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RESEARCH PAPER

Unpacking the Key Influencers for Customer Satisfaction in Tourism Mobile Applications Using Fuzzy Cognitive Mapping

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Abstract

This research tries to identify the critical success factors (CSFs) for Tourism Mobile Applications (TMAs) and to evaluate their influence on customer satisfaction. Our process was twofold. Initially, a framework of potential CSFs was constructed through a comprehensive literature review and expert opinions in the field. Consequently, the interrelationships and relative influence of these factors were analyzed using Fuzzy Cognitive Mapping (FCM). The data feeding the FCM model was derived from two distinct expert-administered questionnaires: one designed for the Analytic Hierarchy Process (AHP) to establish initial weights, and another to define the causal relationships within the FCM. The results reveal that "perceived playfulness" is the most influential critical success factors. By providing strategies for service providers to attract more customers and users, the proposed framework aims to ensure satisfactory service delivery. This research contributes to the operational strategies that can enhance the competitiveness capability of TMAs and highlights the essential considerations for TMA developers.

Keywords:
Analytic Hierarchy Process, Critical Success Factors, Fuzzy Cognitive Mapping, Technology Acceptance Model, Tourism Mobile Applications.

Introduction

Changes are an inseparable part of each economic structure in the world. These changes include the features that firms need to include in the products and services they offer to customers (Tran, Ly, & Le, 2019). One of the top sectors in the world, historically, is the tourism industry. Today, tourism has formed the major sector in different countries all over the world (Danish & Wang, 2019). The tourism industry is undergoing fundamental changes, with increasing the need for travelers' satisfaction and comfort in visiting tourist destinations over time. Also "tourist satisfaction is considered as a main goal in tourism marketing theory and practice, due to its importance for achieving loyalty, repetition in destination visiting and finally profit" (Perovic et al., 2018). Nevertheless, today this sector is known as a very important industry in the

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national economy, and the development of this industry plays a very important role in the country's economic cycle. In fact, "this industry has increased opportunities related to business, investment and employment" (Horng et al., 2018; Bagherabad et al., 2025). While the tourism industry presents several opportunities for businesses, there are also various factors that pose threats to their success. (Jeon et al., 2024) has identified these threats and categorized them into three sections as a set of barriers, which are illustrated in Figure 1.

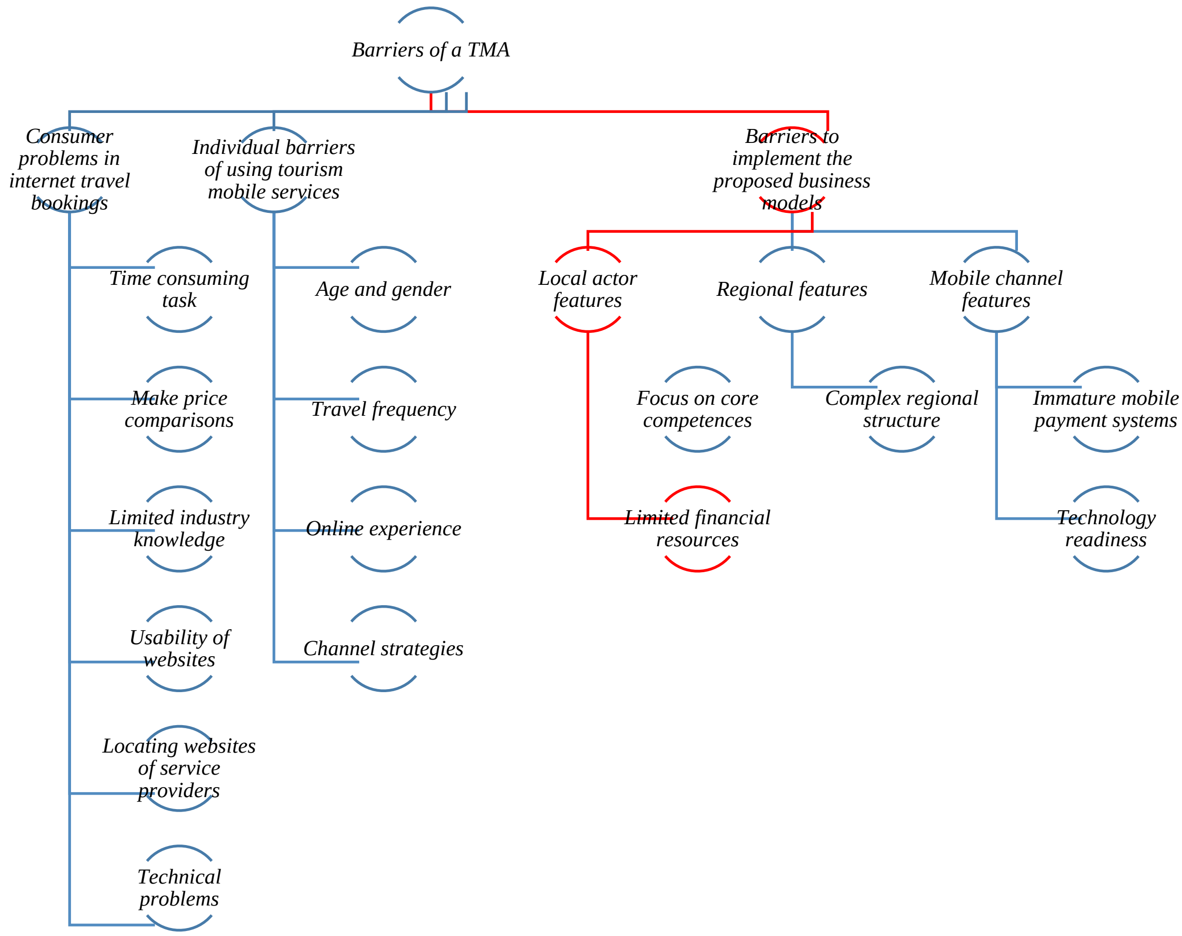

Figure 1. The identified barriers to TMA

To address the third barrier, this study aims to evaluate the relationship between tourism app success criteria and their impact in a competitive environment using an integrated FCM-AHP approach. By doing so, this research focuses on the core of competitiveness and technology readiness, as it identifies CSFs that can help businesses overcome the limited financial resources barrier. The study also seeks to determine the most effective CSFs that can enhance the services offered by businesses in the tourism industry, attract more users, and ultimately achieve customer satisfaction.

Today, human access to products and services is possible easily due to technological advancement and also the presence of the Internet of Things in human daily life. The tourism industry as an important active industry in most countries also uses technology. The extensive dissemination of information and communication technology (ICT) makes structural changes in the dynamics of competitiveness of tourist destinations and the travel procedure (Del Vecchio et al., 2018). In the last decade, mobile applications have been promoted, covering all services in the tourism industry. These services include, for example, all kinds of reservations (such as vehicles ticket, residences, etc.), navigation issues, and services related to tourism destinations and their particular attractions, etc. Moreover, while many studies have focused on the Mobile

Technology Acceptance Model (MTAM) in the tourism sector, our research aims to offer a comprehensive structure that addresses the satisfaction factors influencing behavioral intention (BI) to use mobile platforms. We will investigate the cause-and-effect relationships between these factors, which will enable us to assess the relative strength of each factor in fulfilling others. One of the major implications of our research is to guide effective budget allocation by identifying and prioritizing the most impactful factors, thereby enhancing the overall effectiveness of the TMA development process.

Thus, this paper aims at evaluating and analyzing critical factors for TMAs success in providing customer satisfaction by investigating appropriate conditions and opportunities for TMAs using multi-criteria decision-making (MCDM) principles, in particular FCM which can help to identify the criteria relationships and effects. The implications of this research can be used as a helpful guideline or instruction for managers and decision-makers to attract more customers (users).

Experiments and Theory

Tourism is one of the attractive contexts for researchers over recent years. Many questions have arisen for service providers in the tourism industry regarding the ever-increasing use of information and communication technology (ICT). The research ranges from using the users' opinions in sentiment analysis to the investigation of the different technology acceptance models in smart platforms.

One of the most important aspects of tourism and ICT interaction is smart tourism, which is powered by internet-enabled smartphones. The widespread application of smart tourism, which is adopted by users beyond e-tourism (not only in pre- and post-travel processes but also during travel), has led researchers to evaluate this segment of tourism from various aspects. Due to the significant role of smartphones in this type of tourism, the mobile app market has thrived and created the smart tourism industry and especially TMA. Our principal research question is: What is the most effective critical success factor (CSF) in tourism mobile platforms? Answering this question can provide a significant competitive advantage for service providers in the industry.

Tourism Mobile Apps (TMAs)

TMA has accounted for a large number of studies on e-tourism. Ivanochko et al. (2021) investigated some common problems in existing solutions for TMAs in a tourism destination by considering a hypothesis about sharing real-time locations in the choosing urban attraction process. Also, Alalwan (2020) had undertaken research to gain a greater understanding of the aspects that can lead to Jordanian customer satisfaction as well as their continued use of food ordering applications by using the Unified Theory of Acceptance and Use of Technology (UTAUT2) model. Wong et al. (2018) introduced a new conceptual model by collecting baseline data and improving a comprehensive performance appraisal model of mobile websites. Benaddi et al. (2024) identify challenges in developing tourism-specific chatbots, such as the complexity of integrating AI and the costs associated with using commercial NLP services. Their study proposes a "software factory" approach using Domain-Specific Languages (DSLs) to streamline the development process. Garcia-Lopez et al. (2021) provided some recommendations for TMA's usability that could lead to increasing their usability and as result developing traveling to tourism destinations, reciprocally. Madeira et al. (2021) assessed the accessibility of TMAs by defining 33 quantitative and qualitative requirements for comparing different TMAs. Another study by Calvignac & Smolinski (2020) evaluated the effect of using the smartphone on tourist sightseeing behavior. In another study about the impact of mobile payment on the repurchase intention of consumers, Sun et al. (2020) developed a conceptual model of website evaluation in the mobile hotel reservation drawing upon the theory of planned behavior (TPB). Also, (Magasic & Gretzel, 2020) investigated the roaming condition that provides access to different kinds of digital services by connecting to the internet during travel. Regarding the use of a recommender system and augmented reality innovation, Fun et al. (2021) designed an Android-based TMA which includes low information maintenance and real-time update. In another research, Shrestha et al. (2021) analyzed a TMA in terms of security and based on achieved tourist requirements through different kinds of interviews. The development of digital quality frameworks, such as those for virtual reality in tourism, further underscores the importance of user experience and technological innovation in attracting visitors (Latifi et al., 2024).

In today's landscape, the integration of TMAs as a technical aspect holds a significant market share, with numerous mobile apps offering varying performance attributes while delivering similar functionalities. This diversity complicates the task of identifying the most effective and efficient mobile app for users. Our study aims to present a comprehensive model that examines different types of MTAM across various tourism sectors.

Importantly, there exists a notable disparity in previous literature concerning the critical factors influencing behavioral intention (BI) in using these applications. To provide clarity before engaging with existing studies, we emphasize the primary rationale for implementing MTAMs as a means to achieve CSFs within the tourism sector. In addition, Guleria, Joshi, and Adil (2023) focus on customer-based brand equity through destination attachment, indicating that memorable experiences and satisfaction lead to loyalty, thereby enhancing a destination's competitiveness (Guleria et al., 2023; Rivandi and Oskouei, 2025). Consequently, the effectiveness of a TMA can be assessed by its capacity to draw a larger customer base, which is fundamentally linked to understanding visitor satisfaction, loyalty, and behavioral factors towards utilizing these applications. By addressing these factors, TMAs can significantly contribute to the tourist industry's growth. They not only help destinations stand out in a crowded market but also empower potential visitors with essential information, streamline their travel experiences, and ultimately improve customer satisfaction and loyalty.

Mobile Technology Acceptance Model (MTAM)

There is enriching literature in BI for MTAM in the tourism area. The obvious achieved outcome after investigating them, emphasizes several key factors. Chen & Tsai (2019) developed a location-based mobile tourism app for travel planning, which combined hybrid filtering technology with the ant colony optimization algorithm to create a more efficient customized tourism recommendation. They believed that information quality (IQ), perceived ease of use (PEU), and perceived usefulness (PU) are the key factors in meeting MTAM users' satisfaction. Also, Vasconcelos et al. (2021) emphasize that perceived utility has the greatest influence on the overall intention of use in TMAs due to the correlation's construction.

Some studies identified and introduced other factors as the main criteria for constituting BI. For instance, Hamouda (2022) revealed that word of mouth about a TMA could be a suitable predictor for intention to use by providing a structural equation modeling. In another study, Zhou et al. (2022) developed a new model to investigate the intention to use travel apps among the young generations. They concluded that the hedonic motivation feature in this generation as the main driver has the most effect on TMA's intention of use.

In most studies, one or two specific factors are introduced as the most effective criteria for fulfilling user satisfaction when using tourism MTAM. This category can be referred to as Abu-AlSondos et al. (2023), who investigates mobile information systems and highlights that perceived ease of use and perceived playfulness are essential factors in promoting user acceptance and satisfaction. This research aligns with the Mobile Technology Acceptance Model (MTAM) by demonstrating that ease of use enhances both playfulness and perceived usefulness, contributing significantly to user engagement. This focus on how users process and apply categorical knowledge to understand app functionalities finds a parallel in research on definitional tasks in other educational domains (Azimi Asmaroud, 2022). Ho et al. (2022) discuss that perceived usefulness and ease of use significantly affect behavioral intentions toward AI-powered services in tourism, highlighting how these factors enhance users' willingness to adopt new applications. Similarly, Lew et al. (2020) provided an MTAM for a mobile wallet in the hospitality industry and emphasized PEU and PU as the most effective criteria for meeting user satisfaction. Additionally, Mohamad et al. (2023) examined online mobile hotel booking, finding that perceived usefulness and enjoyment impact behavioral intentions, with perceived cost moderating the effect of enjoyment, aligning with the Technology Acceptance Model (TAM) in hospitality contexts.

The third category provides a contrasting result compared to other investigations. A study by Imtiaz and Suki (2022) applies Partial Least Squares Structural Equation Modeling (PLS-SEM) to examine tourists' perceptions of mobile travel applications in Pakistan, focusing on user satisfaction and engagement. This study provides insights into developing user-centric mobile applications for tourism, reinforcing the role of user satisfaction in enhancing trust and usage intentions He believed that performance expectancy (PE) and perceived usefulness (PU) don’t have a considerable effect on BI to using TMA. They conclude by investigating the Malaysian tourist BI in MTAM. On the other hand, Huang et.al (2019) found that, although PU and PEU don’t affect tremendously on BI they have a positive and direct effect on the user experience of the hotel mobile app.

This paper makes efforts to identify the CSF for providing a framework from customer satisfaction to creating BI to the use of TMAs. Extracting the appropriate criteria for future analysis requires knowledge about some issues such as competitors’ conditions and sufficient cognition from users’ attitudes. This advantage can be available by using competitive intelligence. Nevertheless, 10 CSF are identified in this manner. They are demonstrated in Table 1. Literature review and using expert opinions are two efficient tools for eliciting the criteria.

Because of the existing literature on smart tourism, this study has distinguished itself from prior studies in several ways. The first one is about the identified criteria. A new framework named CSFs is developed based on the previous MTAM in the tourism area and experts’ opinions. The second advantage refers to the analytical method. The FCM as a practical approach helps to determine the most influential CSF. There are three main reasons for choosing this approach: (1) FCM is appropriate to analyze complex structures; (2) taking advantage of the reliability of FCM in uncertain situations, both quantitative and qualitative data can be used; (3) this method reveals the effect of changing one factor on the whole system clearly (Knox et al., 2023). Another advantage of this research is providing practical implications for managers. The extracted final criteria due to previous MTAM in tourism are listed below:

The dual application of the research results is among the most significant aspects of this study as it caters to both service providers and end-users simultaneously. While end-users benefit from being able to identify the best TMA based on their preferences, there are several advantages that service providers can achieve. These include meeting customer satisfaction, building a strong reputation and brand that leads to an increase in credit and market share, and ultimately gaining more profit. Identifying CSFs and determining their effectiveness from two different perspectives is a valuable accomplishment. The first perspective relates to the benefits for service providers. Addressing each identified factor requires investments in corresponding specialized fields. However, by investigating influential relationships between these factors, service providers can focus on specific CSFs that can help meet others. This approach prevents incurring extra charges, which is a significant advantage. Moreover, this research provides a structure for diagnosing a satisfying TMA based on user attitudes, serving end-users by enabling them to make informed decisions. Overall, this study offers comprehensive insights into the factors that drive customer satisfaction, and actionable strategies for service providers to enhance their service delivery. The investigated references (in mentioned fields) are summarized in Table 2.

Table 1. The CSFs

NO.	Performance Benchmark	Target	References
1	Perceived value of mobile technology (PVMT)	Related to customer satisfaction when using mobile technology and according to the individual needs	(Lei et al., 2019; Hemmati-Asiabaraki et al., 2021; Hemmati-Asiabaraki et al., 2022)
2	Performance Expectancy (PE)	A measure that demonstrates people perception about mobile application role in their job achievement	Imtiaz and Suki (2022); (Abu-taieh et al., 2022)
3	Perceived Ease of Use (PEU)	The degree of ease associated with the use of the system	Imtiaz and Suki (2022); (Ch'ng et al., 2023); (Abu-AlSondos et al., 2023); Ho et al. (2022); (Abu-taieh et al., 2022)
4	Social influence (SI)	The impact of joining the community to use an app	Imtiaz and Suki (2022); (Abu-taieh et al., 2022) (Ch'ng et al., 2023)
5	Mobile Innovativeness in Information Technology (MIIT)	Individuals with higher innovativeness tend to have a higher understanding of the subject matter and thus help to reduce the perception of uncertainties	Sim et al. (2014); Imtiaz and Suki (2022)
6	Perceived Playfulness (PP)	This construct denotes the enjoyment, excitement, and pleasure deriving from utilizing a system and is regarded as an intrinsic motivator	(Ch'ng et al., 2023); (Abu-AlSondos et al., 2023); (Abu-taieh et al., 2022)
7	Perceived trust (PT)	Tourists have to rely on information about tourism services because their experience quality can only be evaluated after consumption. Thus, trust may be a key driver for intentions to use an information source, such as a mobile information service	(Ahmad & Sharma, 2023); (Abu-taieh et al., 2022)
8	Perceived service quality (PSQ)	five dimensions that consumers are identified that consumers use when evaluating service quality: tangibles, reliability, responsiveness, assurance, and empathy	(Abu-taieh et al., 2022); (Ahmad & Sharma, 2023; Tavana et al., 2022)
9	Perceived Cost Transparency (PCT)	The degree of transparency in costs can make powerful sense in reliability for customer	(Abu-taieh et al., 2022)
10	Information System Quality (ISQ)	It is a compilation of two criteria: information quality and system quality that indicates the accuracy and completeness of achieved information from applications to meet the characteristics of user requirements which include usability, accessibility, reliability, compatibility, and time	(Ahmad & Sharma, 2023); (Li & Li, 2024)

Table 2. Knowledge areas related to the research purpose

Domain	Description	Relevant Sources
TMAS	Some kinds of services that are provided before, during, or even after a trip	Alalwan (2020), Calvignac & Smolinski (2020), Wong et al. (2018), Benaddi et al. (2024), Ivanochko et al. (2021), Garcia-Lopez et al. (2021), Madeira et al. (2021), Fun et al. (2021), Shrestha et al. (2021) Sun et al. (2020), Magasic & Gretzel (2020)
MTAM	Providing a model for recognition of user behavioral intention to use specially in tourism area	Chen and Tsai (2019), Vasconcelos et al. (2021), Hamouda, (2022), Zhou et al. (2022), (Abu-AlSondos et al., 2023), Ho et al. (2022), Lew et al. (2020), Mohamad et al. (2023), Imtiaz and Suki (2022), Huang et al. (2019)

Research Methodology

The purpose of this paper is to identify TMAs success factor by using FCM approach. Then the cause-and-effect relationship is drawn up and the most effective factors are determined. The obtained conclusion demonstrates the most profitable and efficient sectors for meeting customer satisfaction to the service providers to invest in superior sectors. This process will lead to saving both money and time in a competitive market and prevent the decentralization of tasks in a structure.

In this investigation, 10 CSFs have been identified through a literature review and interviews with experts who provide services in the tourism industry on the web and mobile applications. At this level, the TMA studies were initially investigated. Then all MTAM in the tourism area was evaluated. Eventually, the current study achieves a comprehensive cause-and-effect model containing all tourism areas by using provided models in the previous literature and TMA experts. After determining the criteria, the tourism app users' opinions were asked about the influences of CSFs by using AHP and FCM questionnaires (Tables A and B demonstrated in Appendix).

FCM

FCM was first introduced by Kosko (1986). According to his definition, FCM is a directed graphical diagram aimed at illustrating causal relationships among factors, with the relationship between each pair of factors specified within the range of [-1, 1].

To implement the FCM method, the following steps should be performed in order:

1. Comparing the Importance of Factors (Criteria) for Local Weight Extraction Using the Eigenvalue Method

In this procedure, all factors' weight will be achieved by using the pairwise compression matrix which is obtained from the AHP questionnaire. The Saaty nine-point scale is used for a pairwise comparison matrix and all criteria are compared in pairs. The Saaty linguistic scale (Saaty, 1980) is observed in Table 3.

Table 3. Saaty linguistic scale

Value	Comparison status of *i* with respect to *j*	Explanation
1	The same preference	Both elements (*i* & *j*) have equal importance.
3	Slightly preferred	Element *i* is Slightly more important than element *j*.
5	Much preferred	Element *i* is more important than *j*.
7	Much more preferred	Element *i* is much more important than *j*.
9	Quite preferable	Element *i* is absolutely more important than *j*.
2-4-6-8	Midway	

The equations of this method are demonstrated in appendix.

2. Obtaining an Adjacency (Correlation) Matrix and Drawing the Fuzzy Cognitive Map

"Adjacency matrix" is achieved by experts' opinions which scored as an answer to the FCM questionnaire (Kosko, 1986). This questionnaire determines the impact of all the criteria in the presence of other criteria. The influences of criteria on each other are determined by linguistic variables. All the linguistic variables and their fuzzy values are introduced in Table 4.

Table 4. Fuzzy numbers for linguistic variables

Linguistic Variable	Fuzzy Numbers
No Effect	(0,0,0)
Very Low	(0,1,2)
Too Low	(1,2,3)
Low	(2,3,4)
Relatively Low	(3,4,5)
Medium	(4,5,6)
Fairly High	(5,6,7)
Much	(6,7,8)
Too Much	(7,8,9)
Very Much	(8,9,10)

If more than half of the respondents, diagnose the impact value of a specific factor equal to zero then its specific element will be considered zero in the total matrix, otherwise, according to numerous answers, it is necessary to calculate their arithmetic mean (for each element) and its result creates the adjacency matrix elements as follows.

$$a_{ij} = \frac{1}{H}\sum_{K=1}^{H} x_{ij}^{k} \quad (1)$$

"H" is the number of specialists or experts.

Then it should be normalized by using following equation.

$$D = A/S \quad (2)$$

In this equation, A is the adjacency matrix and S is achieved from the below equation.

$$S = \max\left(\max_{1<i<n} \sum_{j=1}^{n} a_{ij}, \max_{1<j<n} \sum_{i=1}^{n} a_{ij} \right) \quad (3)$$

3. Calculate the Steady-State Matrix (C^*) Using

$$A_i^{(t+1)} = f\left(A_i^t + \sum_{\substack{j=1 \\ j\neq i}}^{n} W_{ji} A_j^t \right) \quad (4)$$

It should be noted that $A^0 = I_{n*n}$ (the initial value of the matrix A) is equal to an $n*n$ "identity matrix" which is used n criteria in this matrix. $f(x)$ is also called the "threshold function" in this equation. Due to the problem can be used various threshold functions in this paper, such as Sign (Bivalent) function, Trivalent function, Sigmoid (Logistic) function, and Hyperbolic Tangent function (Kahraman & Cevik Onar, 2015). This research uses the sigmoid (logistic) function demonstrated in the following equation.

$$f(x)=\frac{1}{\left(1+e^{-x}\right)} \quad (5)$$

The state vector that is calculated in the first iteration is called A^1 which is obtained by putting the initial matrix (A^0) in Eq.6. This value is used as another input for Eq.6 and this process will be continued as far as $A^{t+1}-A^{t}\leq 0.0001$, or the state matrix repeat periodically. Normal Steady State matrix is calculated using:

$$C_n^*=\frac{C^*}{K} \quad (6)$$

In this equation, “*K*” is the greatest steady-state matrix total row.

Based on the normalized steady-state matrix and the weights obtained in the first stage of this method for each criterion, the final weights can be calculated to identify the most influential to the least influential criteria using below equation.

$$G=L_n+C_n^* * L_n \quad (7)$$

In this equation, L_n is the normalized local weight.

Results

The main feature of CI is to consider the competitors and analyze their changes for decision-makers to decide the best way but the following criteria give a vision from a competitive environment and in other words introduce a service provider as a pioneer in his business. This study analyzes the relationships and influences between extracted criteria by using a literature review in TMA field.

The respondents of this research are people who use the TMA services as end users and constitute the paper's statistical population. It should be noted that mobile app users are divided into 5 groups in different research and analysis. The first category is “innovators”. These people are so risky and they have high social status and also have sufficient financial liquidity and high social relationships. The second group is “early adopters”. They are people who create a dynamic opinion in society and other people follow them. Early adopters are placed in a better condition than underside categories in terms of social status, financial liquidity, and advanced education. They use an independent choice of adoption to help them maintain a central communication position. In this category, the third group belongs to the “early majority”. They accept an innovation after a varying degree of time that is significantly longer than the innovators and early adopters. They have better social status than people with conventional social status. The fourth group is the “late majority”. They adopt an innovation after the average of the participant. These people start to use innovation with a degree of doubt and adopt that innovation when the majority of society has accepted it. Also, this category has lower social status and financial liquidity than mentioned categories. Finally, the last group of this category is “laggards”. These people hate the changes usually and focus on traditions most of the time. They have the lowest social status and financial liquidity in this category and they have a relationship only with their family and close friend. This paper uses the first (Innovators) and second (Early adopters) groups as a respondent to questionnaires who have at least one-year experience of using TMA for increasing data reliability in performed analysis. In this regard, 40 FCM and AHP questionnaires are distributed between the mentioned categories of end users.

Now, these criteria as a result of a comprehensive literature review and expert opinions will be analyzed due to the FCM approach. Thus, the adjacency matrix was constituted by expert opinions that are displayed in Table 5.

Table 5. Adjacency matrix

CRT *j* CRT *i*	PVMT	PE	PEU	SI	MIIT	PP	PT	PSQ	PCT	ISQ
PVMT	0	0. 1286	0. 1202	0. 1012	0. 1083	0. 0631	0. 0988	0. 0988	0. 0869	0. 1024
PE	0. 0667	0	0. 1155	0. 0976	0. 1143	0. 0798	0. 1048	0. 1115	0. 0750	0. 1012
PEU	0. 0976	0. 1131	0	0. 0833	0. 0548	0. 0774	0. 0560	0. 0929	0. 0583	0. 0702
SI	0. 0738	0. 0833	0. 0369	0	0. 0929	0. 0702	0. 1071	0. 0762	0. 0488	0. 0762
MIIT	0. 1607	0. 1405	0. 1107	0. 1119	0	0. 0750	0. 1214	0. 1131	0. 0786	0. 0881
PP	0. 0298	0. 0536	0. 0595	0. 1005	0. 0286	0	0. 0405	0. 0667	0. 0190	0. 0571
PT	0. 0679	0. 0643	0. 0250	0. 1036	0. 0369	0. 0060	0	0. 0964	0. 1167	0. 1095
PSQ	0. 0976	0. 1083	0. 0905	0. 1405	0. 0464	0. 0571	0. 0976	0	0. 0917	0. 1381
PCT	0. 0643	0. 0690	0. 0369	0. 0845	0. 0274	0. 0226	0. 1500	0. 0881	0	0. 0619
ISQ	0. 0679	0. 0833	0. 0714	0. 1071	0. 0393	0. 0476	0. 1202	0. 1429	0. 0738	0

The values in this table give the effectiveness of success criteria in the presented system. For instance, the amount of MIIT effectiveness on PVMT is 0.1607 which is the highest level of effectiveness among all success criteria. This value demonstrates that the amount of knowledge a user has in IT will have a huge impact on the value that he perceives from mobile technologies. All of these relations can be interpreted for the other success criteria. The final adjacency matrix is also shown in Table 6.

Table 6. The final adjacency matrix

CRT *j* CRT *i*	PVMT	PE	PEU	SI	MIIT	PP	PT	PSQ	PCT	ISQ
PVMT	0	0	0.1202	0.1012	0.1083	0	0.0988	0.0988	0	0
PE	0	0	0.1155	0.0976	0.1143	0	0.1048	0.1115	0	0
PEU	0.0976	0.1131	0	0	0	0	0	0.0929	0	0
SI	0	0	0	0	0.0929	0	0.1071	0	0	0
MIIT	0.1607	0.1405	0.1107	0.1119	0	0	0.1214	0.1131	0	0
PP	0	0	0	0.1005	0	0	0	0	0	0
PT	0	0	0	0.1036	0	0	0	0.0964	0.1167	0.1095
PSQ	0.0976	0.1083	0.0905	0.1405	0	0	0.0976	0	0.0917	0.1381
PCT	0	0	0	0	0	0	0.15	0	0	0
ISQ	0	0	0	0.1071	0	0	0.1202	0.1429	0	0

The cause-and-effect relationship graph will be drawn by having a final adjacency matrix which a threshold of 0.0905 was applied to exclude weak causal relationships (<10% influence), based on expert consensus and can be seen in Figure 2. Each factor can be influenced by the other criteria simultaneously. These relationships are identifiable completely by observing the cause-and-effect relationships graph. For example, ISQ factor is influenced by form factors such as PVMT, PSQ, PE, and PT and influences SI.

As shown in Figure 2, PP influences SI (0.1005). It is not influenced by any other criteria. This means that this criterion has an impact on people joining a community to use a tourism app. It was identified as the most influential criterion because it operates independently and no other criterion was able to affect it. PT influences PSQ (0.0964), SI (0.1036), ISQ (0.1095), and PCT (0.1167). It is also influenced by MIIT (0.1214), PE (0.1018), PSQ (0.0976), PVMT (0.0988), SI (0.1071), ISQ (0.1202), and PCT (0.1500). This indicates that trust is shaped by almost all upstream factors, especially service quality and cost transparency. Trust also provides feedback to some criteria such as ISQ, SI, PSQ, and PCT, which shows a mutual reinforcement.

In this paper, the logistic threshold function is used according to the problem structure for attaining the steady-state matrix. The steady-state matrix is shown in Table 7.

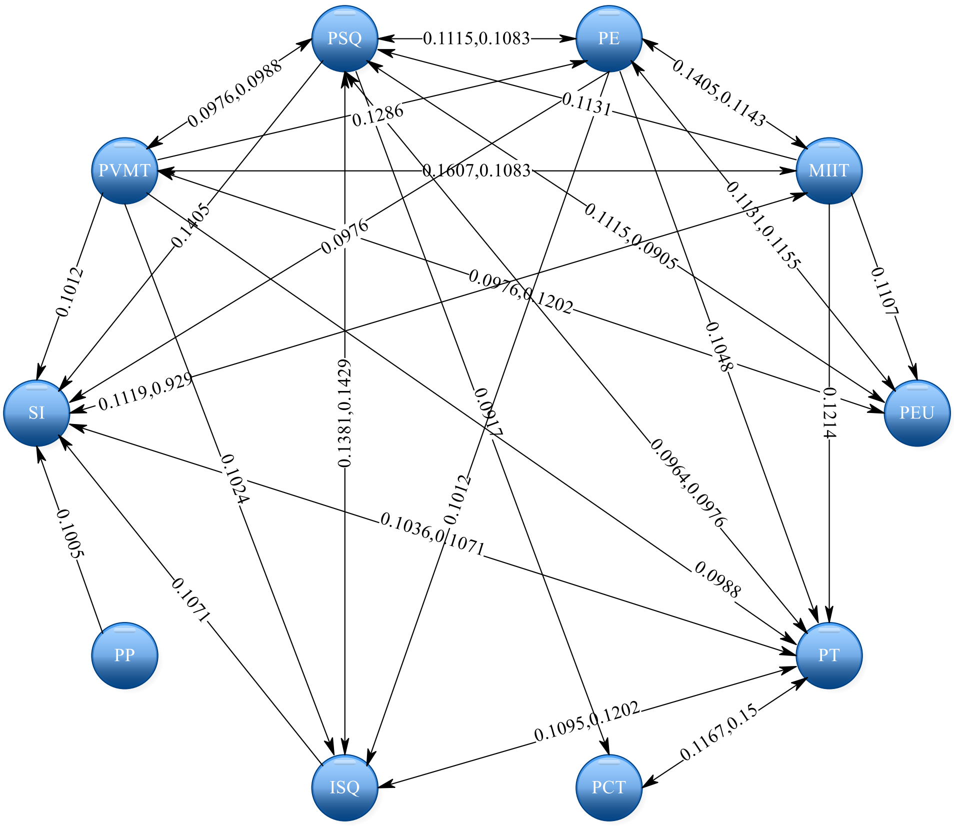

Figure 2. The cause and effect relationships chart

Table 7. Steady-state matrix

CRT *j* CRT *i*	PVMT	PE	PEU	SI	MIIT	PP	PT	PSQ	PCT	ISQ
PVMT	0.6590	0.6590	0.6823	0.6786	0.6800	0.6590	0.6781	0.6781	0.6590	0.6590
PE	0.6590	0.6590	0.6814	0.6779	0.6811	0.6590	0.6793	0.6806	0.6590	0.6590
PEU	0.6779	0.6809	0.6590	0.6590	0.6590	0.6590	0.6590	0.6770	0.6590	0.6590
SI	0.6590	0.6590	0.6590	0.6590	0.6770	0.6590	0.6797	0.6590	0.6590	0.6590
MIIT	0.6902	0.6862	0.6804	0.6807	0.6590	0.6590	0.6825	0.6809	0.6590	0.6590
PP	0.6590	0.6590	0.6590	0.6784	0.6590	0.6590	0.6590	0.6590	0.6590	0.6590
PT	0.6590	0.6590	0.6590	0.6790	0.6590	0.6590	0.6590	0.6776	0.6816	0.6802
PSQ	0.6779	0.6800	0.6765	0.6862	0.6590	0.6590	0.6779	0.6590	0.6767	0.6858
PCT	0.6590	0.6590	0.6590	0.6590	0.6590	0.6590	0.6881	0.6590	0.6590	0.6590
ISQ	0.6590	0.6590	0.6590	0.6797	0.6590	0.6590	0.6823	0.6867	0.6590	0.6590

After obtaining a steady-state matrix, Eq.8 is used for normalization. The normalized steady-state matrix is shown in Table 8.

Table 8. The normalized steady-state matrix

CRT *j* CRT *i*	PVMT	PE	PEU	SI	MIIT	PP	PT	PSQ	PCT	ISQ
PVMT	0.0978	0.0978	0.1013	0.1007	0.1009	0.0978	0.1006	0.1006	0.0978	0.0978
PE	0.0978	0.0978	0.1011	0.1006	0.1011	0.0978	0.1008	0.1010	0.0978	0.0978
PEU	0.1006	0.1011	0.0978	0.0978	0.0978	0.0978	0.0978	0.1005	0.0978	0.0978
SI	0.0978	0.0978	0.0978	0.0978	0.1005	0.0978	0.1009	0.0978	0.0978	0.0978
MIIT	0.1024	0.1018	0.1010	0.1010	0.0978	0.0978	0.1013	0.1011	0.0978	0.0978
PP	0.0978	0.0978	0.0978	0.1007	0.0978	0.0978	0.0978	0.0978	0.0978	0.0978
PT	0.0978	0.0978	0.0978	0.1008	0.0978	0.0978	0.0978	0.1006	0.1012	0.1009
PSQ	0.1006	0.1009	0.1004	0.1018	0.0978	0.0978	0.1006	0.0978	0.1004	0.1018
PCT	0.0978	0.0978	0.0978	0.0978	0.0978	0.0978	0.1021	0.0978	0.0978	0.0978
ISQ	0.0978	0.0978	0.0978	0.1009	0.0978	0.0978	0.1013	0.1019	0.0978	0.0978

The obtained weights by AHP questionnaire and the Eigenvalues and also considering that $\sum_{i=1}^{n} W_i = 1$, are as follows:

(W_1, W_2, W_3, W_4, W_5, W_6, W_7, W_8, W_9, W_{10}) =
(0.999, 0.0834, 0.1049, 0.0722, 0, 1453, 0. 1535, 0. 0684, 0. 0779, 0.1090, 0.0856)

Also according to equation 7, the achieved values are as follows:

(G_1, G_2, G_3, G_4, G_5, G_6, G_7, G_8, G_9, G_{10}) =
(0.1991, 0.1827, 0.2035, 0.1706, 0.2450, 0.2515, 0.1673, 0.1776, 0.2071, 0.1842)

According to the results, all the determined criteria for TMA success can be ranked from 1 (the most influential) to 10 (the least influential). This rating will be as follows: (1) Perceived playfulness, (2) Mobile innovativeness in IT, (3) Perceived cost transparency, (4) Perceived ease of use, (5), Perceived value of mobile technology (6) Information system quality, (7) Performance expectancy, (8) Perceived service quality, (9) Social influence, and (10) Perceived trust. In this rating, “Perceived ease of use” is selected as the most influencing criterion and “Mobile innovativeness in IT” is selected as the most influenced one. It is worth noting, these ranked CSFs collectively shape BI, with PP emerging as the primary driver.

Managerial Implications

Managers in organizations from different industries have five important tasks including planning, organizing, human resource management (HRM), leadership, and ultimately monitoring. But decision making is the most important task of a manager (Szukits & Móricz, 2024). The actual outline of this critical task is totally obvious in all five areas of managerial tasks. If these decisions are made in a right and timely manner, they will bring significant benefits to the organization.

In addition, improving productivity and reducing costs, agility of business, and efficiency and reliability of IT are important concerns of managers. The present study has attempted to provide and present a structural framework to address these concerns in TMAs by a comprehensive investigation of the business context of TMAs.

TMA service providers are always trying to identify and meet the factors that can make them successful in the highly competitive market they deal with. But through understanding the relationship between these factors and identifying their causal relationships as one of the findings of this study, they are able to identify all factors and also the most influential ones and focus on their fulfillment. This will lead to savings (both financially and temporally) and enhance the overall efficiency.

Another advantage is the implementation of the identified factors to alleviate business agility concerns. All the identified criteria are extracted regardless of service providers’ activity period or their time of market entry. Therefore, managers can adapt to the new circumstances quickly by identifying the most effective factors at each time with the lowest cost. Nevertheless, they can achieve agility in the organization in addition to maintaining the path of success.

As noted in the research, the use of IT is recognized as one of the most important and effective competitive advantages in the tourism industry. Hence managers of tourism companies can expand their business by using the IT platform and strengthen their competitive advantage in light of the outputs of this research. The implications of this research not only are useful for managers to identify the most valuable sectors for investment but also help users to diagnose the most appropriate mobile app.

This research's set of critical success factors offers a practical guide for service providers aiming to improve user satisfaction and their competitive edge. Our findings show that perceived playfulness and mobile innovativeness in information technology are the most important factors. Providers need to prioritize two key areas to create a successful mobile experience: designing a captivating user journey and staying ahead of technological advancements. For providers, the takeaway is simple but not trivial: build experiences people want to return to. Rather than stacking features, make the mobile journey playful, personal, and interactive. Thoughtful gamification, tailored recommendations, and responsive micro-interactions raise perceived playfulness. In parallel, keep a steady cadence of well-considered updates and adopt emerging mobile capabilities; this both signals and cultivates mobile innovativeness in information technology. Finally, users extend trust when tools feel effortless and prices are clear: perceived cost transparency and perceived ease of use remain cornerstone drivers of perceived trust. Furthermore, long-term competitiveness will be underpinned by strong perceived value of mobile technology and robust information system quality. While factors such as social influence and perceived trust may exert a more indirect influence, they are still vital components of a holistic adoption strategy and should be carefully considered rather than overlooked.

Conclusion

In this paper, we identified ten critical success factors for tourism mobile applications by drawing on existing literature, analyzing relevant content, and consulting with experts in the field. From there, we collected expert feedback using both AHP and FCM questionnaires. We then leveraged a MATLAB-based computation to implement our multi-method framework and ultimately rank the CSFs through an integrated FCM-AHP approach. Our analysis revealed that Perceived Playfulness emerged as the most influential factor in shaping behavioral intention. This finding suggests that for TMAs, creating an engaging and fun user experience is even more critical for adoption than factors like “Mobile Innovativeness in Information Technology”, “Perceived Cost Transparency”, or “Perceived Ease of Use”. The results also show that while “Perceived Trust” is important for long-term use, it's actually the most influenced factor, meaning it's largely a consequence of those other "upstream" elements: Perceived playfulness, innovation, cost transparency, and ease of use.

Our study's reliance on feedback from innovators and early adopters is a key limitation. Because of this, our findings might not apply to a wider range of users. A significant next step would be to broaden the scope of this research to include other user segments and industries. Future studies could also benefit from larger, more diverse sample sizes and the inclusion of additional criteria for classification. Qualitative data analysis could be a great way to extract new criteria. Once those criteria are identified, researchers could categorize and analyze them using powerful techniques like structural equation modelling, fuzzy analytic network process, interpretive structural modeling (ISM), or fuzzy DEMATEL. Another interesting avenue would be to develop a Quality Function Deployment (QFD) model. This model, paired with multi-objective mathematical programming, could help optimize a variety of factors simultaneously, such as boosting customer satisfaction, improving service quality, and cutting costs.

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Appendix

$\forall\, i, j \;,\; i \neq j$ where *i* is not equal to *j*, and the comparison is from left to right.

Number of equations	Equation
Eq.1	$\left\| A - \lambda_{max} * I \right\|$
Eq.2	$\left(A - \lambda_{max} * I \right) * W = 0$

Table A. FCM questionnaire

criteria	None	Very low	Too low	Low	Relatively low	medium	Fairly high	Much	too much	Very much	criteria
PVMT											PE
PVMT											PEU
PVMT											SI
PVMT											MIIT
PVMT											PP
PVMT											PT
PVMT											PSQ
PVMT											PCT
PVMT											ISQ
PE											PEU
PE											SI
PE											MIIT
PE											PP
PE											PT
PE											PSQ
PE											PCT
PE											ISQ
PEU											SI
PEU											MIIT
PEU											PP
PEU											PT
PEU											PSQ
PEU											PCT
PEU											ISQ
SI											MIIT
SI											PP
SI											PT
SI											PSQ
SI											PCT
SI											ISQ
MIIT											PP
MIIT											PT
MIIT											PSQ
MIIT											PCT
MIIT											ISQ
PP											PT
PP											PSQ
PP											PCT
PP											ISQ
PT											PT
PT											PCT
PT											ISQ
PSQ											PCT
PSQ											ISQ
PCT											ISQ

$\forall\, i, j \;\;,\;\; i \neq j$, choosing the number 5 on the right side means that C_j is much more preferred than Ci.

Table B. AHP questionnaire

criteria	Quite preferable		Much more preferred		Much preferred		Slightly preferred		The same preference		Slightly preferred		Much preferred		Much more preferred		Quite preferable	**criteria**
PVMT																		PE
PVMT																		PEU
PVMT																		SI
PVMT																		MIIT
PVMT																		PP
PVMT																		PT
PVMT																		PSQ
PVMT																		PCT
PVMT																		ISQ
PE																		PEU
PE																		SI
PE																		MIIT
PE																		PP
PE																		PT
PE																		PSQ
PE																		PCT
PE																		ISQ
PEU																		SI
PEU																		MIIT
PEU																		PP
PEU																		PT
PEU																		PSQ
PEU																		PCT
PEU																		ISQ
SI																		MIIT
SI																		PP
SI																		PT
SI																		PSQ
SI																		PCT
SI																		ISQ
MIIT																		PP
MIIT																		PT
MIIT																		PSQ
MIIT																		PCT
MIIT																		ISQ
PP																		PT
PP																		PSQ
PP																		PCT
PP																		ISQ
PT																		PT
PT																		PCT
PT																		ISQ
PSQ																		PCT
PSQ																		ISQ
PCT																		ISQ