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Digitalizing Heritage: A GIS-QR Integrated Framework for Smart Tourism Development in Cao Bang UNESCO Global Geopark

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ABSTRACT: As the tourism industry undergoes a digital transformation, the integration of advanced technologies is becoming essential for managing complex heritage sites. This study proposes a comprehensive framework for digitalizing tourism resources in Cao Bang province, a region characterized by the UNESCO Global Geopark status. The research focuses on two core technical objectives: the construction of a multi-layered Geographic Information System (GIS) database and the deployment of Quick Response (QR) code interfaces to optimize data accessibility. Using a mixed-methods approach, including spatial data modeling and a survey of 475 stakeholders, the findings reveal that a unified GIS-QR ecosystem significantly enhances the "on-site" experience for tourists while providing authorities with a robust tool for resource monitoring. Specifically, the high digital readiness of visitors (79.3% adoption rate) underscores the potential for smart tourism transition in mountainous border regions. The study further addresses technical barriers by proposing encrypted dynamic QR codes and a hybrid offline-online access model. Ultimately, this research provides both a theoretical model and a practical roadmap for transforming traditional heritage assets into digital tourism resources, ensuring sustainable development in the era of Industry 4.0.

KEYWORDS: Digital Heritage, GIS, QR Codes, Smart Tourism, UNESCO Global Geopark, Cao Bang.

INTRODUCTION

The Fourth Industrial Revolution (Industry 4.0) has profoundly impacted all facets of social life and various economic sectors. In Vietnam, the Industrial Revolution 4.0 poses both opportunities and challenges for the tourism industry. The application of Information Technology helps the tourism industry to promote, introduce, and develop more quickly, stimulating the growth of sustainable tourism. Cao Bang province is richly endowed with natural beauty, boasting not unique biodiversity and significant geoheritage values but also a concentration of famous historical and archaeological relics. Therefore, Cao Bang province has the potential and strengths to develop tourism into a key economic sector, forming many famous tourist destinations. However, despite the rapid increase in tourist arrivals to Cao Bang province in recent years, the level of visitor satisfaction with the destination remains low. Tourist destinations seem to have only stopped at the level of introducing and promoting tourist attractions, but have not yet collected and provided information in a flexible, diverse, and systematic way to traders, managers, and tourists, so orienting the development of the tourism industry sustainably faces many difficulties.

In this context, tourism databases are increasingly important and popular in the digitization of the tourism industry. With the rapid development of technology and the internet, this industry has adopted and leveraged big data to o enhance the visitor experience. At the same time, optimize business operations and predict future trends. The construction of a general tourism database in Cao Bang province, combined with the application of technology to exploit the Tourism Database, plays an important role and is the initial foundation in the development of smart tourism. This enhances the efficiency of marketing and promotional activities, manages customer information, increases the attractiveness of tourism products, improves the quality of the tourist destination experience, and facilitates market prediction and analysis, thereby improving the effectiveness and efficiency of state management.

Building a comprehensive database for Cao Bang is not just a technical solution; it contributes to STE theory by proposing a Multi-layered Data Integration Model for border destinations. Research indicates that, for destinations with limited resources, prioritizing GIS digitization and communication via QR codes is a crucial step towards developing 'Destination Intelligence,' enabling ecosystems to self-regulate based on data rather than subjective experience.

Therefore, in this article, we will present the research on building a comprehensive tourism database, applying QR codes to develop smart tourism in Cao Bang province, with the desire to improve the experience of tourists, attract tourists, and thereby contribute to promoting the tourism industry of Cao Bang province to develop further.

OVERVIEW OF RESEARCH LITERATURE AND METHODS

Documentation overview

Amidst the trend and requirements of smart tourism development, tourism businesses and organizations are increasingly recognizing the necessity of establishing a comprehensive tourism database. The Department of Travel has coordinated with the Tourism Information Center (Vietnam National Administration of Tourism) to build and manage the online database website www.huongdanvien.vn. On this website, we introduce the national network of tour guides and offer comprehensive support for the profession. Our resources include guidance on policies and procedures for applying for a tour guide license, programs for professional training and retraining, information on tourism education institutions, and details about career opportunities for guides. Along with the database of guides, the Department of Travel also coordinates with the Tourism Information Center to build a database website on international travel businesses at the website: www.quanlyluhanh.vn.

According to Le and Nguyen (2019), "Building an information database model for *smart tourism destinations: A case study of Hue City".* The authors have researched, collected, identified and classified 4 groups of information needs about a smart tourism destination that tourists are interested in: (1) accommodation facilities (hotels, motels, etc.); (2) attractions and entertainment; (3) services (shopping, dining, transportation) at attractions and entertainment; (4) Other information (weather conditions, security alerts, epidemics, etc.). Lan Phuong Nguyen Thi, Van Hai Do (2020), *"Building a general database for tourism development in Lao Cai province using GIS and remote sensing technology".* The authors have researched, collected, identified, and classified natural, eco-tourism destinations, festivals, and cultural characteristics in Lao Cai province. Since then, the compilation has completed the database of tourism potential in Lao Cai province (including all tourist attractions with spatial and attribute data). Thi Hoai Thuong Vo & Van Phuong Nguyen (2019) *"Building a database to promote the culinary value of Nghe country"* have proposed to build a list of tourism data layers that need to be built into 4 groups: (1) Tourism services, (2) Humanistic tourism resources, (3) Natural tourism resources, (4) Tourism figures. In particular, the culinary culture database belongs to the tourism services category. However, existing studies have generally failed to address database construction based on the format of tourist destinations, nor have they focused on developing a tourism database specifically for Cao Bang province. While smart tourism is a growing field, a significant gap exists in how to integrate spatial (map-based) and non-spatial data for mountainous border regions like Cao Bang. Most previous studies have focused on urban areas or simple information systems, often ignoring the powerful combination of GIS and QR codes to improve the visitor experience at remote heritage sites.

Currently, tourism management in Cao Bang relies on fragmented data, which makes it difficult to monitor resources and engage visitors effectively. Furthermore, there is a lack of practical evidence on how a unified provincial database can connect local managers with international tourists within a Global Geopark. This research fills these gaps by proposing a framework to digitize tourism assets and optimize access through an integrated GIS-QR ecosystem. This provides a practical roadmap for smart tourism in similar geographic areas.

Based on the identified gaps and the provincial digital transformation goals of Cao Bang, this study addresses the following three research questions: (**RQ1)** How can a multi-layered tourism database be designed and standardized to integrate spatial GIS data with the diverse natural and cultural heritage attributes of the Non Nuoc Cao Bang Global Geopark? (**RQ2)** In what ways can GIS technology and QR code applications be utilized to effectively exploit this database for enhancing visitor accessibility and smart management at tourist destinations? (**RQ3)** What is the current level of technology readiness among stakeholders, and what are the primary barriers to the adoption of QR-based tourism services in a mountainous destination context?

Theoretical Framework

The conceptual foundation of this study is rooted in the Smart Tourism Ecosystem (STE) framework and the Technology Acceptance Model (TAM). According to Gretzel et al. (2015), an STE is defined as a digital-physical platform that supports the exchange of data and the co-creation of value among various stakeholders, including tourists, local authorities, and service providers. Central to this ecosystem is the "Infostructure" layer—the systematic integration of hardware, software, and data repositories that enables a destination to transition from a traditional to a "smart" state.

In the context of Cao Bang province, the development of a general tourism database serves as the fundamental Data Layer of the STE, providing the "Destination Intelligence" necessary for informed decision-making. By integrating Geographic Information Systems (GIS), this study extends the STE theory into the spatial dimension, transforming static information into dynamic, location-aware assets that mitigate information asymmetry in remote mountainous regions. Furthermore, the application of QR Code technology is analyzed through the lens of TAM, which posits that Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) are the primary determinants of a user's intention to adopt new technology (Davis, 1989).

This research contributes to the existing literature by proposing a Hybrid Integration Model where digital touchpoints (QR codes) act as the physical-digital interface (Phygital), bridging the gap between the tourist's immediate

environment and the province's centralized GIS database. By doing so, the study shifts the focus from purely technical data management to a Data-Driven Destination Management approach, emphasizing how technological convergence can enhance the resilience and competitiveness of emerging ecotourism destinations in the Fourth Industrial Revolution

Research methods

To address the research questions effectively, this study employs a mixed-methods approach, combining qualitative systematic modeling with quantitative empirical analysis. The research process is divided into three primary phases: (i) *Framework for Database Development*: The construction of the tourism database followed a systematic 10-step process, ranging from data collection to final product acceptance. Data Inventory: Secondary data were synthesized from official reports of the Cao Bang Provincial People's Committee (2023) and the Department of Culture, Sports, and Tourism. Data Classification: Following the model proposed by Le and Nguyen (2019), the database was structured into seven functional layers: (1) Background data, (2) Tourism resources, (3) Accommodation, (4) Attractions, (5) Services, (6) Human resources, and (7) Supplemental information (weather/security). Field Investigation: Primary data were gathered through field surveys to verify the spatial coordinates and attribute characteristics of key sites, such as Ban Gioc Waterfall and Nguom Ngao Cave. (ii) *Technical Implementation and Data Exploitation:* This phase focuses on the technical integration of GIS and QR code technologies to exploit the digitized data. Geospatial Modeling: Using GIS technology, spatial data (points, lines, and polygons) were linked with non-spatial attributes (history, utility, and descriptions). This allowed for the creation of heritage density maps and conservation zoning for the Non Nuoc Cao Bang Global Geopark. Interface Design: The study implemented a system where information is encoded into QR codes. These codes serve as a direct interface, allowing users to scan and retrieve real-time multimedia content hosted on the provincial tourism portal. *(iii) Stakeholder Survey and Technology Readiness Analysis*: To evaluate the practical effectiveness and adoption barriers, a quantitative survey was conducted. Participants: The study utilized a sample of 475 respondents, including 250 tourists, 15 business owners, 60 tourism staff, and 150 local community members. Demographics: The majority of participants were in the 18–40 age bracket (94.2%), representing the primary demographic for smart tourism applications. (iv) *Expert Interviews*: Interview tourism management officials and IT experts to verify the data flow diagram. (v) *Data Analysis*: Quantitative methods were used to measure the frequency of QR code usage, which reached 79.3% among respondents, and to identify barriers such as internet connectivity and cybersecurity concerns.

Furthermore, the application of GIS enables the analysis, evaluation, and creation of several outcome maps, including Resource maps and tourism resource assessment maps, maps illustrating tourism facilities, maps of tourist routes, points, and core areas (nuclei), and a map detailing the spatial orientation for tourism development.

RESULTS

The concept of 'smart tourism' or 'smart tourism system' gained popularity with the advent of the Fourth Industrial Revolution (Industry 4.0). Essentially, smart tourism is a specific application within the smart city framework, leveraging technological infrastructure to enhance the visitor experience.

Consequently, in Cao Bang province, the development of a comprehensive tourism database, along with the application of GIS and QR codes to exploit this data for tourism growth, represents an urgent requirement.

Building a comprehensive tourism database for the development of smart tourism in Cao Bang province

The database has been mentioned in the Law on Information Technology and documents related to the implementation of information technology applications in state agencies (Lorenzo Ardito, 2019 & Ardito, L., 2019). As defined by the Oxford Dictionary: "A database is a structured collection of data stored in a computer, which in a particular way can be accessed in different ways." To build a tourism database information system, it is necessary to rely on constituent factors such as tourism resources (scenic spots, historical-cultural relics, and tangible and intangible cultural heritages); infrastructure system and facilities for tourism; entertainment spots, additional works for tourism... thereby building a comprehensive tourism database model in Cao Bang province.

Based on the analysis, synthesis and evaluation of factors that tourists are interested in at a destination, the authors propose a tourism database model for smart tourism development including data layers of information on interested tourists: *(1) Background data layer, (2) Tourism resource data layer, (3) accommodation facilities* (hotels, motels, etc.)*; (4) attractions and entertainment; (5) services* (shopping, dining, transportation) *at attractions and entertainment; (6) Personnel serving in tourism (7) other information* (weather conditions, security warnings, epidemics, etc.). For the group of accommodation facility information, the survey results show that the information that tourists are most interested in includes: the name of the accommodation establishment, user rating of the accommodation establishment, room rates that may change according to the season (real time), the address of the website to make the reservation, and the accommodation establishment located on Google map. Based on this, the Accommodation class was built. For the group of information about attractions and entertainment, a general class Tourist_attraction. For the group of information about services at attractions and entertainment, the authors created a class called Service. The

Tour Guide Information group encompasses data on both domestic and international guides. The Weather Conditions and Epidemic Security Warnings information is designated to form the 'Other Information' category.

The process of building a comprehensive database for smart tourism development is initially implemented: *(1) Collecting tourism database information content => (2) Analyzing tourism data content => (3) Designing a tourism database model => (4) Building a data catalog and entering data => (5) Tourism data in numerical form => (6) Standardization and design of appropriate tourism data => (7) Tourism data editing => (8) Product inspection => (9) management and testing of the use of tourism data => (10) Acceptance of tourism database products. In this process: In step (5),* if the travel data is missing, continue to supplement the data information, and *return to the process from step (1).*

Within the tourism data system, information regarding resource potential and current tourism status is vital and requires substantial investment. Given its unique natural conditions and resources, Cao Bang province possesses favorable characteristics for tourism development. Cao Bang tourism is not only a key economic sector but also has a close relationship with many other fields (Cao Bang Provincial People's Committee, 2023). The development of tourism contributes to promoting economic growth through the creation of income, employment, investment attraction, and increased foreign exchange earnings. At the same time, tourism also supports the development of related industries such as transportation, accommodation, entertainment, OCOP production, handicrafts, and medicinal herbs, creating a driving force for the local economy.

Natural tourism resources include: (1) *Geological and topographic resources*: this is the most important and characteristic natural tourism resource of the province. With high geological and topographic values, Cao Bang Non Nuoc Geopark has been recognized by UNESCO as a global geopark. Non Nuoc Cao Bang is Vietnam's second Global Geopark, following the Dong Van Karst Plateau Geopark in Ha Giang province. To date, scientists have successfully identified, evaluated, and proposed the ranking of over 130 unique geological heritage sites. These sites boast rich and diverse karstic landscapes, including stone towers, cones, valleys, caves, and complex river, lake, and underground cave systems. Furthermore, other geological heritage types, such as paleontological fossils, have also been identified. Cao Bang has many high mountain peaks interspersed with narrow valleys, especially the widely distributed karst terrain has created many beautiful landscapes such as Ngom Ngao cave, Ban Gioc waterfall (Chongqing), Thang Hen lake, Mat Than mountain (Quang Hoa), passes (Ma Phuc, Khau Coc Cha, Me Pia), etc, high peaks (Phia Ya 1970 m, Phia Oac, Phia Den), ...; (2) *Climate resources*: climate is an important natural component that has the effect of attracting tourism participants. Climate affects travel through 2 main factors: temperature and humidity. For the territory of Cao Bang, Most temperature and humidity indicators are suitable for year-round tourism activities, although the annual thermal amplitude remains unfavorable. In winter, on high mountain peaks such as Phia Ya (1,987 m), Phia Oac (1,931m), snowfall appeared. This phenomenon only appears in a few mountain peaks of the North of our country and is an attractive feature for tourists to explore and experience; (3) *Resources of rivers, lakes and waterfalls*: Cao Bang does not have many rivers and lakes, although they are not large, but they are very valuable for tourism, typically can be mentioned as Ban Gioc waterfall, Thang Hen lake, Ban Viet lake, Khuoi Lai lake, Thoong Loc waterfall, Thoong Ma waterfall ... In addition, rivers such as the Gam River and Quay Son River are very valuable in developing some types of tourism, such as experiential boating, sports, adventure, etc.; (4) *Biological resources*: Cao Bang has a fairly large forest area, over 370,000 hectares, with a forest coverage rate of over 55%. In which the natural forest area accounts for over 353,000 hectares. Concurrently, the province is renowned for its significant biodiversity, harboring numerous endemic ecosystems, species, and varieties of flora and fauna. Important areas with high biodiversity levels of the province are: Phia Oac – Phia Den National Park, Cao Vit Gibbon Conservation Area, Thang Hen Habitat Species Conservation Area, Pac Bo Landscape Protection Area, and Tran Hung Dao Forest.

Cultural tourism resources: Cultural tourism resources are highly diverse, encompassing a rich collection of tangible and intangible assets. These include historical and revolutionary relics, cultural and spiritual sites, archaeological sites, architectural heritage, traditional festivals, distinctive cuisine, craft villages, and other intangible cultural forms. These resources are often combined with natural landscapes to create unique features for Cao Bang tourism. (1) *Cao Bang historical relics*: the province has more than 200 relics of all kinds, of which 98 relics have been ranked, including 3 special national relics, 26 national relics, and 69 provincial relics. Special national-level relics such as Pac Bo relic, Tran Hung Dao forest relic, 1950 border victory relics are of great significance in the province's tourism development planning; (2) *Traditional festivals*: including several festivals such as the Long Tong festival (the festival of going down to the fields), the Thanh Minh festival of the Nung people, the festival of Pac Bo sources, the festival of Ban Gioc waterfall tourism and other temple festivals (Vua Le temple, Ky Sam temple festival, etc Gie Doong temple festival, Sung Phuc pagoda festival...); (3) *Folk performing arts*: Cao Bang is inhabited by ethnic minorities such as Tay, Nung, Mong, Dao, San Chi, Lo Lo, each ethnic group owns its own unique folk art treasures. Typically, such as: Then singing of the Tay people, singing sli, gliding of the Nung people, singing Pao Dung of the Dao ethnic group, trumpet dance of the Mong people...; (4) *Traditional craft*

villages: Cao Bang is also known to tourists for its long-standing traditional craft villages: brocade weaving in Ha Quang, beeswax pattern printing of the Dao Tien people, Phia Thap incense making, sugar making (Phuc Sen - Quang Hoa), paper making, etc silver carving, lute crafting, blacksmithing village of the Nung An people (Phuc Sen commune, Quang Hoa district); (5) *Village landscape*: villages and hamlets of ethnic minority communities are also a strength in the province's tourism development. Many villages and hamlets also retain unique and attractive cultural features, such as: Pac Rang community tourism village, Phia Thap community tourism village, Giuong village, the traditional cultural village of Tay ethnic groups Khuoi Ky village, community tourist spot Khuoi Khon village (Bao Lac), community tourist attractions in Hoai Khao village, and Lung Luong village.

Possessing diverse and rich tourism resources, including majestic natural landscapes and unique cultural heritage, Cao Bang is steadily affirming its tourism brand on Vietnam's map. The province's typical tourism products not only carry unique experience values but also contribute to preserving indigenous culture, promoting economic development, and improving the quality of tourism services. Currently, Cao Bang focuses on effectively exploiting four main product lines: cultural and historical tourism, eco-tourism, community tourism, and border tourism. (*i*) *Cultural and historical tourism*, (*ii*) *Ecotourism*, (*iii*) *Community tourism,* (*iv*) *Border tourism operates sightseeing and shopping tours* (*v*) *spiritual tourism, and MICE tourism*. However, compared to its potential, Cao Bang tourism is still limited, not fully exploiting the advantages of its resources. Tourism products must be further diversified, with a focus on developing signature offerings and strengthening experiential activities to ensure longer visitor stays.

In recent years, tourist arrivals to Cao Bang province have increased significantly. During the period 2016–202X, Cao Bang welcomed over 5 million visitors, including 420 thousand international arrivals, generating revenue exceeding 1,200 billion VND. However, the province faces challenges as the majority of tourists are domestic (92.9%), and the average length of stay remains short (1.4 days). Visitors primarily originate from Hanoi and the Northeastern provinces, often concentrating on key attractions such as Ban Gioc Waterfall, Pac Bo, and Ngom Ngao Cave. Looking ahead, the tourism sector is projected to recover and achieve remarkable milestones in 2024. According to the Department of Culture, Sports and Tourism, the total number of tourist arrivals in Cao Bang reached 1,834,730, including 49,097 international visitors.

Significantly, Cao Bang has been recognized for the first time in the Top 10 Friendliest Destinations in Vietnam, an award presented by Booking.com—a global ticket and accommodation booking platform—within the framework of its 12th annual Traveller Review Awards. Ban Gioc Waterfall is in the Top 21 most beautiful waterfalls in the world, selected by Travel+Leisure International Travel Magazine to introduce to tourists, affirming the attractiveness of Cao Bang tourist attractions to domestic and foreign tourists

- Tourism general database application: After completing the tourism general database of Cao Bang province, the dataset can be applied to different subjects. For tourism managers and businesses, the database is structured into distinct data layers representing spatial features, organized as lines (roads), points (attractions), and polygons (regions/areas). Therefore, it is easy for managers to monitor, observe, exploit, and update data for tourism management purposes. For users, the database will provide the following application functions (I. Roiby, 2019): (1) *Search for information*: This is the basic function of the database, helping users search for tourist attractions and related service points in the province. (2) *The 'View Information with QR Code' function* is the most frequently utilized feature within the tourist database. It allows visitors to access detailed information about attractions and on-site facilities. This function directly addresses the basic informational needs of tourists seeking essential data and visual content for their intended destinations. The displayed information can cover both the attractions themselves and related points of interest. (3) *Determine the distance*: Travelers can easily know their distance and route to reach the tourist destination, as well as the map to guide visitors. Help tourists have an overview of the destination area, create convenient conditions for tourists to plan and arrange routes to visit, eat, and sleep.

The finalized general tourism database for Cao Bang province is crucial for the effective state management of tourist attractions, providing a robust scientific foundation for local tourism planning and development. Furthermore, this database serves as a vital tool to promote the region and support tourists in their journey planning and scheduling. and support tourists in learning about destinations, planning their itineraries, and scheduling travel. Concurrently, it contributes significantly to the construction of a comprehensive national tourism database.

Application of GIS technology in the construction and exploitation of spatial databases and information on tourism map attributes of Cao Bang province

The application of GIS technology in building Cao Bang province's tourism map database involves collecting and digitizing the spatial and attribute data of tourism objects, then integrating and managing them within a database capable of querying, analysis, and visualization on digital maps.

This technology is vital for closely linking spatial data (geographical location) with attribute data (such as name, description, utility, and history), thereby overcoming the limitations of traditional methods and enhancing the efficiency of sustainable tourism management, exploitation, and development for the province.

The GIS technology application process involves the following key stages (Lan Phuong Nguyen Thi, Van Hai Do,

Van Hung Hoang, Van Cuong Tran Pham, 2020): (1) *Data Collection and Standardization*: Data Collection (Spatial Data and Attribute Data): Utilize GIS tools to digitize tourism objects (e.g., monuments, scenic spots, hotels, restaurants, and routes) into distinct data layers (points, lines, and polygons). Standardization and Input: Standardize and input attribute information into the database, ensuring consistency and accuracy. Database Organization: Structure the database according to specific themes and data layers for efficient access and management. (2) *Data Analysis and Exploitation*: Spatial Analysis: Employ GIS's spatial analysis tools to analyze tourism data, including potential zoning, current status assessment, and spatial planning. Output Generation: Generate essential outputs such as attraction routes and information maps detailing tourism businesses, hotels, and restaurants.

Displaying information on data layers on digital tourism maps, allowing users to query detailed information about each object, and view maps by topic (e.g., maps of historical sites, maps of adventure tourism routes).

Table 1: Spatial data structure for building a tourism database in Cao Bang province.

Group	Data Layer	Type	Key Attributes (Data Fields)
I. Background Data	Administrative Boundaries	Polygon	Name, Area, Administrative Level, Population
	Hydrology (Rivers/ Lakes)	Line/ Polygon	Name, Type (River/Lake), Water level
	Transportation Network	Line	Road Name, Type (National/Provincial), Length, Width
	Relief/Topography	Raster/ Point	Elevation, Slope, Contour intervals
II. Tourism Potential	Natural Resources	Point/ Polygon	Site Name, Classification (Waterfall/Cave/Geopark), Biodiversity index
	Cultural Resources	Point	Relic Name, Ranking (Special National/Provincial), History, Heritage Type
	Resource Evaluation	Polygon	Potential Level, Carrying Capacity, Priority Development Zone
III. Infrastructure	Accommodation Facilities	Point	Hotel Name, Rating, Room Rate, Capacity, Website URL
	Service Points	Point	Restaurant Name, Cuisine Type, Shopping, Medical Facilities, ATMs
	Tourist Attractions	Point	Site Name, GPS Coordinates, QR Code ID, Operating Hours

All collected data are converted into a digital format suitable for GIS software (Feng, R., & Morrison, R.M., 2011), resulting in the creation of essential base maps and tourism maps for Cao Bang province. These outputs include specialized tourism maps of typical areas and attractions. Adding New Objects: Using GIS tools, dataset administrators can easily integrate new objects into the tourism database. As the database is managed, new attractions, hotels, restaurants, motels, amusement parks, or medical sites can be readily incorporated. Managers can swiftly update the system by simply adding new data or initiating the editing functions. Modifying Objects (Spatial and Non-Spatial): Object modification encompasses changes to both spatial and non-spatial attributes. For instance, infrastructure investment (e.g., in traffic) during socio-economic development requires updating road width and type. Similarly, adding new gas stations or ATMs necessitates immediate and synchronous data updates for users. Furthermore, modifications to attribute information, such as the facilities provided by operators, health stations, and markets, can also be updated via the Start Editing function. The Cao Bang system, managed via GIS technology, allows administrators to perform comprehensive management tasks, including adding, correcting, and deleting objects, as well as controlling information layers and attributes.

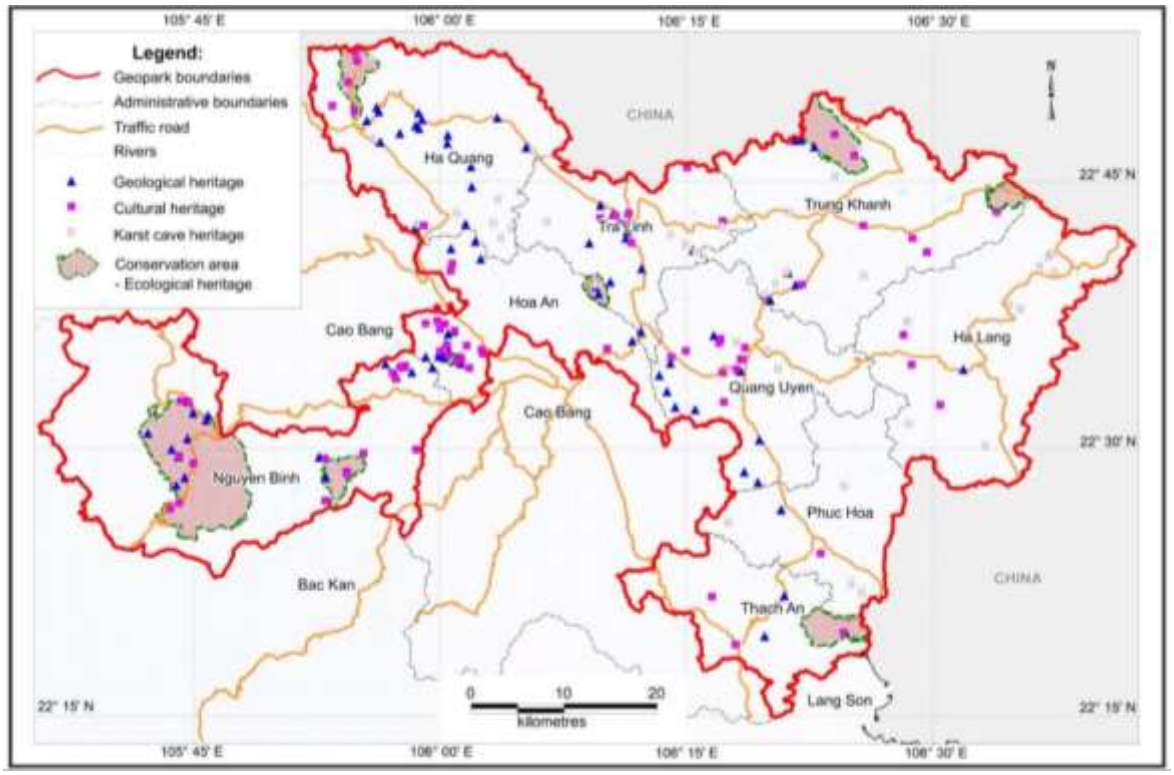

Fig. 1 Heritage density at the Non Nuoc Cao Bang Global Geopark (Dieu Trinh Nguyen, Quoc Lap Kieu, 2024)

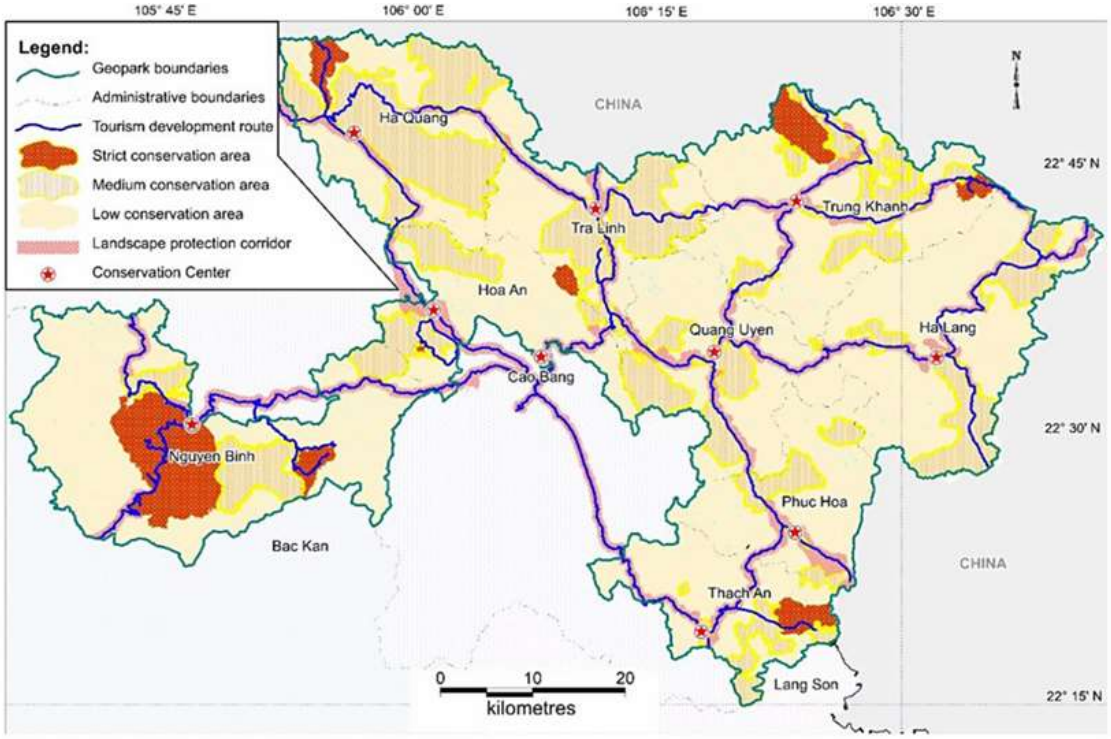

Fig. 2 Map of heritage conservation zoning in the Non Nuoc Cao Bang Global Geopark

This synchronous tourism database is especially valuable for tourism managers, aiding in the planning, orientation, and development of specific tourist routes and areas within the province. For end-users, the database serves the primary purpose of managing and promoting tourism to a broad visitor base.

Exploiting QR Codes and general databases for tourism development in Cao Bang province

A "QR code" (Quick Response Code) is a two-dimensional barcode that can be used to encode a certain type of information. Initially developed in Japan in 1994, QR codes have since been widely adopted globally, primarily driven by

the significant advancements and deep penetration of mobile and internet services. "QR Codes" represent a powerful and fast way to access the Website for many purposes; Among them are advertising, operational, and social interaction purposes. "QR codes" have recently been used by the tourism, hospitality, and aviation industries in addition to cultural heritage sites and attractions.

The rapid proliferation of mobile devices, coupled with round-the-clock Internet connectivity, has simplified customer access to product and service updates. Globally, smartphone penetration is significant: According to a Ministry of Science and Technology report, 63% of the world's 7.3 billion phone users utilize smartphones, a figure that rises to over 84% in Vietnam.

Vietnam also boasts extensive 4G coverage (99.8%), slightly surpassing high-income countries (99.4%). This explosive penetration of mobile devices, along with the inherent benefits during use, is the primary factor driving the emergence and widespread adoption of QR codes. "QR Codes" can be generated using a code generator and decoded using a mobile camera or a downloadable scanning app. "QR Codes" can be generated using a code generator and decoded using a mobile camera or a downloadable scanning app.

Table 1: Online and offline usages of "QR codes" (I. Roiby, 2019)

"QR codes"	
Online usage	***Offline usage***
- Links to product information- no need for memorizing URLs, thus overcoming language barriers - Social media links like WhatsApp and Facebook - GPS locations - Calls - Translating Web pages - Tourist information on relevant historical and cultural places - Paperless tickets for different means of transportation - Linking exhibits with audio tours - E-learning material - Airline boarding passes - Coupons and discounts - Voting - one code for each of the different options - Access WiFi networks - Application downloads - Connecting to mobile hotspots	- Product instructions - Restaurant menus - Poster/flyer/ brochure - Business card or ID card - Multimedia messages

QR codes are increasingly prevalent across various tourism and travel sectors. As a vital digital tool in the industry, they enhance the visitor experience by allowing easy access to diverse information and services through a simple smartphone scan.

Creating a travel information QR code offers convenience and flexibility, allowing customization tailored to specific needs and devices. Some common generation methods include: Creating QR codes online through websites that offer free or paid QR code generation services; generating codes via mobile apps (both iOS and Android); performing QR code generation using software installed on the computer; You can also use social media sites to create QR codes (Facebook, Instagram). How to get a QR code for the travel and tourism industry using the platform (Ekundayo, 2020): (1) Log in to the QR code and choose a QR code solution. (2) Enter the required information to generate your QR code; (3) Select Static QR or Dynamic QR, then tap Generate QR Code. To maintain the ability to edit the embedded travel data and track its performance, the code creator must utilize a Dynamic QR code. (4) Customize the QR code and integrate the branding elements of the destination. The code creator can change the QR code's pattern, eyes, frame, and colors, accompanied by a destination logo and a clear call to action. (5) Scan the QR code to check. If it works perfectly, hit Download to save the travel QR code and use it.

In tourism business in Cao Bang province, QR codes help simplify the travel experience (Travel QR codes simplify many aspects of travel. For example, URL QR codes allow visitors to check in for flights, hotels, and events without the need for paper tickets or confirmation emails); Increased participation and accessibility: At tourist attractions, QR codes act as a private tour guide. Scanning a travel QR code can display detailed descriptions, historical events, and multilingual support to cater to an international audience. This not only enriches the travel experience but also makes it more accessible to non-locals; it offers environmental and economic benefits (Digital travel QR codes significantly reduce the need for printed materials such as brochures and maps, which significantly reduces paper waste. Economically, they reduce the costs associated with printing and distributing these documents and increase the efficiency of marketing and customer service efforts.

For Cao Bang province, according to Plan No. 487/KH-UBND dated March 9, 2023, of Cao Bang Provincial People's Committee on implementing comprehensive digital transformation of the province's tourism industry by 2030, the province determines "Taking the experience and satisfaction of tourists as the center of the comprehensive digital transformation of the tourism industry". Specifically, in the forthcoming period, the province will complete the digital data system on tourism, encrypt information on tourist areas and attractions with QR codes, integrate data and digital maps, and create a platform for smart applications to serve tourists. Cao Bang province has prioritized the digitization of all ranked historical, cultural, scenic, and intangible cultural heritages within its borders. This initiative is a key component of the digital transformation strategy for the culture and tourism sector, aimed at building a centralized, synchronous digitization database to effectively support the long-term propagation, promotion, storage, and value enhancement of its heritage. Through digitization, the monuments will be vividly introduced in many modern visual forms such as 3D videos, automatic audio narration, interactive e-magazines, digital heritage maps, and specialized websites. The content will be presented in a bilingual format (Vietnamese and a foreign language), integrating QR codes and linking to smart tourism digital platforms. This design ensures that both residents and tourists can easily access information with just a few simple steps on their smartphones.

For tourists, in the past, when visiting tourist attractions and learning about traditional tourism artifacts at destinations in Cao Bang, tourists were required to travel in groups and arrange services in advance to secure a dedicated guide. To enhance visitor convenience, numerous destinations have implemented QR code scanning applications, allowing tourists to independently access information about artifacts and enjoy new, engaging experiences. This adoption significantly contributes to the modernization of the tourism business and strengthens the brand image of tourist destinations in Cao Bang province. Business units and management boards of tourist zones must continue to collect and update new content and images of artifacts for QR code encoding. Additionally, units are utilizing QR codes for payment and facilitating ticket gate access to streamline the sightseeing process. Currently, many local destinations and tourist areas have deployed QR codes to enhance visitor convenience and experience. For instance, the management at the Non Nuoc Cao Bang tourist attraction has successfully integrated advanced technologies to enhance visitor engagement.

Specifically, the Management Board of the Cao Bang Non Nuoc Geopark utilizes smartphone-based QR code scanning technology. This enables visitors to effortlessly retrieve artifact-related information, thereby delivering novel and convenient experiences.

However, the key to truly maximizing the effectiveness of QR code applications lies in the underlying information platform: the website address where digitized data of monuments and destinations is hosted and automatically connected after a code scan. These information pages (posted on the local web portal or tourism industry site) must be designed vividly, rich in descriptive information, high-quality images, and introductory videos or clips of the sites, instead of the current simplistic and dull web presentation of the relics.

In the coming period, Cao Bang province intends to expand QR code services to hotel reservations, catering, entertainment, and transportation. This comprehensive integration aims to create an 'electronic travel handbook,' making information readily accessible to tourists.

(3)

(3)

(4) (5)

Figure (3,4,5): Accessing Cao Bang tourism information with QR code
(**Source:** Cao Bang Provincial Center for Culture, Information, and Tourism)

Although "QR codes" are considered a nascent technology, especially in developing countries, from the results of a survey of tourists (250 guests including domestic and international tourists), tourism business owners (managers and operators of 15 travel businesses), tourism staff (60 people including tour guides, destination staff and hotel restaurant staff), local community (150 votes). The study sample was predominantly female (72.5%), with males accounting for 27.5%. The age distribution showed a high concentration in the 18–40 age bracket (94.2%), while the 40–60 age group represented the remaining 5.7% of respondents. The results showed that most respondents used their smartphones primarily for communication purposes (100%), followed by entertainment (76.5%), music (64.3%), and news (42.6%). The majority of respondents (79.3%) have used and scanned "QR codes" before. 61.5% of respondents explained that they primarily used and scanned social media apps such as Zalo and Facebook, followed by product websites (23.7%), and app downloads (21.3%). Respondents pointed out that the level of use of "QR codes" in some travel and tourism areas is weak. This makes sense as the majority indicated that they rarely encounter "QR codes" on items that link to the Website, marketing materials, links to social media, GPS locations, hotel facilities, and boarding passes. The results also showed that respondents did not consider having a mobile phone with a camera, a permanent Internet connection, or storage limitations as a barrier to use for "QR codes."

However, "QR codes" may have several barriers when applied in tourism business including: operators (tourists, tourism workers), mobile phones must have cameras; have an Internet connection for online data stored in a "QR code"; the need for a QR code scanner app; It is not possible to update or refresh the "QR code" on print media; "QR codes" can become a tool for malicious attacks, facilitate phishing (QR Phishing) attacks, and redirect users to malicious websites that may host viruses; Malicious URLs can lead to malware being installed on mobile devices (Narayanan, 2012).

CONCLUSION

This research has successfully developed a comprehensive framework for a general tourism database and demonstrated the integration of GIS and QR code technologies as a catalyst for smart tourism development in Cao Bang province. Based on the findings, several key conclusions can

be drawn: First, the study established a multi-layered database structure that effectively bridges the gap between static geographic information and dynamic tourism attributes. Based on the analysis, synthesis and evaluation of factors that tourists are interested in at a destination, the author has built a general tourism database in Cao Bang province which is systematized into 7 main tourism data layers (including (1) Background data layer, (2) Tourism Resources Data Layer, (3) Accommodation Establishments, (4) Attractions and Entertainment; (5) services at attractions and entertainment; (6) Other Information. This system provides a robust digital foundation for the management of the Non Nuoc, Cao Bang Global Geopark, ensuring that heritage values are preserved and promoted in a digital format. Second, the empirical results confirm a high level of digital readiness among tourists, with 79.3% already engaging with QR code technology. The application of QR codes as an interface to the GIS database not only enhances the visitor experience through instantaneous information retrieval but also mitigates the limitations of traditional physical signage in complex mountainous terrains. Third, while technical challenges such as internet stability and cybersecurity (QR phishing) remain, the proposed transition to encrypted dynamic QR codes and a hybrid offline-online access model offers a practical roadmap for regional authorities to ensure a seamless and secure digital ecosystem. The research results have contributed to meeting the requirements of developing the tourism industry in Cao Bang province in the context of the current digital transformation.

Future Research Directions

Integrating Dynamic Data and Artificial Intelligence for Predictive Analytics. While the current database provides a robust structural foundation, transitioning to a truly Smart Tourism Destination (STD) requires the integration of Dynamic Data and Artificial Intelligence (AI). Current international trends emphasize the shift from static repositories to real-time information streams, such as live weather conditions, crowd density at heritage sites (e.g., Ban Gioc Waterfall), and real-time service availability.

The proposed system architecture can be enhanced by incorporating a Machine Learning (ML) Layer to analyze visitor behavioral patterns captured through QR code interactions. By tracking the frequency, timing, and sequence of QR scans across different coordinates in the GIS framework, the system can employ Collaborative Filtering and Content-based Recommendation Algorithms to provide Personalized Recommendations to tourists. For instance, if a visitor frequently scans QR codes related to ethnic culture, the AI engine can proactively suggest nearby hidden gems like the Khuoi Ky Stone Village.

Furthermore, the database should support Predictive Analytics to assist Cao Bang provincial authorities in sustainable management. By applying Time-Series Analysis to historical visit data, the system can forecast peak tourist arrivals, allowing for proactive "carrying capacity" management—a critical factor for UNESCO Global Geoparks. This evolution from a descriptive database to a Prescriptive Analytics Tool ensures that Cao Bang's tourism development remains resilient, data-driven, and aligned with the global standards of Industry 4.0.

Beside this, data Governance and Cyber Security Framework to ensure the long-term viability and legal compliance of the Cao Bang smart tourism database, a robust Data Governance framework must be established. This addressing the critical challenge of "data decay" and the protection of stakeholder information.

- Data Stewardship and Maintenance: A sustainable system requires a clear hierarchy of Data Stewardship. It is proposed that the Cao Bang Department of Culture, Sports and Tourism acts as the primary Data Owner, while local service providers (hotels, restaurants, and attractions) are designated as Data Contributors. To prevent "garbage data" (obsolete or inaccurate information), an Iterative Update Protocol should be implemented, requiring contributors to verify and update their respective entities (e.g., room rates, seasonal menus) quarterly via a dedicated administrative portal.

- Cybersecurity and Privacy Compliance: In the era of digital tourism, protecting the Personally Identifiable Information of travelers is paramount. The system architecture must be aligned with the Vietnam Law on Cybersecurity (2018), Data Law 2025 of the Vietnam National Assembly and international standards such as the General Data Protection Regulation (GDPR). Specifically, the integration of QR codes and GIS tracking must employ Data Anonymization techniques to ensure that visitor movement patterns are analyzed in aggregate without compromising individual identities.

- Security Protocols: The technical implementation should incorporate AES-256 Encryption for data at rest and SSL/TLS protocols for data in transit between the GIS server and user mobile devices. Furthermore, a Role-Based Access Control (RBAC) system will be enforced to limit data editing privileges, ensuring that the integrity of the provincial heritage CSDL remains untampered by unauthorized users. While this study is situated within the specific geographic and administrative context of Cao Bang Province, the integration of a centralized tourism database with GIS and QR-based interfaces yields significant implications for mountainous and peripheral regions globally. The structural challenges identified in Cao Bang—ranging from acute information asymmetry to the logistical complexities of rugged terrains—are not unique to Northern Vietnam. Rather, they are endemic to numerous high-altitude destinations, including UNESCO Global Geoparks in the Andean highlands of Peru, the Himalayan regions of Nepal, and the rugged peripheries of the Swiss Alps.

The scientific merit of the Cao Bang model resides in its "Resource-Light, Intelligence-High" methodology. In emerging economies where the deployment of high-cost

infrastructure, such as ubiquitous 5G networks or advanced robotics, remains fiscally or technically unfeasible, the use of QR codes as a "phygital" gateway to geospatial databases offers a cost-effective path toward digital maturity. This framework provides a scalable blueprint for two critical development pillars: (1) Heritage-based Resilience: By digitizing indigenous cultural assets, remote regions can mitigate the erosion of traditional knowledge often exacerbated by mass tourism, ensuring that cultural narratives remain under the stewardship of local authorities. (2) Digital Inclusion: The system fosters a more equitable tourism value chain by enabling ethnic minority communities to participate directly in the digital economy, bridging the "digital divide" through accessible data entry and management protocols.

Furthermore, the three-tier architecture (Data–Processing–Interface) validated in this research suggests that any destination with a documented heritage inventory can operationalize a similar data-driven management system. By establishing a standardized taxonomy for classifying tourism entities, this study contributes to the broader discourse on Smart Mountain Tourism. It offers a pragmatic pathway for remote regions to align with the United Nations Sustainable Development Goals (SDGs), specifically addressing Goal 8 (Decent Work and Economic Growth) and Goal 11 (Sustainable Cities and Communities) through the lens of technological empowerment.

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