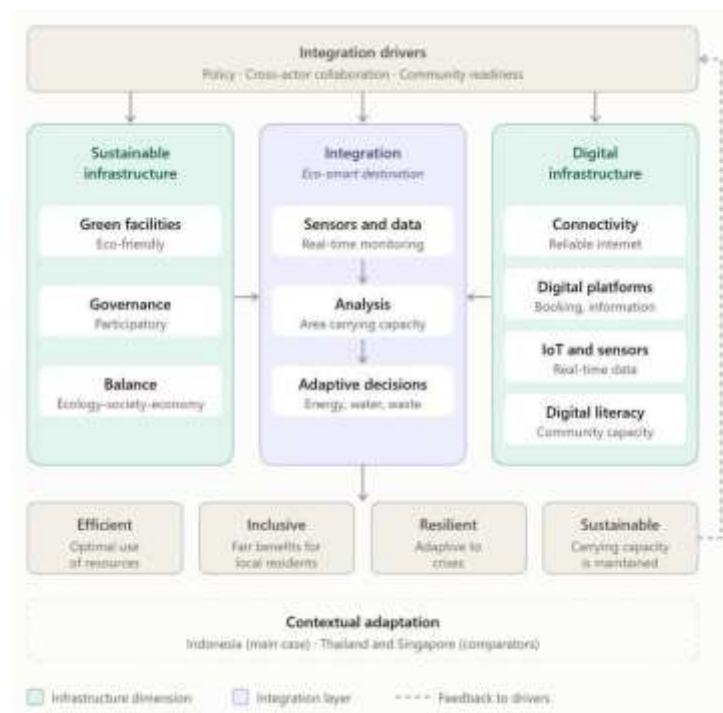


Figure 1. Integration model of sustainable and digital tourism infrastructure

The *sustainable infrastructure dimension* becomes a physical and ecological foundation through green facilities (transportation, tourist routes, parking areas, and sanitation designed to reduce ecological pressures, especially in coastal and mountainous areas), participatory governance (community-based tourism that encourages participation and resilience of local economies), and ecological-socio-economic balance measured through indicators such as tourists' carbon footprint and environmental carrying capacity indices (Hutagalung et al., 2025; Firdasari et al., 2025). The *digital infrastructure dimension* provides management and empowerment capabilities through connectivity, digital platforms, IoT sensors, and digital literacy; without literacy, people are at risk of becoming passive users of third-party platforms (Aryapranata et al., 2025; Nugroho et al., 2024). The drivers of integration are beyond the two dimensions but determine their relationship (Table 2).

Table 2. Integration drivers in models

Drive	Roles in models	Basis of findings
Policy	Aligning physical and digital agendas and supporting green investments	Cross-sectoral integration and alignment on green investment need to be strengthened (Hutagalung et al., 2025)
Cross-actor collaboration	Connecting the government, managers, business actors, and the community	The success of digital systems depends on the collaboration of actors (Firdasari et al., 2025)
Community readiness	Ensuring that technology can be used and managed by residents	The knowledge gap of the community is the main obstacle (Firdasari et al., 2025)

The *eco-smart destination layer* distinguishes this model from the physical and digital agendas that run separately. This layer works in three consecutive steps. Sensors and data monitor the condition of sustainable infrastructure in *real-time*, such as tourist density, energy and water consumption, air quality, and waste volume. The area's carrying capacity analysis compares the data with the destination's capacity limits, so that the problem of *overtourism* can be answered because the threshold can be known and informed to tourists through digital platforms. Adaptive decisions then allow managers to regulate the flow of tourists, optimize energy and water, and schedule waste management and facility maintenance. Through this flow, digitalization serves as a management instrument, not just a promotional tool, and sustainability extends from building green facilities to the way they are used and managed.

The model is directed at four complementary outputs: efficiency of energy, water, and operational utilization; inclusivity, so that economic benefits are felt fairly by local communities and the risk of managed gentrification; resilience, given that the impact of crises differs between urban and rural areas (Jang et al., 2021); and the sustainability of the carrying capacity of destinations in the long term. Outputs do not stop at the end result. Issues such as overcrowding or low use of platforms by citizens are returned to integration drivers as material for policy evaluation, strengthening collaboration, and community training, so that the model works as a learning cycle and not a one-way program.

1.2 Contextual Adaptation in Three Countries

Indonesia combines a wealth of natural and cultural resources and large community potential with regional scale challenges, development inequalities, institutional capacity, and non-uniform infrastructure quality. The *100 Smart Tourism Villages* program demonstrates the government's commitment, but its benefits are uneven due to poor connectivity and limited training (Aryapranata et al., 2025). Canggu is growing organically into a *digital nomad hub* with significant sustainability challenges, while Labuan Bajo and Mandalika do not yet have a structured strategy (Rahmad & Amir, 2026). At the digital backbone, Indonesia recorded the fastest growth of data centers in Southeast Asia and acquired new connectivity corridors through NCCs (Brono, 2026; Coordinating Ministry for the Economy, 2026), but the benefits for destinations outside Greater Jakarta and Batam still need to be bridged.

Singapore shows the importance of an integrated digital ecosystem, which is an interconnected system and not a stand-alone application. Singapore also links the growth of data centers to energy efficiency and green energy standards (IMDA, 2024), as well as utilizing neighboring areas such as Batam through the NCC corridor to overcome land and electricity limitations (Gunawan, 2026;

Coordinating Ministry for the Economy, 2026).

Thailand is a benchmark in the development of technology and tourism experiences in diverse destinations, and at the backbone, in requiring investment incentives in energy performance and workforce development (Yong, 2025).

Given the scale and diversity of its region, Indonesia needs to differentiate the application of the model according to the characteristics of the destination, the capacity of local governments, the readiness of the community, and the carrying capacity of the environment. Tourist villages with limited connectivity can start from basic components such as QR-Code, booking platforms, and digital literacy, while congested areas such as Bali can move to sensor-based capacity monitoring.

1.3 Theoretical implications

This study expands the study of sustainable tourism by combining two dimensions that have been discussed separately, namely sustainable infrastructure and digital infrastructure, in one comparative framework of Indonesia, Thailand, and Singapore. These findings reinforce the view that tourism infrastructure is a system consisting of physical devices, technology, and human capacity (Firdasari et al., 2025), so its success is not sufficiently measured from the completeness of facilities. The resulting model, with its integration drivers, *eco-smart destination* layers, outputs, and feedback mechanisms, offers a new analytical framework that places technology as a tool and digital transformation as a socio-cultural evolution (Aryapranata et al., 2025). The study also complements previous comparative studies limited to Lisbon and Canggu with a *focus on digital nomads* (Rahmad & Amir, 2026).

1.4 Practical and Policy Implications

For the central government, the physical and digital infrastructure agendas need to be aligned in a single policy, not run as separate programs, and cross-sectoral integration and alignment with green investment need to be strengthened (Hutagalung et al., 2025). The *100 Smart Tourism Villages program* needs to be accompanied by expanded connectivity and training (Aryapranata et al., 2025). Governments can also adopt the practices of Singapore and Thailand by linking data center incentives to energy efficiency standards, renewable energy utilization, and local workforce training, so that the growth of digital infrastructure is in line with the sustainability agenda (IMDA, 2024; Yong, 2025).

For local governments and destination managers, the application of the model must be differentiated according to destination characteristics, regional capacity, community readiness, and environmental carrying capacity. Sensor and data flows, carrying capacity analysis, and adaptive decisions can help overcome *overtourism* through the regulation of tourist flows and energy, water, and waste management.

For the community and business actors, the community needs to be positioned as subjects, not passive users of third-party platforms. Digital literacy is key so that technology functions as an instrument of empowerment and does not cause dependency that weakens local autonomy (Aryapranata et al., 2025). For the *digital nomad segment*, destinations such as Canggu, Labuan Bajo, and Mandalika need structured strategies that protect communities from the risk of gentrification (Rahmad & Amir, 2026).

For all stakeholders, collaboration between the government, managers, business actors, and the community is a prerequisite, because the success of the digital system depends on this cooperation (Firdasari et al., 2025). Data privacy and security risks, technological compatibility, and the magnitude

of investment needs also need to be anticipated (Nugroho et al., 2024).

1.5 Limitations and Directions of Further Research

This analysis is conceptually comparative and not a quantitative measurement or formal ranking of the three countries, as it relies on documents and findings of previous studies; the definition and scope of indicators between countries may also differ. Subsequent research is recommended to validate the model empirically through field studies in all three countries, develop measurable indicators such as the carbon footprint of tourists and environmental carrying capacity indices (Becken, 2022, in Hutagalung et al., 2025), as well as test models on destinations with different characteristics.

6. CONCLUSION

This study compares sustainable and digital tourism infrastructure in Indonesia with Thailand and Singapore. For the first question, Indonesia excels in the diversity of natural and cultural resources and the potential of local communities, but its implementation is uneven and is still overshadowed by *overtourism*, unplanned development, weak cross-sector coordination, development inequalities, and inconsistent infrastructure quality. The main problem is not the lack of infrastructure, but ensuring that infrastructure is appropriate, inclusive, and environmentally friendly.

For the second question, digitalization in Indonesia is growing through online booking platforms, social media, and digital literacy in tourist villages, but connectivity gaps, financial limitations, and low human resource capacity still hinder equity. Singapore provides lessons about an integrated digital ecosystem, while Thailand is a benchmark for technology development in diverse destinations. At the backbone, Indonesia is growing the fastest in data center capacity and strengthening the digital corridor with Singapore through the NCC, but still lags behind in the instruments that tie that growth to energy efficiency.

For the third question, sustainable and digital infrastructure reinforce each other and should not run as separate agendas. Sustainable infrastructure provides a physical and ecological foundation, digital infrastructure allows for optimal management, and its integration is determined by policies, cross-actor collaboration, and community readiness, resulting in efficient, inclusive, resilient, and sustainable destinations.

For the fourth question, lessons learned from Singapore and Thailand should be adapted to the Indonesian context, not simply transferred. The main recommendations are to align physical and digital policies, expand connectivity and training, gradually implement models according to the character of the destination, and strengthen collaboration and community empowerment. The success of tourism is ultimately not determined by how modern the infrastructure is, but by how well it responds to human needs, safeguards the environment, strengthens the local economy, and keeps destinations relevant in the long term. This is what it means *beyond physical boundaries*: looking at infrastructure as an ecosystem that connects space, technology, people, economy, and the environment.

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