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Development and validation of the smart tourism service ecosystem scale: An investigation through tourists' experience with smart applications in an emerging country

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Abstract

Demand for smart tourism service ecosystem (STSE) is growing as a result of the digital transformation within tourism. This pattern is global, extending to emerging countries. Vietnam, with its rich tourism resources, is now advancing STSE applications. Nevertheless, the technological gap between developed and emerging economies, combined with limited research on smart tourism in the latter, makes an appropriate STSE measurement scale essential. This study, conducted from January to October 2024, used an exploratory sequential mixed-methods design, including interviews, focus groups, fuzzy Delphi, and surveys, across eight steps to establish a reliable and valid scale. The findings support a validated 23-item STSE scale organized into six dimensions: smart sight (3 items), smart lodging (4), smart transportation (3), smart catering (4), smart shopping (5), and smart payment (4). Empirical results further suggest that nearly all STSE dimensions significantly improve traveler enjoyment—except smart catering, which shows no significant relationship. This study is the first to introduce the STSE scale based on tourists' application experiences in an emerging country. Furthermore, the proposed STSE scale could serve as a valuable template for assessing tourists' application experiences in countries similar to Vietnam.

Keywords Emerging country · Fuzzy Delphi · Smart tourism service ecosystem · Scale development

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1 Introduction

The smart tourism service ecosystem (STSE) integrates technological, infrastructural, and socio-cultural factors to enable seamless, personalized, and sustainable experiences. It plays a critical role in the advancement of destination tourism (Chuang 2023). Primarily, the STSE enhances the customer experience by leveraging artificial intelligence (AI) and big data, which contribute to personalized services and immersive interactive experiences (Ting et al. 2025). The STSE improves destination management by analyzing real-time data to support timely decisions. It also fosters an interactive relationship among stakeholders, including local authorities, tourism businesses, tourists, and the community, with an emphasis on the tourists' role in co-creating value (Bhuiyan et al. 2022). This collaboration helps improve service quality and cultivates a welcoming environment (Chuang 2023). In particular, the integration of technologies enhances the overall experience, increases satisfaction, and promotes repeat visits or recommendations (Sustacha et al. 2023).

Extensive research has examined smart tourism (Azimi et al. 2025). However, STSE is an emerging concept, still inadequately defined, especially in developing countries. The STSE platform integrates tourism services and management, leveraging technology for real-time tourist information. Smart systems connect online booking services with destination options, including attractions, transport, accommodation, dining, e-commerce (Hussin & Wahid 2023) and payment processes (Flavián et al. 2020). Further research is needed to deepen understanding, as existing studies focus on conceptualization and primarily examine developed destinations with advanced technology. Recent studies examine how smart tourism technologies (STT) influence tourist well-being, showing that informativeness, interactivity, and personalization support both hedonic and eudaimonic outcomes (Zheng & Wu 2023). However, these studies tend to focus on individual STT components, without offering a systemic evaluation of the STSE, especially in emerging contexts.

Chuang (2023) explores the concept of smart tourism service platforms, highlighting their role in enhancing tourists' value co-creation behaviors through an integrated ecosystem approach. The study identifies a significant gap in research concerning the development of STSEs across different stages, particularly in the creation of applications that provide essential tourism services. The findings show that smart applications facilitate seamless interactions between tourists and providers, promote sustainability, and emphasize the need for a framework to capture the dynamics of STSE development. While existing studies offer new perspectives, they fall short of providing a comprehensive framework for the technological components and services necessary for an effective STSE, especially in developing countries. The current literature also lacks a validated scale to assess STSE in emerging economies like Vietnam, which is advancing smart tourism through STSE and blockchain, despite facing ongoing challenges (Huy et al. 2024). In Vietnam's tourism sector, the lack of a coherent and standardized assessment architecture impedes comprehensive diagnosis of embedded systemic inefficiencies and undermines robust performance measurement of digital tourism initiatives. Thus, Vietnam represents an ideal context for developing an STSE scale, offering a blend of opportunities and challenges shared by other emerging nations. Addressing these research gaps is essential for enabling stakeholders to effectively assess and enhance their smart tourism initiatives.

This paper lays out the development and validation of a proposed STSE measurement scale for emerging economies based on the experience of Vietnam. By identifying the specific technological and socio-cultural dimensions of the STSE, this study provides stakeholders with a diagnostic tool to overcome the current fragmentation of services, enhance cross-sectoral collaboration, and improve the overall competitiveness of Vietnam's tourism industry. The study uses a sequential mixed-methods approach, drawing on both qualitative and quantitative work. A Fuzzy Delphi step was included to check content validity. In addition, the study looks at the socio-cultural and infrastructural realities of developing nations. It contributes in three ways: first, by offering the first STSE scale tailored to emerging contexts; second, by grounding that scale in tourists' real application experiences; and third, by setting out a framework that future research can extend.

2 Conceptual background

Chen et al. (2022) define smart tourism as a combination of information and communication technology (ICT) that improves tourism products, services, and experiences. It is founded on three layers: smart experience, smart business ecosystem, and smart tourism destination (Gretzel et al. 2015a, b). Buhalis and Amaranggana (2013) describe smart tourism as a strategic approach that optimizes the tourist experience by linking destination elements. More than technology adoption, it is a complex ecosystem where diverse stakeholders collaborate to generate value (Gretzel et al. 2015a, b). The degree of "smartness" depends not only on the presence of technology but on how effectively it is used to enhance value (Tsang & Au 2023).

Smart tourism services (STS) extend this idea. Emerging from research on intelligent systems, STSs focus on applications for tourism services or destinations (Buhalis & Amaranggana 2015; Chuang 2023; Gao et al. 2022; Zhang et al. 2024). Examples include mobile applications that integrate recommendations, travel information, and route updates, creating a unified environment and improving user experience.

The STSE (Fig. 1) is newer still. It connects service providers and tourists to create sustainable value in the industry (Bhuiyan et al. 2022; Buhalis et al. 2023; Gretzel et al.

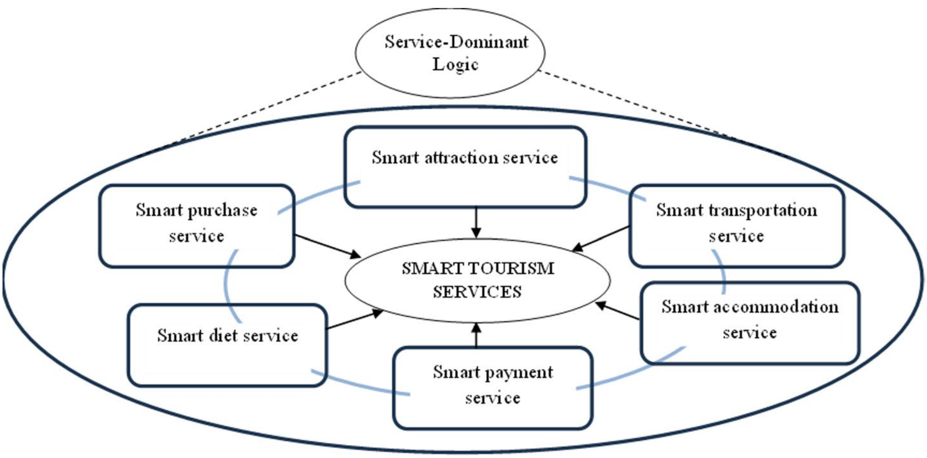

Fig. 1 A smart tourism service ecosystem (adapted from Chuang 2023)

2015a, b). Core services in a smart tourism ecosystem usually cover the basics: attractions, transport, food, accommodation, shopping, and payment (Chuang 2023).

Research on smart tourism and STSE is grounded in several well-established theoretical frameworks. The Technology Acceptance Model (TAM) (Davis 1989) examines the factors influencing tourists' adoption of new technologies. Pine and Gilmore's (1998) work underscores the increasing consumer demand for experiential tourism. The Diffusion of Innovations Theory (Rogers 2003) provides insights into the processes through which smart applications disseminate among users. Additionally, the Theory of Mind (Premack & Woodruff 1978) emphasizes the importance of understanding and anticipating tourists' needs. In particular, Service-Dominant Logic (SDL) (Vargo & Lusch 2004) offers a valuable perspective, asserting that value is co-created through the interactions between service providers and customers.

Notably, these theories are often based on wealthier economies, which assume reliable infrastructure, high digital literacy, and easy access to technology. That picture changes in emerging economies. Adoption is shaped by patchy infrastructure, cultural diversity, and socio-economic limits.

There are shortcomings, too, with other theories. For example, TAM must account for lower trust in digital platforms, while Diffusion of Innovations can stall when connectivity is weak. SDL becomes more complex where service sectors are fragmented, and collaboration is harder to sustain. These differences underline why building an STSE scale matters in places like Vietnam.

Chuang (2023) describes an STSE as a platform that offers tourists a range of smart services and enables value co-creation among stakeholders—providers, government, residents, and tourists.

At a basic level, the ecosystem pulls together the main services. Firstly, attractions, transport, accommodation, food, shopping, and payment. Additionally, the remaining layers are smart technologies (Wang et al. 2016) and platforms for co-creation that boost satisfaction (Chuang 2023; Van Riel et al. 2019). In summary, this amounts to collaboration and technology sitting at the heart of making tourism more efficient and enjoyable.

3 Research methodology

3.1 Study site

Vietnam's tourism sector is a cornerstone of the national economy, with 2024 revenue reaching approximately 850,000 billion VND, primarily driven by top-ranked destinations in the Tourism Development Capability Index (TDCI) such as Da Nang, Quang Ninh, and Kien Giang. According to the National Digital Transformation Portal,[1] while these hubs lead in ICT readiness, the sector still faces "information silos" that hinder the integration of unique natural resources—from UNESCO-recognized heritage sites to diverse marine ecosystems—into a unified smart ecosystem. The current revenue structure, heavily dependent on accommodation and F&B (accounting for over 60% of total tourist spending), necessitates the implementation of STSE to shift towards high-value, technology-driven services. By validating an STSE scale in this context, the study provides a framework to optimize

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resource allocation and reduce operational costs for stakeholders, ensuring that Vietnam's natural priority areas become sustainable economic drivers for both the government and local communities.

3.2 Research design

We followed a four-phase, eight-step instrument development procedure (Netemeyer et al. 2003; Churchill 1979) to capture the multifaceted nature of the STSE. This process moved from qualitative exploration to quantitative validation, as shown in Fig. 2.

We triangulated data from a literature review, in-depth interviews (IDIs), and focus group discussions (FGDs). Using both methods ensured information saturation as IDIs capture deep, personal narratives, while FGDs surface shared social norms (Fusch & Ness 2015). Relying on a single method would have yielded incomplete data; skipping them in favor of expert opinions would have ignored the actual stakeholder perspective.

We employed the Fuzzy Delphi method to refine the generated items. Since STSE is an emerging and somewhat ambiguous concept, Fuzzy Delphi was superior to standard methods as it allowed us to quantify expert consensus and account for uncertainty in the evaluations (Okoli & Pawlowski 2004).

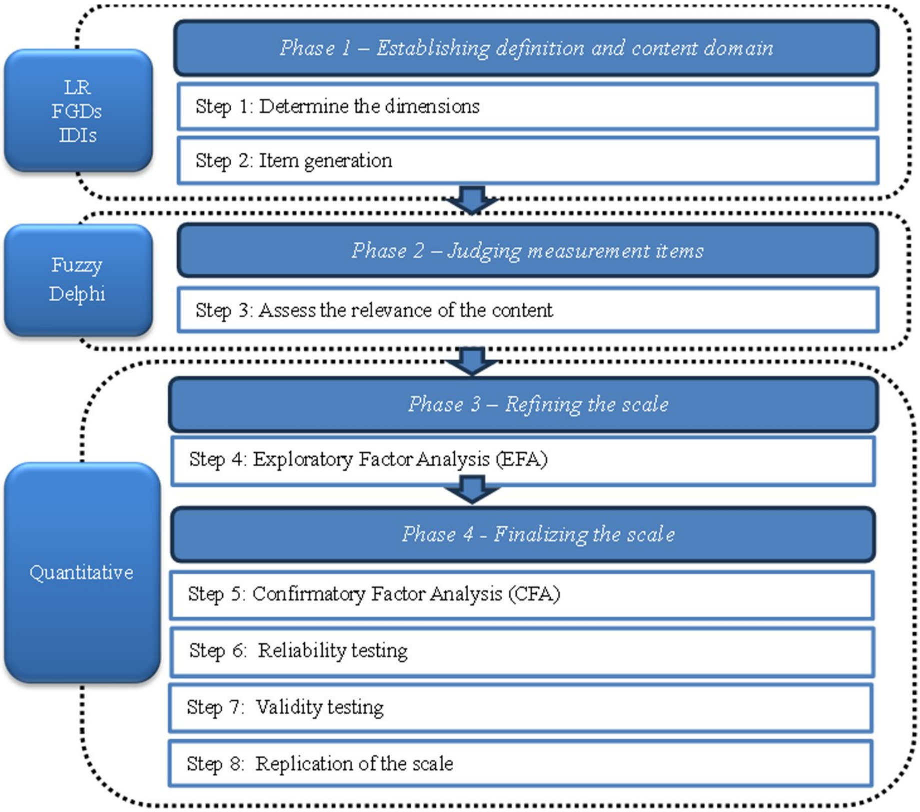

Fig. 2 Procedure of developing and validating a measurement scale

The quantitative validation involved three distinct sampling efforts: Exploratory Factor Analysis (EFA), which was used to identify the underlying factor structure (Netemeyer et al. 2003). Confirmatory Factor Analysis (CFA) was used to validate and confirm the structure derived from the EFA. Thirdly, for replication, we tested the final scale with an independent sample in Can Tho, Vietnam. This region was selected for its substantial smart tourism investment, allowing us to examine the scale's impact on traveler enjoyment in a real-world context (Bogicevic et al. 2017).

We must acknowledge the limitation that this study relies on convenience sampling within a single country, Vietnam. Utilizing this approach ensured a focused context for initial scale construction. However, it inherently limits generalizability. Future research should aim for broader, cross-cultural sampling to validate these findings globally.

3.3 Procedure

3.3.1 Establishing definition and content domain

3.3.1.1 Literature review and content analysis Based on Chuang (2023) and the SDL framework, we treated the STSE as a platform for value co-creation. As STSE is a nascent concept, we avoided rigid pre-existing scales in favor of a bottom-up approach that captures the reality of Vietnam's digital transformation in Vietnam.

3.3.1.2 Focus group discussions (FGDs) and in-depth interviews (IDIs) Our sample counts prioritized "information saturation", an approach that relied on six Focus Group Discussions (FGDs). These discussions involved professionals from organizations undergoing digital transformation (e.g., tour operators, hotels, e-commerce channels). This laid the groundwork for 15 In-Depth Interviews (IDIs) with high-level government officials and tech directors, selected for their direct influence on tourism digitization.

Focus group and interview participants were selected for their direct involvement in digital transformation within the tourism sector in Vietnam. The interviews were conducted in Vietnamese, from January to March 2024.

Using NVivo 14, we analyzed this data iteratively—moving from open coding to higher-level categorization—until no new themes emerged. This gave us confidence that the items captured the way people in the industry actually talk and the real hurdles they face, rather than sounding purely theoretical.

3.3.2 Judging measurement items

To ensure content validity, we submitted the 58 initial items to a panel of 35 experts through a Fuzzy Delphi study. Over three rounds, the experts not only scored the items but also systematically reviewed and refined them for clarity and relevance. Items were retained only when at least 75% of the experts reached consensus, ensuring that the final scale accurately reflects a shared professional perspective rather than a statistical average.

Through purposive sampling, we could select informative cases that enhance our intuition of the research-pertained issues at hand (Patton 2002). It is worth noting that in Delphi studies, it is common for some experts to withdraw after certain rounds due to various factors, including the time commitment required for surveys and individual interest level (Franklin & Hart 2007). In this context, purposive sampling is essential as it enables the exclusive of information-rich cases that contribute to a deeper insight of the issues relevant to the study. Thanks to advancements in information technology, many Fuzzy Delphi studies have transitioned to using online forms instead of the conventional paper-and-pencil approach. To ensure content validity, 58 items obtained in phase 1 were sent to a carefully selected group of 35 leading experts in tourism and information technology. The results from the subsequent round were synthesized and compared with those from the previous round, leading to expert consensus. For each round, the experts meticulously evaluated the attributes of the STSE, focusing on the clarity, rationality, and representativeness of each attribute. We then synthesized and compared experts' opinions to reach the highest level of consensus.

Experts' opinions were gathered using a three-round Delphi questionnaire. While the literature does not provide strict criteria for establishing consensus, researchers must define the percentage of participants' responses that will be considered representative of consensus. Murry Jr. and Hammons (1995) defined consensus as a 75% agreement among participants on a specific item. In this study, while the content validity of the questionnaire was analyzed qualitatively, the scored responses were used to calculate the mean and variance. On the other hand, following Murry Jr. and Hammons (1995), a 75% agreement threshold among participants was applied to each item. Additionally, experts were invited to provide further explanations or suggest new items, aiming to address any limitations of the original item list. The design of the questionnaire for the subsequent round closely mirrored that of the previous one but incorporated statistical analyses from the prior round to facilitate expert consultation and encourage convergence on previously divergent viewpoints.

3.3.3 Refining the scale

The three surveys with tourists were administered in four cities in Vietnam that are recognized for their advanced digital transformation: Da Nang, Ho Chi Minh City, Hue, and Can Tho. A pilot study was conducted with 65 tourists in Ho Chi Minh City to assess the reliability and comprehensibility of the survey questions. The first main survey was conducted with 250 tourists who had traveled within Vietnam and utilized smart tourism applications. To achieve the research objectives, a purposive sampling technique was applied to recruit respondents. Purposive sampling was employed to ensure that all participants possessed sufficient experience with smart tourism services, thereby providing high-quality data for the validation of the STSE dimensions. This approach allowed to filter out individuals who may not be familiar with smart applications, ensuring the accuracy of the scale development. To ensure the reliability of the findings, the sample size was determined based on the guidelines outlined by Hinkin (1998) and Hair et al. (2017). A convenience sampling method was employed, utilizing QR-coded questionnaires distributed with the assistance of tour guides to maintain data quality. The questionnaire was divided into two sections and initially constructed in English, then translated into Vietnamese.

Exploratory Factor Analysis (EFA) was performed using SPSS 28.0 to uncover the initial structure of the scale. EFA was suggested to be used in this stage (Netemeyer et al. 2003), applying the principal components method with varimax rotation. The reliability of a scale is accepted when its Cronbach's Alpha coefficient is equal or superior to 0.6 and all the variable-total correlation coefficients (adjusted) are equal to or greater than 0.3 (Nunnally & Bernstein 1994). An item will be excluded if it loads on more than one extracted factor and/or has a factor loading lower than 0.5 cutoff (Hair et al. 2019). The extracted factor must meet a cut-off rule (eigenvalues > 1.0; KMO ≥ 0.5; Bartlett, $p < 0.05$) and has at least three items retained (Hair et al. 2019).

3.3.4 Finalizing the scale

This step aimed at assessing measurement instrument quality. A CFA of 305 survey questionnaires was conducted to confirm the proposed structure using AMOS 28.0 software. This phase implemented the same sampling method as in the previous phase (phase 3 – step 4). Based on the guidelines of having 10 observations for each estimated parameter in a CFA, the sample size for the CFA was 305, exceeding the minimum requirement of 250. This step focused on assessing the reliability and technical validity of the scale. However, at first, using the same assessment criteria as in the phase 3 – step 4, EFA was conducted using SPSS 28.0. A model is considered suitable for the data if the test result of χ^2 has a p-value < 0.05, the RMSEA index ranges from 0.06 to 0.07 (Hair et al. 2019), and the cut-off point of the CFI, GFI, and TLI is equal to or greater than 0.9 (Hu & Bentler 1999).

Reliability is a vital condition for scale validation, which reflects the precision of a measurement scale. Scholars suggested a range of Cronbach's alpha values such as 0.70 for exploratory measures (Nunnally 1978) and 0.60 for newly developed scales (Flynn et al. 1990).

Validity testing: According to Fornell and Larcker (1981), convergent validity is evaluated by examining whether the items in a given construct converge together. To test convergent validity, we followed the recommendations of Fornell and Larcker (1981) and Nunnally and Bernstein (1994). Discriminant validity was assessed using both techniques proposed by Fornell and Larcker (1981) and Henseler et al. (2015).

Second-order model assessment: STSE was conceptualized not only as a first-order but also as a second-order construct to show that tourists relied on specific dimensions of the STSE to evaluate the services (Lages & Fernandes 2005). Thus, a second-order model CFA was conducted to conceptualize STSE as a higher-order construct. The CFA test treated the six dimensions of STSE as reflective indicators of the overall construct.

Scale replication: This last study aimed to establish the nomological validity of the scale. The objective of nomological validity of a scale is to establish whether the constructs it measures fit within a broader theoretical framework and exhibit expected relationships with other related constructs. It ensures that the scale behaves as theoretically predicted in relation to other constructs, confirming its place within a nomological network—a system of related concepts, propositions, and hypotheses (Azimi et al. 2025; Hinkin 1998).

For step 8, 664 valid questionnaires were collected to investigate the relationship between STSE and traveler enjoyment. In this final study, the STSE scale was extracted from the previous stages. The traveler enjoyment scale from Bogicevic et al. (2017) (4 items, one sample item: "Having layover at Cantho would be enjoyable") was selected to examine its relationship with the STSE scale. Indeed, previous research (e.g., Balakrishnan et al. 2023; Bogicevic et al. 2017; Jeong & Shin 2020) shows that smart tourism technology experience indirectly influences travelers' satisfaction through memorable experiences, making trips more enjoyable; hence, we hypothesize that the STSE scale may have a relationship with traveler enjoyment.

This last study took place in Can Tho, Vietnam, a region that has made significant investments in smart tourism technologies to enhance its economy and attract more visitors. The survey targeted tourists who visited Can Tho and engaged with the STSE via Canthotourism application between July and October 2024. Using convenience sampling, travelers were surveyed at various locations, including Wink Hotel, Sojo Hotel, Con Son tourist area, Cantho Ecoresort, the Can Tho Museum, and the Cai Rang floating market. The questionnaire was split into two sections, first developed in English, then translated into Vietnamese. All the measurement scales were assessed using a five-point scale, ranging from 1 (strongly disagree) to 5 (strongly agree). Using IBM SPSS AMOS 28.0 software, the path coefficients and goodness of fit of the overall model were estimated to determine the relationship between endogenous and exogenous variables. In addition, bootstrap technique (with $n=10,000$ and $p=0.05$) was also applied to test the estimates in the model with the impact of various constructs of a STSE on traveler enjoyment.

4 Results

4.1 Definition and content domain

Based on the literature review, FGDs, and IDIs, we uncover six primary themes for a STSE in the context of Vietnam. While new service areas such as smart entertainment, personalized smart services, and enhanced local cultural experiences were mentioned, they were not prominent due to their infrequent references by participants. Consequently, a total of six themes (Fig. 3) and 58 items among which 32 items were extracted from Chuang (2023) and 26 items were newly generated from FGDs and IDIs, were identified. The integration of items from FGDs, IDIs, and literature allows us to maximize the relevance, comprehensiveness, and effectiveness of the scale while mitigating errors arising from respondents overlooking pertinent issues (Xie et al. 2020). The complete STSE scale after phase 1 is presented in Table 1.

Overall, the results indicate that the perceptions of the STSE significantly differ between Vietnam and developed countries, which is influenced by several factors, including technological infrastructure, service integration, and user participation (Buhalis & Amaranggana 2015; Chuang 2023). Despite the development of numerous smart tourism applications, public awareness of the concept of smart tourism remains limited in Vietnam.

4.2 Measurement items judgment using Fuzzy Delphi

Some experts were unable to participate in the study throughout three rounds for personal reasons. Concretely, we collected 29 questionnaires in the first round, 25 in the second round, and 20 in the final round. Participating experts possess high qualifications, with over 80% holding a PhD and possessing a minimum of five years of experience in the tourism industry (Table 2).

After the first round, we received 29 complete responses from 29 experts. The scale structure after this round comprises 6 constructs and 30 items, instead of 58 items initially.

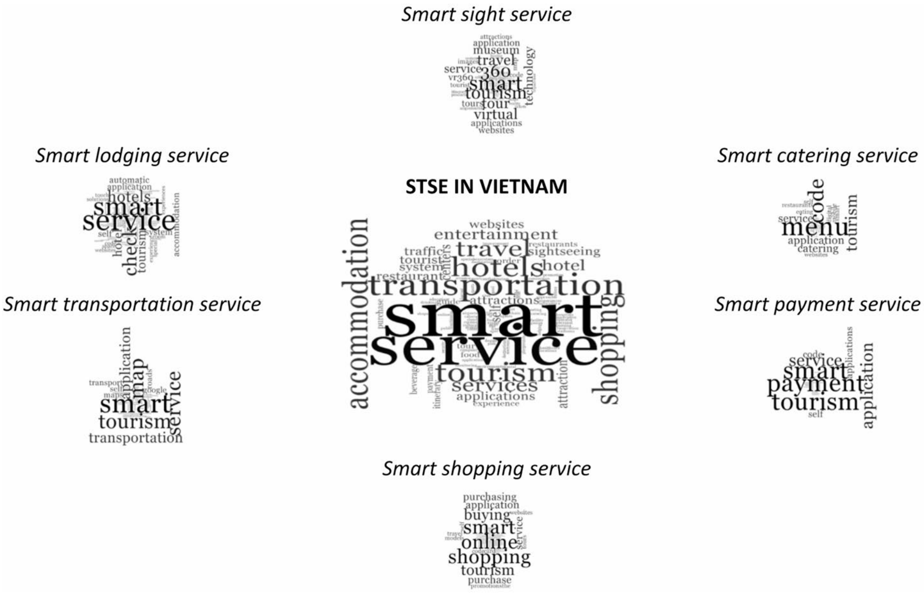

Fig. 3 STSE in the context of Vietnam

Smart sight service has 6 items: 2 items from Chuang (2023) including "Online reservation system built in the tourist attraction" and "Itinerary planning system developed in the tourist attraction" and 4 items from FGDs and IDIs. **Smart transportation service** has 5 items from FGDs and IDIs exclusively. **Smart lodging service** has 4 items: 3 items adapted from Chuang (2023) to align with the smart lodging service in Vietnam and 1 new item "Self-service laundry and ironing options, with completion notifications sent via app" generated from FDGs and IDIs. **Smart catering service** has 5 items: 3 items generated from FDGs and IDIs and 2 items adapted from Chuang (2023) to fit the Vietnamese context ("Apps allow ordering food and beverage" and "Ordering food and beverage via touch screens or tablets has been implemented". **Smart shopping service** has 6 items: 5 items from FGDs and IDIs and 1 item from Chuang (2023) "Quickly purchase goods with a variety of convenient electronic payment methods through the smart information system*"*. **Smart payment service** has 4 items with 1 item form FGDs and IDIs "The smart travel card (*Thẻ Việt*) is utilized for payment" and 3 items from Chuang (2023) (Table 3).

The second round of evaluations involving 25 experts indicated that 6 domains and 25 items achieved a consensus level exceeding 75%. In the **smart sight service** domain, 5 items were retained, while one item was removed. In the **smart transportation service** domain, only 3 items were retained. All the 4 items in the **smart lodging service** were retained. The **smart catering service** domain included 4 items instead of 5 items. The **smart shopping service** domain had 5 items instead of 6 items. The **smart payment service** domain preserved 4 items.

The third round involving 20 experts achieved a consensus of 100% regarding a scale of 6 themes (i.e., constructs) and 25 items obtained in the second round (Table 3).

Table 1 Chuang's (2023) scale and 26 new items generated from FGDs and IDIs

Chuang's (2023) **scale** 6 themes, 32 items	**Complete scale after phase 1** 6 themes, 26 new items + 32 items from Chuang (2023)
Smart attraction service: Instant services related to travel experiences and decision support are realized through the connectivity between attractions and stakeholders via a dynamic platform that facilitates in-depth information flow **7 items,** sample item: "Tourist flow control system set up in the tourist attraction"	**Smart sight service (S)** primarily involves providing information and services related to attractions, along with suggestions for activities and dining options via mobile apps. The latter aims to assist tourists in effectively planning their visits and maximizing their time at the destination **4 new items:** **S1.** The apps provide information on attractions, events, tourism services, and digital maps for tourists **S2.** The apps facilitate the reflection of information at tourist sites for visitors **S3.** The apps enable VR3D/360 of attractions for tourists **S4.** The apps recommend activities and locations that align with tourists' preferences and schedules +**7 items** from Chuang (2023)
Smart transportation service: The provision of location-based information, quality public transportation, navigation, and parking is realized through the integration of technology and transportation systems. This integration enhances the travel experience by ensuring that tourists have access to relevant data and services that facilitate their movement and decision-making within the destination **5 items**, sample item: "Public transport information system developed for transportation"	**Smart transportation service (T)**: In Vietnam, motorcycles are the predominant mode of transportation, with public transport still underdeveloped. Vietnam is focusing on digitalizing tourist transportation service via providing digital maps and developing smart tourism applications that integrate VR/AR technologies **5 items:** **T1.** Technology-based ride-hailing applications such as Grab, Be, VATO, and Mai Linh Taxi have been developed to meet the transportation needs of tourists at destinations **T2.** Companies like Xanh SM offer electric taxi services, car rentals, and electric scooters aimed at promoting green transportation and environmental protection **T3.** Information regarding travel times, speeds, delays, road accidents, route changes, and navigation is provided through electronic devices such as variable message signs, radio broadcasts, the internet, and SMS notifications **T4.** Smart tourism ecosystem applications at destinations integrate Google Maps and 3D mapping to facilitate tourists' navigation between attractions **T5.** The development of smart electric bus models, public bicycles, and electric scooter services is underway +**5 items** from Chuang (2023)
Smart accommodation service: Tourists are provided with access to integrated IT information about accommodations and convenient booking services, allowing them to arrange suitable lodging based on their needs. This integration enhances the overall travel experience by ensuring that tourists can easily find and book accommodations that meet their specific preferences and requirements **3 items,** sample item: "Smart room access control and cabinet systems installed for accommodation"	**Smart lodging service (L)**: The focus on essential elements such as automated check-in/check-out, mobile room control, and integration with Accommodation Management Software (AMS) for customer information notifications is becoming increasingly significant in the lodging industry **4 items:** **L1.** Self-service kiosks enable guests to check in and check out, manage reservations, and access various services without direct interaction with front desk staff **L2.** An application controls smart room devices (e.g., safe, curtains, television, room color, etc.) **L3.** Smart booking is facilitated through apps **L4.** Self-service laundry and ironing options are available, with completion notifications sent via app +**3 items** from Chuang (2023)

Table 1 (continued)

Smart diet service: Tourists can access integrated information and technology solutions for dining, along with convenient ordering services that provide healthy and suitable meal options. These advancements enhance the travel experience by allowing travelers to explore local cuisine, receive meal recommendations, and place orders seamlessly through smart applications **6 items**, sample item: "Smart guide system established for catering"	**Smart catering service (C)**: The catering service provides food for events, restaurants, or organizations using technology to manage the entire process from ordering and preparation to serving. This integration enhances efficiency and ensures high-quality food service for various occasions **4 items:** **C1.** The catering service apps have been developed **C2.** Ordering food and beverage via touch screens or tablets has been implemented **C3.** The online menus encoded through QR codes to introduce local dishes, ingredients, and culinary stories have been established for dining services **C4.** Apps allow ordering food and beverage +**6 items** from Chuang (2023)
Smart purchasing service: The integration of ICT with e-commerce has created mobile commerce platforms, allowing tourists to access product information and make purchases anytime, anywhere **7 items,** sample item: "Get preferential price through the smart information system"	**Smart shopping service (SH)**: The provision of shopping information and support services at destinations includes suggestions for stores, local products, and special offers. The STSE app plays a crucial role in enhancing the shopping experience **4 items:** S1. The STSE app enables direct shopping experiences either within the app or through links to various shopping centers and locations S2. The STSE app allows price comparison, enabling tourists to make quick purchasing decisions S3. Tourists receive special prices or discounts when utilizing services within the STSE app S4. The STSE app facilitates the comparison of items, helping tourists make rapid decisions S5. The STSE app integrates local souvenirs and specialties for tourists' convenience +**7 items** from Chuang (2023)
Smart payment service: **4 items**, sample item: "Mobile payment system established in the tourist attraction"	**Smart payment service (P)**: Mobile and smart card payment have been developed for different tourism services (accommodation, catering, attraction, shopping, transportation) **4 items** P1. The smart travel card (*Thẻ Việt*) is utilized for payment P2. A payment app has been established for dining services P3. A payment app has been developed for accommodation services P4. A payment app has been implemented at tourist attractions +**4 items** from Chuang (2023)

4.3 Scale refinement

The detailed descriptive statistics from the three survey samples are shown in Table 4.

Exploratory factor analysis with the first sample of 250 respondents: The results showed a satisfactory scale with 25 items distributed on 6 constructs. Cronbach's alphas of all the measurement scales were greater than 0.8 (ranging from 0.823 to 0.932), meeting the standard. KMO was equal to 0.800 ($0.5 < KMO < 1$), $sig = 0.000$. The total extracted variance of 71.644% was higher than the threshold of 50%. All the items had outer loadings greater than 0.6 (ranging from 0.605 to 0.954).

Table 2 Fuzzy Delphi study through 3 rounds

Information	Detail	Initial list: 35 experts	Number of rounds		
			Round 1	Round 2	Round 3
			N=***29***	N=***25***	N=20
Scientific title	Prof. Ph.D	3	3	3	3
	Assoc. Prof. Ph.D	3	3	2	2
	Ph.D	14	12	10	7
	Master	15	11	10	8
Sex	Male	18	18	15	12
	Female	17	11	10	8
Age	31–35	6	5	5	4
	36–40	9	6	5	3
	41–45	8	7	5	3
	46–50	7	6	6	6
	>=51	5	5	4	4
Position	CEO, Director, Dean, Deputy Dean, Head of Department, Head of Division, Senior Leader				
Work experience	<5 years	7	6	5	4
	5–10 years	10	9	8	6
	>10–15 years	10	8	6	5
	>15 years	8	6	6	5
Research fields	Tourism, IT, smart tourism				

Table 3 Summary of Fuzzy Delphi study results

No	Round 1 6 domains 30 items	Round 2 6 domains 25 items	Round 3 6 domains 25 items
1	Smart sight service 6 items	Changed from round 1 5 items	Unchanged from round 2 5 items
2	Smart transportation service 5 items	Changed from round 1 3 items	Unchanged from round 2 3 items
3	Smart lodging service 4 items	Unchanged from round 1 4 items	Unchanged from round 2 4 items
4	Smart catering service 5 items	Changed from round 1 4 items	Unchanged from round 2 4 items
5	Smart shopping service 6 items	Changed from round 1 5 items	Unchanged from round 2 5 items
6	Smart payment service 4 items	Unchanged from round 1 4 items	Unchanged from round 2 4 items

Table 4 Profiles of the respondents

		Exploratory sample		Confirmatory sample		Scale replication sample	
		N	%	N	%	N	%
Gender	Male	143	57.2	178	54.8	366	55.1
	Female	107	42.8	127	41.6	298	44.9
Age (years)	< =30	79	31.6	83	27.2	229	34.5
	31–40	111	44.4	123	40.3	259	39
	41–50	32	12.8	47	15.4	104	15.7
	51–60	12	4.8	35	11.5	47	7.1
	> =61	16	6.4	17	5.6	25	3.8
Education	High school	55	22	82	26.9	135	20.3
	Bachelor	45	18	95	31.1	168	25.3
	Master/Doctorate	56	22.4	100	32.8	120	18.1
	Other	94	37.6	28	9.2	241	36.3
Occupation	Student	51	20.4	48	15.7	130	19.6
	Public sector	54	21.6	112	36.7	123	18.5
	Private sector	73	29.2	107	35.1	256	38.6
	Self-employment	45	18	28	9.2	129	19.4
	Other	27	10.8	10	3.3	26	3.9
Total		**250**	**100**	**305**	**100**	**664**	**100**

4.4 Final scale

4.4.1 Confirmatory factor analysis

At first, with a sample of 305 respondents, through the EFA, 2 items had standardized factor loadings inferior to 0.5. Additionally, the removal of these two items allowed to improve the AVE value of the related scale (i.e., the smart sight service scale). Hence, 23 resulting items were included in further analysis. CFA displayed the suitability of the measurement model. All items across the six constructs had factor loadings greater than 0.5 (ranging from 0.556 to 0.928, $p<0.01$). Furthermore, other indices were satisfactory: CMIN/df of 391.001/215; $\chi^2/df=1.819<2$, $p=0.000$; $GFI=0.904>0.9$; $CFI=0.951>0.9$; $TLI=0.943>0.9$, and $RMSEA=0.052<0.06$.

4.4.2 Reliability testing

As illustrated in Table 5, the Cronbach's alpha values of the six factors exceeded 0.70 (ranging from 0.782 to 0.893), thereby meeting the reliability requirement.

4.4.3 Validity testing

For the confirmatory sample ($n=305$), all the Composite Reliability (CR) values ranging from 0.786 to 0.893 exceeded 0.7, meeting the requirement (Nunnally & Bernstein 1994). Additionally, the Average Variance Extracted (AVE) values ranging from 0.552 to 0.677 were greater than the threshold of 0.5, and the maximum shared variance (MSV) for each

Table 5 Main indices – Confirmatory sample

Items	Standardized loading	Cronbach alpha	CR	AVE	MSV
Smart sight service (S)					
S1. STSE app/web provides information about services at attractions	0.831	0.848	0.852	0.659	0.128
S2. … allows tourists to take a VR 3D/360 of the attractions	0.928				
S4. … has online attraction booking	0.658				
Smart lodging service (L)					
L1. … allows guests' self-service without staff (e.g., check in/out, manage reservations, access various services)	0.655	0.852	0.853	0.594	0.201
L2. Smart room access control and cabinet systems installed for lodging	0.866				
L3. … has mobile room booking	0.797				
L4. Self-service laundry and ironing options, with completion notifications sent via app	0.738				
Smart transportation service (T)					
T1. … provides real-time traffic information via electronic devices	0.556	0.782	0.786	0.552	0.204
T2. … has google maps, 3Dmaps	0.819				
T3. … has technology ride-hailing apps (e.g., Grab, Vinfast, Be)	0.779				
Smart catering service (C)					
C1. … has service request system	0.877	0.893	0.893	0.677	0.178
C2. … has touch screen self-service ordering system (e.g. QR code menu)	0.828				
C3. … established smart guide system	0.803				
C4. … has mobile reservation and ordering	0.778				
Smart shopping service (SH)					
SH1. … has e-commerce and travel apps	0.687	0.884	0.885	0.607	0.204
SH2. … gets a fair price	0.795				
SH3. … gets preferential prices	0.835				
SH4. … gets quickly purchase goods	0.835				
SH5. … introduce souvenirs and local specialties	0.711				
Smart payment service (P)					
P1. … established existing smart card payment system	0.736	0.865	0.866	0.618	0.070
P2. … established a mobile catering payment system	0.839				
P3. … established a mobile lodging payment system	0.803				
P4. … established a mobile attraction payment system	0.764				

factor was less than its AVE (Fornell & Larcker 1981) (Table 5). These results ensured the convergent validity of all the scales.

The square root of the AVE for each factor was greater than its correlation with any other factor (Fornell & Larcker 1981) (Table 6). Moreover, no concern was identified in the HTMT analysis using both strict (0.850) and liberal (0.900) thresholds (Henseler et al. 2015) (Table 7), guaranteeing the discriminant validity of the scales.

Second-order model assessment. The results provided good fit indices (χ^2/df = 1.788 < 2, p = 0.000; GFI = 0.902; CFI = 0.951; TLI = 0.945; RMSEA = 0.051). All regression paths were significant at p < 0.001, indicating strong correlations between STSE and its various

Table 6 Fornell-Larcker criterion – Confirmatory sample

	SH	C	P	L	S	T
SH	**0.779**					
C	0.351***	**0.823**				
P	0.184**	0,140*	**0.786**			
L	0.448***	0.338***	0.265***	**0.771**		
S	0.358***	0.271***	0.225**	0.342***	**0.812**	
T	0.452***	0.422***	0.123†	0.407***	0.268***	**0.743**

Bold values on the diagonal: square roots of AVE values

*† $p<0.100$; * $p<0.050$; ** $p<0.010$; *** $p<0.001$*

Table 7 HTMT analysis – Confirmatory sample

	SH	C	P	L	S	T
SH						
C	0.314					
P	0.162	0.121				
L	0.404	0.307	0.218			
S	0.329	0.229	0.189	0.294		
T	0.382	0.367	0.091	0.341	0.238	

Table 8 Reliability and validity analysis – Scale replication sample

	Alpha	CR	AVE	MSV	S	L	SH	P	C	T	TE
S	0.916	0.916	0.687	0.106	**0.829**						
L	0.920	0.920	0.743	0.153	0.193***	**0.862**					
SH	0.897	0.897	0.692	0.021	0.147***	0.008	**0.832**				
P	0.896	0.902	0.754	0.106	0.326***	0.095*	0.007	**0.868**			
C	0.841	0.844	0.643	0.153	0.168***	0.391***	0.037	0.172***	**0.802**		
T	0.817	0.819	0.603	0.031	0.177***	0.103*	0.050	0.069	0.015	**0.776**	
TE	0.918	0.918	0.738	0.000	—	—	—	—	—	—	**0.859**

Bold values on the diagonal: square roots of AVE values; Traveler enjoyment: TE

** $p<0.050$; *** $p<0.001$*

dimensions. Factor loadings on the higher-order factors were respectively SH (0.680); L (0.657); T (0.640); T (0.548); S (0.052), and P (0.310).

4.4.4 Scale replication

Measurement model analysis results: With the scale replication sample (n=664), EFA was first conducted to identify latent constructs among the items. The results indicated that Cronbach's alpha values exceeded the acceptable threshold of 0.6 (Table 8). However, the item loadings for $C_{4,}$ $P_{4,}$ SH_5 were identified as insufficient, leading to their removal before the second rotation. Following this adjustment, all remaining loadings were superior to 0.5 (the minimum value was 0.603) and were statistically significant at p=0.001, which supports the reliability of the scales.

The AVE values were also robust, ranging from 0.603 to 0.754 (>0.5) and the MSV for each factor was less than its AVE (Fornell & Larcker 1981) (Table 8). The CR values ranged

Table 9 HTMT analysis – Scale replication sample

	S	L	SH	P	C	T	TE
S							
L	0.177						
SH	0.210	0.031					
P	0.334	0.085	0.043				
C	0.144	0.345	0.067	0.147			
T	0.155	0.081	0.074	0.070	0.024		
TE	0.788	0.224	0.204	0.347	0.185	0.174	

Table 10 Results of hypotheses testing on the relationships between STSE and TE

Hypothesis	Standardized regression weight	S.E	*P* value	Result
H1: S—>TE	0.845	0.039	0.000	Accepted
H2: T—>TE	0.108	0.039	0.005	Accepted
H3: L—>TE	0.015	0.026	0.000	Accepted
H4: C—>TE	0.057	0.031	0.071	Rejected
H5: SH—>TE	0.074	0.022	0.055	Accepted
H6: P—>TE	0.064	0.018	0.000	Accepted

from 0.819 to 0.920, largely exceeding the threshold of 0.7 (Nunnally & Bernstein 1994) (Table 8). These results established the convergent validity of the scales.

For the scale replication sample, the square root of the AVE for each factor was also greater than its correlation with any other factor (Fornell & Larcker 1981) (Table 8). In addition, no trouble was detected in the HTMT analysis using both strict (0.850) and liberal (0.900) thresholds (Henseler et al. 2015) (Table 9), assuring the discriminant validity of the scales.

Structural model results: A summary of the hypothesis testing results is presented in Table 10. About the impact of STSE on traveler enjoyment, the tests were significant for all hypotheses with $p < = 0.05$ (95% confidence level), except for H_4 which was rejected ($p > 0.05$).

5 Discussion

The literature review indicates a need to have a proper STSE scale in the specific context of developing countries. It is critical to identify the fundamental service components of a STSE and create an STSE scale that fully reflects the actual conditions in these countries, incorporating both smart tourism technology elements, core tourism services, and tourists' experiences. While existing studies have highlighted the influence of individual smart technologies on tourist satisfaction or well-being (Zheng & Wu 2023), they rarely provide a systemic evaluation of the STSE as an integrated platform. The present study addresses this gap by developing a holistic measurement framework that captures the multidimensional nature of STSE, including its operational scope, technological infrastructure, and service-user interactions in emerging destinations. This study represents an initial effort to develop and validate a STSE scale tailored to developing countries through a multi-stage process.

The offered STSE scale provides criteria for evaluating the effectiveness of a STSE in emerging economies. By performing a vast literature review, FGDs, IDIs, and Fuzzy Delphi study, this study provides a holistic view of the level of smartness of Vietnam's tourism platforms and the development of smart tourism services globally (through the literature review). While Vietnam embraces 6 STSE service areas similar to international benchmarks, their implementation differs significantly due to Vietnam's unique context. Vietnam focuses on basic digitalization and information provision via apps (e.g., 3D maps, activity suggestions for smart sight, initial steps in smart transportation, tech-enabled food services like QR menus, and basic automation in accommodations), Vietnam lags behind developed countries. The latter prioritizes immersive experiences (VR/AR), comprehensive smart transport systems (AI, IoT, MaaS), personalized shopping and dining, and fully integrated smart infrastructure. Despite rapid growth in smart payment services (VNPay, MoMo, ZaloPay, Viet Smart Travel Card), Vietnam's STSE needs further investment and collaboration to achieve more holistic integration, personalization, and advanced technological adoption. Subsequently, a panel of experts selected the most appropriate set of criteria for the current Vietnamese context through three Delphi rounds with 6 dimensions and 25 items. Following this, the quantitative part was employed to refine and finalize the STSE scale. EFA results ($n=250$) showed a scale with 25 items distributed in 6 dimensions. The results with the confirmatory sample ($n=305$) indicated that, after removing 2 items, the reliability, convergent validity, and discriminant validity of the scales met recommended thresholds. The second-order model assessment results provided good fit indices. Loadings on the higher-order factors were respectively SH (0.680); L (0.657); T (0.640); T (0.548); S (0.052) and P (0.310), providing significant correlations between STSE and its 23 items distributed on 6 dimensions. Finally, the scale was re-tested ($n=664$). The findings revealed a significant impact of the STSE on traveler enjoyment in the context of Vietnam. This last quantitative analysis further validated the applicability of the STSE scale within the Can Tho destination. Notably, the smart catering service dimension of the STSE scale did not exhibit a statistically significant effect on traveler enjoyment. This suggests that the influence of different dimensions within the STSE scale on traveler enjoyment may be context-dependent, indicating that the impact of these factors can vary across different tourist destinations.

Academically, this study makes several key contributions. First, it develops a robust and objective measurement tool, identifying 23 items across 6 service groups to assess the STSE in Vietnam. This scale not only serves as a foundation for future research in similar contexts but also advances conceptual understanding of how a STSE functions under constrained technological and infrastructural conditions. Notably, existing measurement scales designed for developed economies are not suitable for developing economies. Moreover, while prior studies (e.g., Zheng & Wu 2023) have demonstrated that specific STT features—such as informativeness, personalization, and interactivity—can enhance hedonic and eudaimonic well-being, our study extends these findings by embedding such features within a broader service ecosystem. In doing so, it reframes the analysis from a feature-level evaluation toward a platform-level understanding that reflects operational reality, policy constraints, and socio-technical readiness of developing countries.

Second, methodologically, the research combined multiple qualitative techniques to gather novel insights into the research topic until saturation. In particular, it employed the Fuzzy Delphi method to enable experts to select the most appropriate criteria for the STSE in Vietnam. The quantitative part involved a rigorous three-sample test to refine and finalize the STSE scale.

Third, from a practical standpoint, the research identifies a comprehensive set of criteria to guide investment decisions and foster smart tourism product and service development. These criteria offer a strategic framework for policymakers, businesses, and organizations to optimize resources and improve operational efficiency in a STSE.

In the smart sight service dimension, integrating technologies like AR enhances tourist interactions with cultural and historical sites. Policymakers can form partnerships with tech providers to improve local attractions and reduce operational costs through automated information delivery, such as AR-guided tours in heritage sites.

In smart lodging service, IoT devices can improve operational efficiency by monitoring room conditions, managing energy use, and automating check-ins. For example, smart sensors adjusting lighting and temperature based on guest preferences optimize energy consumption and enhance guest satisfaction.

For smart transportation services, investments in real-time data analytics can optimize fleet management and route planning. Predictive maintenance systems prevent service disruptions, while autonomous electric shuttles offer eco-friendly, on-demand transportation, reducing congestion and carbon emissions.

In smart catering service, AI-powered systems for personalized dining experiences and automated order processing can optimize inventory management, reduce food waste, and improve efficiency. For instance, mobile apps enabling pre-orders based on dietary restrictions speed up service and minimize wait times.

For smart shopping service, smart retail technologies like Radio Frequency Identification tags and mobile apps improve inventory tracking, customer recommendations, and checkout processes. A practical example includes mobile apps offering discounts or loyalty rewards to tourists in specific shopping districts.

Lastly, in the smart payment service domain, blockchain and digital wallets facilitate secure, cashless transactions across tourism services, reducing costs for businesses. A unified mobile payment system across tourism sectors allows tourists to use one digital wallet for lodging, meals, transportation, and shopping, improving user experience and operational efficiency.

6 Conclusion

This research successfully developed and validated the STSE scale, demonstrating high reliability and robust psychometric properties. By offering a structured framework for evaluating smart tourism sustainable ecosystems, the STSE scale not only contributes to academic discourse but also provides a practical diagnostic tool for tourism authorities and stakeholders, particularly in emerging economies like Vietnam. Destination managers, in particular, can leverage this scale to identify technological bottlenecks and sustainability gaps, enabling data-driven resource allocation and facilitating the transition towards more smarter and resilient tourism development.

While the study establishes a solid foundation, its findings should be interpreted with awareness of certain limitations. The reliance on convenience sampling, coupled with a focus on tech-savvy tourists, may restrict the comprehensiveness of the results, potentially overlooking the perspectives of the broader community and governance structures. Furthermore, the research was conducted within Vietnam's unique socio-economic context, raising questions about the STSE scale's applicability and generalizability across different international settings. Another limitation of this study is that while it identifies discrete dimensions of the STSE, it does not fully capture the interconnected harmonization between core sectors such as accommodation, transportation, catering, attraction, and payment. Future research should employ systemic modeling or path analysis to investigate how these various applications synergize to create a seamless tourist journey, rather than evaluating them as independent components. Additionally, exploring the integrated impact of these harmonized services on the overall national tourism revenue structure would provide deeper insights into the economic sustainability of smart ecosystems in emerging countries.

Moreover, future research should adopt longitudinal designs to capture the dynamic evolution of smart ecosystems over time. Last but not least, expanding the scope to include elements such as smart governance and smart community would offer a more comprehensive understanding of the ecosystem as a whole. Ultimately, this study highlights that the true value of a STSE does not lie merely in its technological sophistication, but rather in its capacity to create long-term sustainable benefits for both visitors and host destinations, fostering a balanced and resilient tourism framework.

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Declarations

Conflict of interests Disclosure of potential conflicts of interest

Informed consent Research involving human participants and/or animals informed consent

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