Estimating Tourist Growth at Destination Sites: A Mathematical Equation and a Connectivity Model Through Mobile Application

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Abstract

Social science researchers have endeavored with the literature showcasing various individual mobile recommendation systems to assist stakeholders in the tourism sector. The challenge of formulating a mathematical equation to predict tourist growth at specific sites arises due to the diverse environmental conditions unique to each destination. This research seeks to develop a mobile application model fostering connectivity among significant tourism stakeholders. Within the app, stakeholders can effortlessly retrieve information about others and directly engage with relevant authorities without exiting the application. The app also provides navigation guidance to tourist destinations. The study explores the specific growth rate of tourists, assuming a doubling of tourist numbers after a specific time interval has been illustrated. While there may be an initial exponential growth in tourist numbers at a destination, the count eventually stabilizes. The Monod equation is employed in conjunction with the tourist equation for a comprehensive representation in this study. Additionally, the research delves into the graphical analysis of the feasibility conditions proposed by Casagrandi and Rinaldi's connectivity model. It is essential to note that this analysis remains abstract, and the creation of a universally applicable mathematical tourism model for every destination proves nearly impossible.

Keywords: Minimal tourism model, Mobile application, Monod equation, Tourism, Tourism stakeholders, Tourism stakeholder connectivity.

Introduction

The tourism industry is listed as a priority in Oman's vision 2040 under *omic Diversification and Fiscal Sustainability*. Revenue generation from the tourism industry has contributed to many countries' economies. Oman is one among them. Economic contribution to the GDP from the tourism in the European Union is being investigated and proposed a ready to use procedure for calculating economic impact indirectly [1]. In [2], the author studied the existence of dependencies between economic growth and tourism in Nigeria and the data is analyzed using *Autoregressive distributed lag model (ARDL)*. At 1% level of significance, based on the value of F-statistics, there is a long run dependency among three significant components *economic growth*, *growth in the receipt from tourism* and

exchange rate. Tourism in Oman contributed 2.4% to the state GDP in 2021 and as per data available in the National Center for Statistics and Information (NCSI), Oman set its target of achieving 5% by 2030 and 10% by 2040. The direct or indirect contribution of the tourism sector to the state economy was RO 700 million in 2018, which increased to 1.3 billion by the end of 2019 [3]. Tourism sustainability indicators and smart city destinations are correlated and their relationship is examined by a content analysis of planning instruments applied in smart strategies in Spain. Long-term planning, infrastructure development, capital investment, and publicity largely impact the growth of the tourist rate at a destination. Every new destination will attract tourists at the beginning phase but the maintenance of tourist sustainability depends on many factors, such as customer satisfaction, facility provided, bearing cost, maintenance, and safety and security of tourists [4]. The *Ministry of Heritage and Tourism* is currently maintaining the Oman tourism. To maintain sustainability, local vendors or agents can take the initiative to invest in the associated infrastructure based on the needs and requirements of the tourist at a particular site that will attract tourists. For example, opening a restaurant and hotel near a tourist destination, becoming a tourist guide, Direct and indirect entities related to the tourism industry function individually. Standard tools or functioning units are rarely available to facilitate easier and faster communication.

Owing to the exponential growth in the usage of electronic gadgets and online resources, searching and the correct selection of a resource has become challenging, and users are flooded by multiple options, which are sometimes not possible to assess due to the shortage of time or knowledge. There are studies available in the literature that explain recommendation systems using mobile devices [5], where the author developed a Recommender Systems (RS) that helps to filter information while searching. Most recommender systems use the details of the user's choice and preferences, and based on the selection criteria, the RS filters the data and is presented to the users [6,7]. An RS system tries to match the user's search of interest with an existing similar product based on rating, such as frequency of usage, and will push the available options to the user. Nowadays, e-commerce websites mostly use techniques similar to mobile recommendation systems to recommend their products to potential users. The tourism sector has adopted similar strategies to promote it. Different tour operators registered their business entities that are searchable on the Internet and sent different trip packages, discount offers, promotion offers, launch offers, etc. to attract visitors. During such recommendations, $content-based\ filtering$, $collaborative\ filtering,$ and $hybrid\ filtering$ approaches are used [8,9]. In [10], the authors of a recent study examined how technology integration impacts the tourism experience in smart destinations. They employed a random-effects meta-analysis model, utilizing the restricted maximum likelihood method for estimation. The findings support a positive correlation between smart technology and the tourism experience, particularly highlighting the significance of informativeness and interactivity. Conversely, there is an observed negative association concerning security and privacy concerns. This research emphasizes the importance of destination managers' comprehension of smart technology's potential in enriching the tourism experience. Implementing strategies to enhance this understanding can lead to increased visitor satisfaction and loyalty. The technological advancement impact on tourism in smart destination in a great extent. Smart Tourism Technologies (STTs) serve as the fundamental framework that merges hardware, software, networks, travel services, and ICTs to furnish real-time data, thereby aiding destination stakeholders in making more informed decisions. This infrastructure encompasses a diverse range of solutions, including but not limited to the Internet of Things (IoT), cloud computing, artificial intelligence (AI), mobile devices and applications, big data analytics, Wi-Fi connectivity, virtual reality (VR), augmented reality (AR), chatbots, wearable devices, QR codes, near field communication (NFC), radio frequency identification (RFID), social networks, and beacons. Different authors used the $social\ network\ analysis$ software Netminer, for Patent classifications and investigated the associations between patents' $International\ Patent\ Classification$ (IPC)

codes. The author collected contents from different news articles, journals, and patents, and text analysis has been carried out with the help of T-LAB software. Some authors also studied mobile application reviews from users using Leximancer software [11-13]. Recently, researchers in [14] designed a mobile application that will suggest and guide the routes to the zoo and display some related images of currently existing animals in the zoo. The mobile app also guides visitors with audio-visual services that can help illiterate and low eye-site people who find it difficult to read textual information during the day. In [15], the author checked the authenticity of the user's participation experience in real time with the help of a heritage preservation lens. The author provided the option of receiving feedback and suggestions from tourist site managers and visitors to enhance the mobile application design and include useful additional features in the app during the next modification in the future. In [16], the authors used the $Confirmatory\ Factor\ Analysis\ (CFA)$ method to develop a $Sustainable\ Creative\ Tourism\ (SCT)$ model through a mobile application. The author initially collected all possible forms of data and later data is selected them using the Delphi technique. The SCT model proposed by the authors has 8 components and 36 indicators. The findings of the study indicate that it meets the eligibility criteria for designing the SCT model. The outcome of the SCT model is perfect, indicating the possibility of developing a mobile application for $Sustainable\ Creative\ Tourism$ assessment.

Several attempts have been made to design mathematical models that can predict the number of tourists at a tourist location. A model mentioned in [17], where the author proposed a tourism sustainability model based on the interaction between the three main stakeholders of tourism: $tourists\ T(t),\ environment\ E(t)$ and $capital\ C(t)$. The minimal model is framed using the $Monod\ function$ which can be used as a predictive model for tourism infrastructure. The model can also be used as an economic model dominated by a $black-box\ model$. This model can establish a reliable connectivity between the bifurcation theory of system analysis and sustainability. Works with similar approaches were conducted in [18], where a mathematical model of the $slash-and-burn$ agricultural system was framed and the model was applied to the $Tsembaga\ ecosystem$. The model was examined and analyzed for different physical and socioeconomic conditions. Unstable conditions that affected the model were considered, and a reliable stable mechanism was established. A qualitative analysis of the model proposed in [17] was carried out in [19], where the model was solved mathematically and the comprehensive solution was interpreted by considering different cases. In [20], the authors developed a mobile application for monitoring on ThingSpeak using MIT App Inventor 2. The application includes control system that can control MATLAB/Simulink in two modes (ON/OFF). In [21], the authors applied data mining techniques to predict the good choice of business area that can support business people for right investment. The authors used four classifiers JRIP, Random Tree, J48 and REP Tree on tourist datasets and compared their accuracy. In [22], the authors developed a mathematical model that explains an application of non-additive measures and its association in tourism management. The author used fuzzy integral for evaluation of the grade of satisfaction given by tourist. Social Media feedback and sentiments are analyzed using text mining and a modest model was proposed that can evaluate Facebook reviews of e-tourism companies. The comments were classified by three methods KNN, Naïve Bayes and Rough Set theory. The outcome of the experiments revealed to the e-tourism companies for their future predictions [23].

Stakeholders

The term $stakeholders$ refers to the major components that are functionally essential and have significant contributions to the tourism industry. Stakeholders in the tourism industry are individuals, groups, or entities with a vested interest in the development, success, and sustainability of the tourism sector. According to the definition mentioned in [24], entities such as a larger society or destination, tribes, and communities that shape the tourism industry can have both direct and indirect contributions to the outcomes. Some of the key stakeholders identified in the tourism industry are the Government and Regulatory Bodies, $Ministry\ of\ Heritage\ and\ Tourism$, Tourism Boards and Destination Management Organizations,

Local Communities, Tourists, Hospitality Industry, Transportation Sector, Tour Operators and Travel Agencies, Cultural and Heritage Organizations, Environmental Organizations, Investors and Developers, Academic and Research Institutions, Non-Governmental Organizations (NGOs), Media and Marketing Agencies, and Local Businesses. In [25], the authors used two-dimensional power-interest matrix and fuzzy logic to classify stakeholders of sustainable energy development in Iceland. Some authors categorized *functional stakeholders* into two categories: *primary* and *secondary*. Essential entities required to function in the tourism industry are treated as *primary stakeholders*. These include government organizations related to tourism, tourism promoters or tour operators, hotels, restaurants, locals, tourist site attractions, and transport companies. The term secondary stakeholders includes those who are not directly involved in the business process of tourism but are still silent contributors such as *Chambers of Commerce*, hypermarkets, community groups, social media, gas stations, and promotion or offer of the tourist destination.

Considering the core principles and imperative of sustainability, as well as the integration of stakeholder engagement and participation into the development of sustainable tourism, the authors constructed a five-point framework for tourism stakeholders. This framework elucidates how stakeholders can leverage their roles and collaborative strengths to oversee destinations through regulation, conservation efforts, and livelihood enhancement [26]. The researchers in [27] initiated a fresh direction in the investigation of tourism destinations within the Dhofar Governorate, Oman. It delves into the correlation between the culinary tourism scene in the southernmost region of the country and the economic development objectives outlined by the Government. Given that tourism is an emerging sector in this area, sustainable development is crucial. The authors also ascertained the strategies for leveraging the natural and human assets of the region to broaden the scope of culinary tourism and facilitate sustainable economic growth, such as optimizing stakeholder advantages. In [28] the author conducted a survey on the Stakeholders Management in Rainfall Enhancement Project of Oman. The collected data by reaching 332 stakeholders through a structured questionnaire on identifying the critical success factors contributing to project management success. A conceptual model has been proposed based on the result of an exploratory analysis of the collected data.

Ministry of Heritage and Tourism

The *Ministry of Heritage and Tourism* is responsible for developing and managing the country's cultural heritage and tourism industry. The ministry focuses on preserving Oman's historical sites, promoting cultural events, and enhancing the tourism experience of both local and international visitors. MoHT functions with different directorates such as

- *Directorate General of Tourism Development*
- *Directorate General of Tourism Promotion*
- *Directorate General of Antiquities*
- *Directorate General of Museums*
- *Directorate General of Admin & Finance*
- *Directorate General of Planning*
- *Directorate General of Heritage & Tourism in Dhofar*

The *Directorate General of Tourism Development* is responsible for overall monitoring, including the planning, design, and implementation of quality control of tourism products. This directorate is responsible for issuing licenses to all tourism service providers. Details of the other responsibilities can be found in [29].

Tourists
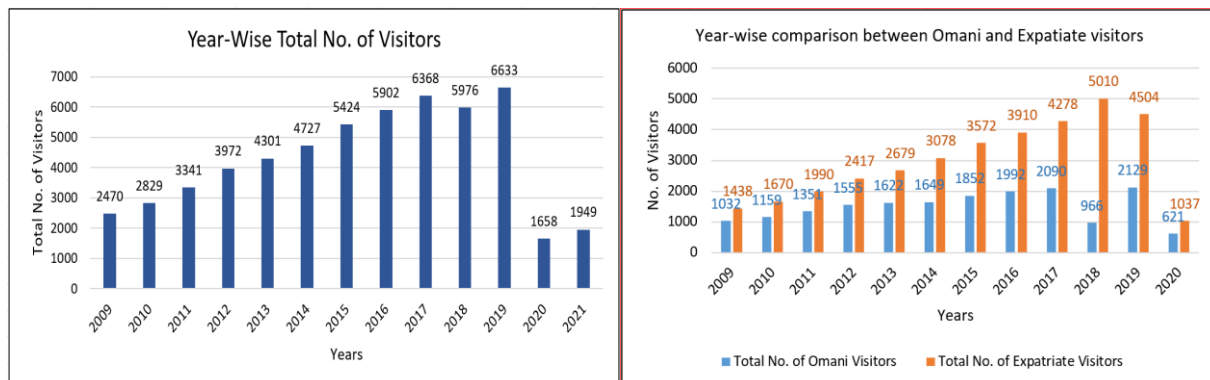
Figure .1 Bar graph of total number of year-wise tourists and a comparison between the Omani and Expatriate tourists from 2009 to 2021.

An individual travel to a destination outside or their usual place of residence for leisure, recreation, or pleasure. Tourists typically stay temporarily at their chosen destinations and engage in activities that differ from their everyday routines. The purpose of tourism is to explore new places and experience new cultures, landscapes, cuisines, historical sites, and other attractions that are unique to the destination. From the data available on the *Ministry of Heritage and Tourism* website, it can be inferred that there is a gradually increasing trend in the number of tourists, both Omani and expatriate visitors. The bar chart in Fig. 1 indicates a pictorial representation of tourist data from 2009 to 2021. During the pandemic, there was a sharp decline in the number of tourists in both Omani and expatriate communities. (Data source *Ministry of Heritage and Tourism* website.)

Tourist Guide

Whenever a new tourist reaches a new place, they need to be guided properly so that they can reach the new destination without any hassle. Experience tourist guides can inform tourists of the most demanding and attractive destinations that they may not be aware of. A tourist can cover a maximum destination if he/she is properly guided by an experienced tourist guide. Time is the most significant factor for tourists. Every tourist wants to visit the maximum number of locations in less time and effort. A tourist can frame a road map of his or her tour for maximum coverage of tourist spots. A tourist guide can play a key role in making tourists

aware of the risks, pros, and cons of a particular tourist spot. All authorized tourist guides registered their details with the *Ministry of Heritage and Tourism* in Oman. There might be a possibility of robbery (although it is very less in Oman) of the tourist's belongings, and the tourists might not be aware of the risk factors that need to be considered before planning a trip at a destination. If a tourist visits under the guidance of a registered tourist guide, MoHT can track the record of the tourist easily, if required.

Tour Operator

There are many government companies or private authorized agencies in Oman that are licensed to operate and arrange tours for different tourists. Their main duty is to arrange tours with different packages and different facilities to provide maximum satisfaction to the tourist and to avail them to visit and explore maximum sites with minimum expenditure time and effort. Some tour operators are listed below.

• Desert Adventures Tourism
• Oman Expeditions
• Arabian Adventures
• Tours Oman
• Nomad Tours Oman
• Oman Day Tours
• Golden Highlands
• Mark Tours
• Trekking Oman
• Panorama Tours Oman

Before booking a tour with any operator, it is highly recommended that they see their reviews, compare itineraries, and check if they are licensed and adhere to safety standards. In addition, ensure that tours align with your interests and preferences. It is suggested that availability and offerings might change, so it is a good idea to reach out to the operators directly or visit their websites for the most up-to-date information.

Tourist Site Manager

Tourist sites in Oman are managed by various entities such as the *Ministry of Heritage and Tourism,* private companies, and individuals. The person in contact and in-charge details may change over time. Generally, updates will be available with the *Ministry of Heritage and Tourism* or on the destination website. Some well-known tourist destinations and their management are listed below.

- *Royal Opera House Muscat*, a world-class cultural venue hosts a variety of performances and events. It is managed by the Royal Opera House Muscat Authority.
- *The Sultan Qaboos Grand Mosque,* an iconic mosque, is one of the most famous landmarks in Oman. It was maintained by the Ministry of Endowments and Religious Affairs.
- *Mutrah Souq*, a historic Mutrah Souq in Muscat, is a popular tourist destination for shopping and experiencing the Omani culture. Management may vary among individual shop owners, but the broader area falls under the governance of Muscat Municipality.
- *Nizwa Fort*, a historic fort in the city of Nizwa, is managed by the Ministry of Heritage and Culture of Oman.
- *Al Hoota Cave,* located in Al Hamra, Al Hoota Cave is managed by Oman Tourism Development Company (OMRAN).
- The *Salalah Tourism Festival*, an annual festival in Salalah, is managed by the Ministry of Tourism, and is a popular event during the Khareef (monsoon) season.

There are many more historical places, cultural heritage destinations, wadis, desert destinations, beautiful villages, and gardens in Oman that are managed by individuals or private teams. For further information on tourist sites or up-to-date details on site managers, it is suggested to refer to the official website of the Oman *Ministry of Heritage and Tourism*, local tourism boards, or contacting sites directly.

Restaurant Manager

A person who manages the restaurant, looks after all the necessities of the restaurant, and manages the customers and all the ordered food items to be provided at least time to receive maximum customer satisfaction. A restaurant manager oversees the daily operations of a restaurant, ensuring that it operates smoothly and efficiently. In [30], researchers conducted a survey on the knowledge and skills required to become a food service manager. Their observations have emerged as technical and practical skills are more important than theoretical or conceptual skills. Their role involves a wide range of responsibilities, including staff management (hiring, training, and supervising restaurant staff, including servers, cooks, and other employees; scheduling and managing shifts; payment; leave), customer service, financial management, menu and food quality, health and safety compliance, inventory and supply chain management, marketing and promotion, facility maintenance, administrative duties, problem-solving, compliance with legal requirements, planning, and strategy. In [31], the authors interviewed 387 managers and 365 support staff regarding their food safety knowledge and assessed their opinions and feedback. The results showed that the food safety knowledge of managers and workers with certification was better than that of managers and workers without certifications. Restaurant managers often work long and irregular hours, including evenings and weekends, to ensure the smooth functioning of the restaurant. Their role requires a combination of leadership and organizational skills, and a deep understanding of the restaurant industry.

Hotel Manager

A designated individual or group of people who manage the hotel look after all the necessities of the hotel manages the guests and all the requirements of the guests to give them maximum satisfaction. In the realm of the hospitality industry, the role of a hotel

manager stands as a linchpin that connects the diverse facets of running a successful hotel. In [32] the authors categorized the responsibility of a hotel manager into two parts: *theoretical* and *practical*. In the theoretical section, the author considered the conceptual ideas required to run the hotel smoothly. In practical, the researchers discussed actual implementations such as customer satisfaction and feedback. A hotel manager plays a pivotal role in ensuring that guests have a memorable and comfortable stay, while maintaining the financial health of the establishment. This essay delves into the multifaceted responsibilities, skills, and challenges faced by hotel managers, showcasing their indispensable role in the ever-evolving world of hospitality. The key responsibilities of a hotel manager include satisfactory guest experience by treating with warmth and courtesy, meeting their needs promptly, efficiently resolving any issues, managing staff, ensuring cleanliness, maintaining amenities, optimizing room occupancy, and ensuring compliance with safety and regulatory standards. Regarding financial management, a hotel manager's role is to manage a hotel's finances. They are liable to manage budgets, control costs, and implement revenue management strategies to maximize profitability. This involves analyzing financial reports, setting room rates, and optimizing occupancy levels. Managers are often involved in planning and executing marketing campaigns, establishing partnerships and maintaining strong online presence. Hotel managers also recruit, train, and motivate employees and handle HR-related issues. Hotel managers need to maintain high-quality standards for sustainability and a hotel's reputation. Managers ensure that rooms, facilities, and services meet or exceed guest's expectations.

Cab/Taxi

The stakeholder cab or taxi refers to people who are recognized by the "*Ministry of Heritage and Tourism*" and they have a license or authorization to run a taxi for tourists in Oman. It is not allowed for every individual taxi driver who can assist, guide, or make a trip with tourists legally. Once a tourist lands in a new place, the first thing is conveyance. Unfortunately, if they choose an incorrect person or an unauthentic person, they can be misguided, which

may lead to any kind of risk or crime. To avoid such possibilities, the government of Oman along with *Ministry of Heritage and Tourism* have given permission or license to a listed number of taxi or cab drivers who are authorized to take care of the tourist. This is a trusting step in terms of the safety and security of both local and foreign tourists. Therefore, for a new tourist it is important to know the listed people who are allowed to hire for a trip. The *Ministry of Heritage and Tourism* maintain a list of licensed cab or taxi drivers. It is necessary to have all the details of the taxi or cab riders with the *Ministry of Heritage and Tourism* for any future tracking if anything goes wrong with the tourist, and the government can track them easily.

Bus Service

The authorized Oman government bus service is run by the Oman National Transport Company (ONTC), commonly known as MWASALAT, which plays a pivotal role in shaping Oman's transportation landscape and the nation's connectivity and accessibility. It was established in 1972 and has evolved into Oman's primary national public transport company, offering an array of services to cater to the diverse needs of its residents and visitors. Over the years, MWASALAT has expanded its fleet and services to become a crucial player in fostering sustainable and efficient transportation solutions. The services that currently offered by MWASALAT are city buses, express buses, and intercity services that connect various regions in Oman. Additionally, the company provides corporate transport services, school transportation, and special-needs transportation, showcasing its commitment to inclusivity and accessibility.

One of MWASALAT's notable initiatives is the provision of tourist transportation services, facilitating seamless travel for visitors to explore Oman's breath-taking landscapes, historical sites, and vibrant cities. The company's dedication to meeting diverse transportation needs has positioned it as a key enabler of Oman's economic development and the tourism sector.

Others

By the terms others in stakeholders of the tourism industry, the authors refer to ATM, pharmacy, bank,

hospital, mosque, gas station, shopping mall, repairing houses, and service centers, which are directly or indirectly related to tourists. It is important to build a connectivity model that includes the necessary components. Although these are not vital stakeholders in the process of connecting tourism, they have a significant silent role in making tourism successful.

Proposed Model of Connectivity of Major Tourism Stakeholders

In the connectivity model, the mobile application will be at the center through which all tourism stakeholders will be connected, as shown in the data flow model in Fig. 2. The app connects all major tourism stakeholders in such a way that they can communicate with each other. Every individual stakeholder can register and login to the app and add or update their information.

Mobile Application Layout and Data Flow Model

As mobile devices are the most commonly used electronic devices today, a mobile application can be the best tool to bring different components of tourism into a single platform for communication as shown in Fig. 2. The developed mobile app consists of a registration screen and a login screen, through which the user can register for the first time and login later. After login, the user will select their role as a Tourist, Tourist guide, Tour Operator, Hotel Manager, Restaurant Manager, MoHT, Tourist site operator, etc. For the selected role, the user will get the option to add related information about the identity, photographs, website link, contact details, salient features, and so on. Once the information is added by the individual user, some of the information requires approval from the concerned authority (Possibly MoHT) for example, hotel grading like three stars, four stars, five stars, etc. Tourists can search for sites from the available list of tourist sites. After selecting a site, the information was displayed. Once the mode of travel is chosen, the estimated travel time from the current location to the tourist destination is shown along the route. During travel, if the traveler deviates from the suggested route, the application recalculates the estimated time with a new route and guides accordingly. Data for a tourist site will be recorded as the number of times a site is searched, how much time is spent on the site, and how many like and dislike the site is. The site that is being searched more will be treated as a more famous destination so that

MoHT can make necessary steps to facilitate more visitors. However, for sites with low search rates, MoHT can take measures to promote the site. The mobile app has a feedback option for rating by the user after visiting a site or receiving a service from a tourist guide or tour operator. The user can make a call directly to the chosen entity from the app itself without logout of the app, send SMS messages, and share information through the social media platform.
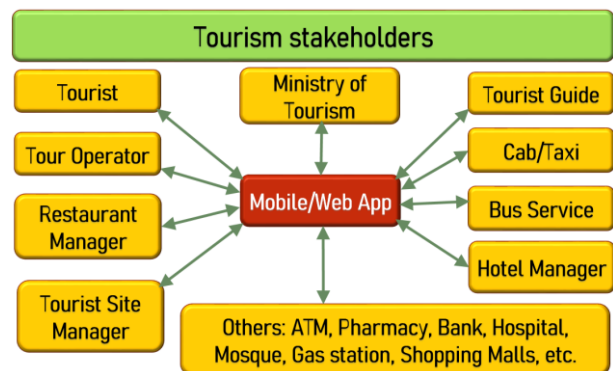
Figure 2. Communication process among different tourism stakeholders through mobile app

SWOT Analysis of the Mobile App

The SWOT analysis is a strategic planning tool used to identify and evaluate the Strengths, Weaknesses, Opportunities, and Threats of a project. It provides a comprehensive overview of the internal and external factors that can affect the success or failure of a particular initiative.

Strengths: This includes internal factors or characteristics of the project that give the entity a competitive advantage over other competitors.

Weaknesses: Internal factors that may obstruct an entity's performance or put it at a disadvantage. This could include limited resources, outdated technology, a lack of skilled personnel, poor management, and operational inefficiencies.

Opportunities: Opportunities are external factors that could be gaps in existing competitors that leverage the entity's advantage. This may arise from market trends, social and cultural needs, and technological advancements.

Threats: Threats are external factors that could negatively impact an entity's performance. Threats may put a project at risk. Threats may arise from competition, economic downturns, changes in consumer behavior, regulatory challenges, or external risks, such as natural disasters.

The SWOT analysis of our research works is mentioned in Table 1.

Table 1. SWOT Analysis of the Mobile App

Parameter/ components	Observation / Result
Strength	• Major tourism stakeholders are connected through one platform.
	• One stakeholder can communicate with another without hassle.
	• MoHT can track easily the details of tourist, tourist guide etc.
	• Navigation guidelines with routes for a chosen location are available, along with the estimated required time. If a traveler changes its route, the app will recalculate and provide a new route with the updated estimation time.
	• Data for a tourist site will be recorded as the number of times a site is searched, how much time is spent on the site, and how many like and dislike the site is.
	• Feedback option for rating by the user.
	• Can make calls directly to the chosen entity from the app itself, send SMS, and share it through a social media platform.
Weakness	• Time is not sufficient to add more features to the mobile application.
	• Currently, mobile applications are developed for Android mobile only. Many users have iPhone mobile devices. Therefore, they will not be able to use this application.
	• Some relevant features are not included in the application.
Opportunities	• The mobile app market is continually growing, providing opportunities for new user acquisition.
	• Adding new features or functionality can attract more users.
	• Expanding to new geographic regions can open up new markets.
	• Analyzing user data can uncover opportunities for app improvements and user engagement.
	• Staying updated on changing user preferences can lead to new opportunities.
Threats	• Availability of similar mobile applications can be a strong competitor in the market.
	• Legal and regulatory changes may affect the operation of the application.
	• The risk of data breaches or cyberattacks is a significant threat.
	• Economic downturns can impact user spending on apps.
	• Growing concerns about user data privacy can affect user trust.
	• Changes in app store policies can affect app distribution.
	• Rapid changes in mobile technology can render the app obsolete.
	• Less interest of users to add the data in the application.

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Specific Tourist Growth Rate

If $T(t)$ is the number of tourists present at a tourist site at time t, t_0 is the initial time of the experiment, t_d is the doubling time of the number of tourists as shown in Fig. 3 and $T(t_0)$ is the number of tourists available initially at the tourist site.

$$T(t) = T(t_0) \cdot 2^{\frac{t-t_0}{t_d}} \qquad 1$$

Differentiating Eq. 1 w.r.t time

$$\frac{dT}{dt} = T(t_0) \cdot 2^{\frac{t-t_0}{t_d}} \cdot \ln 2 \cdot \frac{1}{t_d}$$

$$\Rightarrow \frac{dT}{dt} = \mu \cdot T(t) \qquad 2$$

Where $\mu = \frac{\ln 2}{t_d}$ is termed as a specific growth factor.

$$\Rightarrow \frac{dT}{T(t)} = \frac{dT}{T} = \mu \cdot dt$$

$$\Rightarrow \int \frac{dT}{T} = \int \mu \cdot dt$$

$$\Rightarrow \ln T = \mu t + \ln T_0$$

$$\Rightarrow \frac{T}{T_0} = e^{\mu t}$$

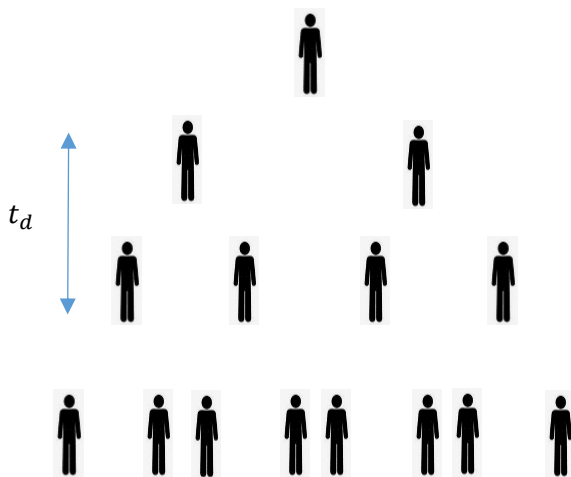$$\Rightarrow T(t) = T_0 e^{\mu t} \qquad 3$$

Figure 3. Tree structure of tourist growth

Monod Equation

The Monod equation was developed by Jacque Monod in 1940 after conducting a series of experiments. In view of the tourist growth rate, the governing equation can be used in the form

$$\mu = \frac{\mu_{max} S}{k_s + S} \qquad 4$$

where μ is the specific growth rate of the tourist, μ_{max} is the maximum specific growth rate of the tourist, S is tourist site compactness, k_s is the half-saturation constant. It is also sometimes termed as an affinity constant. When the crowd in the tourist destination is reasonably reduced, the specific growth rate μ becomes a function of tourist site compactness S.

$$i.e. \mu \approx f(S)$$

In addition, at high tourist site compactness, the specific growth rate μ gradually reaches its maximum value, μ_{max}. Consequently, the growth function becomes independent of S.

$$i.e. \mu \approx \mu_{max}$$

Assumption and Equation of Growth Rate

It is assumed that the growth rate of tourists at a particular tourist site is not affected by any other factors, and that there are no additional expenses borne by the site manager or no special treatment offered to the tourist for attraction.

Eq. 2 and Eq. 4 implies,

$$\frac{dT}{dt} = \frac{\mu_{max} S}{k_s + S} \cdot T \qquad 5$$

Now, the relationship between S and k_s is considered in two different cases.

Case I: At high tourist site compactness i.e. for $S \gg k_s$, it can be written as $k_s + S \approx S$.

$\therefore$ from Eq. 4,

$$\mu = \frac{\mu_{max} S}{S} = \mu_{max}$$

From Eq. 5,

$$\frac{dT}{dt} = \mu_{max}T \qquad\qquad 6$$

Thus maximum growth rate can occur for $S \gg k_s$.

The ideal growth rate for Eq. 6 can occur in relatively few instances. One such case can be found at the initial stage when a tourist site is visited by a smaller number of tourists. As a result, the attractiveness of tourist sites remains intact. Such ideal growth is unlikely to be observed under natural conditions, where the rate of attractiveness of a tourist site gradually decreases over time.

Case II: At low tourist site compactness i.e. for $S \ll k_s$, it is possible to write $k_s + S \approx k_s$.

$\therefore$ from Eq. 4,

$$\mu = \frac{\mu_{max} S}{k_s}$$

In this case, a dependency on the compactness occurs in the form of a first-order differential equation. i.e.

$$\frac{dT}{dt} = \frac{\mu_{max} S}{k_s}T \qquad\qquad 7$$

From Eq. 7, it can be inferred that when the tourist site compactness or density S is at a lower rate, the growth $\frac{dT}{dt}$ is dependent on S. Moreover, as S appears in the numerator, the rate of growth of the number of tourists at time t is directly proportional to the tourist site compactness or the number of tourists. From Fig. 4, It is observed that there is a sharp increase in the growth rate until the value of μ reaches its half-life. For the values $S > k_s$ the growth rate slows down, and at some point in time, the growth rate becomes stationary, which is independent of tourist site compactness.
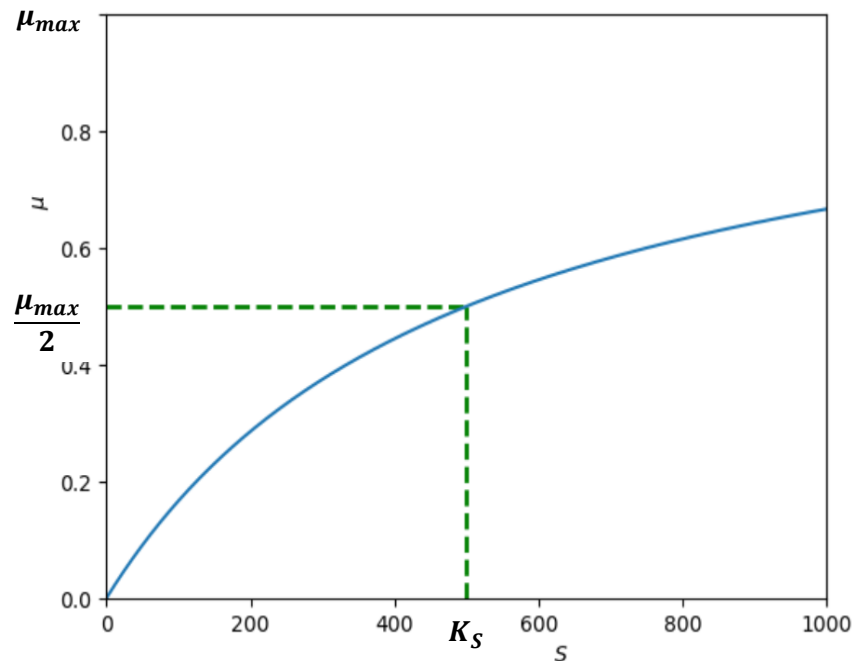
Figure 4. Behavior of Monod Function

Mathematical Model of Stakeholders Connectivity

A good fit mathematical model that can connect the major components of tourism is rarely available. In [17], R. Casagrandi and S. Rinaldi proposed a model for tourism sustainability. Later, a qualitative analysis of the said model was conducted in [19]. The model is framed to connect three main tourism stakeholders: the number of tourists at a place (region) $T(t)$, the quality of natural resources at a location or environmental attraction $E(t)$ and the fund or capital $C(t)$ invested in tourist infrastructure development. The mathematical form of the model is as follows.

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The Tourist Model

In [17], the author proposed that the rate of change of tourists at a given site at time t is $\frac{dT}{dt}$ which is proportional to the product $(t) \cdot A(T, E, C)$, where $A(T, E, C)$ is the site attractiveness visited by the tourist. A is measured as the relative attractiveness of $A(T, E, C) = \hat{a}(T, E, C) - a$ where $\hat{a}(T, E, C)$ is the absolute attractiveness of a specific site for which T , E and C values are known, and a is the mean attractiveness of all demanding tourist destinations. Using the Monod equation, rate of change of tourists is written in [17] as:

$$\frac{dT}{dt} = T\left(\frac{\mu_E E}{E + \varphi_E} + \mu_C \frac{\frac{C}{1+T}}{\frac{C}{1+T} + \varphi_C} - \alpha T - a \right) \quad 8$$

Where at $E \to \infty$, μ_E represents the environmental location attractiveness; at $C \to \infty$, μ_C represents the infrastructure attractiveness; φ_E and φ_C are the half saturation constants; α is the coefficient of the rate of decrease of the attractiveness of the environment with an increasing number of tourists.

The Quality of Natural Resources at a Location or Environment

In the absence of tourists and funds invested in infrastructure development, the quality of environment $E(t)$ can be written as

$$\frac{dE(t)}{dt} = zE(t)\left(1 - \frac{E(t)}{K} \right) \quad 9$$

The environmental damage function $D(T, E, C)$ due to visitors at a tourist destination always negatively affects the environment. Thus, the function D has the form $E(\beta C + \gamma T)$ so that the rate of change of the environment can be written as

$$\frac{dE}{dt} = zE\left(1 - \frac{E}{K} \right) - E(\beta C + \gamma T) \quad 10$$

where z is the rate of growth of the quality of the environment for a small E, K is the capacity of the ecosystem, and the parameters β and γ are positive. These parameters can also be negative under exceptional conditions, such as when a very high effort has been made to revive the environment.

The Fund Investment

$$\frac{dC}{dt} = -\delta C + \varepsilon T \quad 11$$

ε is the investment rate , δ is the pace of depreciation of the infrastructure.

Graphical Analysis

A qualitative analysis and solutions of the model mentioned in Eq. 9, Eq. 10 and Eq. 11, considering different conditions are presented in [19]. In this study, a graphical analysis of the solution was performed.
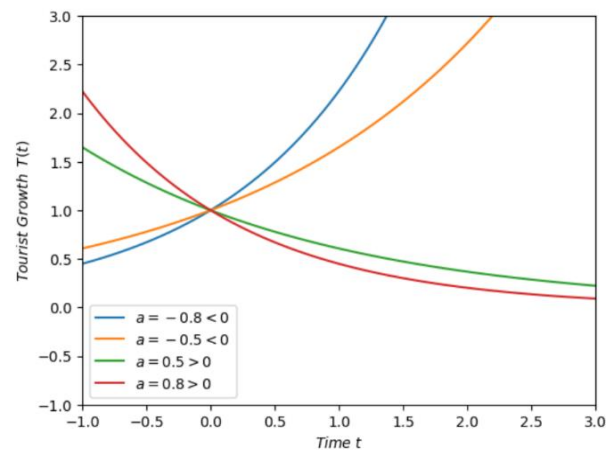
Case I: At the initial stage i.e. when $T = 0, E = 0$ and $C = 0$,

$$T(t) = e^{-at}T(0) \quad 12$$

$$E(t) = e^{zt}E(0) \quad 13$$

$$C(t) = \frac{\varepsilon T(0)}{-a + \delta}e^{-at} \quad 14$$

From Fig. 5, it is observed that if the value of $a > 0$, there is a decrease in the number of tourists over time, and for $a < 0$, an exponential growth occurs, which is acceptable.

Figure 5. Tourist Growth with time for $a < 0$ and $a > 0$

Similarly, from Fig. 6, it can be infer that, an acceptable solution occurs for $z > 0$. Thus, the validity of Eq. 12 and Eq. 13 lies in the condition $a < 0$ and $z > 0$ which represents the beginning of a peak tourist season. Eq. 14 also has a similar representation; however, the solution has a *singularity at $a = \delta$*. Moreover, the validity of the

solution in Eq. 14 has the restriction $\delta > a$ and $\varepsilon > 0$ which provides a reasonable result.
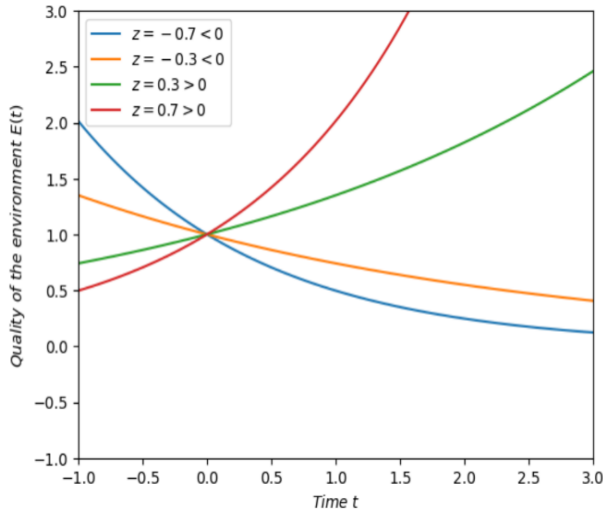
Figure 6. Quality of the environment with time for $z < 0$ and $z > 0$

Case II: At a peak stage of tourist visit at a destination i.e $T(t) \gg 1$, $E(t) \gg \varphi_E$ i.e. $E(t) + \varphi_E \approx E(t)$ so that $\frac{\mu_E E(t)}{E(t)+\varphi_E} \approx \mu_E$. Moreover if the stationary point is at half-life μ_E, the solution of the model takes the following form [18].

$$for \quad T_0 = \frac{\mu_E - a}{\alpha},$$
$$T(t) = T_0 + e^{(\mu_E - a - 2\alpha T_0)t}[T(0) - T_0] \quad 15$$

$$for \; T_0 > \frac{\mu_E - a}{2\alpha},$$
$$E(t) = \frac{zK}{z + \gamma T_0} + \left(E(0) - \frac{zK}{z + \gamma T_0} \right) e^{-(z+\gamma T_0)t} \quad 16$$

And

$$C(t) = \frac{\varepsilon}{\delta} T_0 + \left(E(0) - \frac{\varepsilon}{\delta} T_0 \right) e^{-\delta t} \quad 17$$

When $z + \gamma T_0$ is infinitely large, Eq. 16 gives $E(t)$ approaching zero. This represents the initial stage of the environment. In addition, when $T(t) > > 1$, the solutions become $E(t) = \frac{zK}{z+\gamma T_0}$ and $C(t) = \frac{\varepsilon}{\delta} T_0$.

Results and Discussion

Important finding and properties of the model have been explained below:

Salient Features of the Proposed Model

Following are some of the noticeable features of the connecting model.

- A single mobile app connects the important stakeholders of tourism.
- Easy and fast communication among the stakeholders through the app.
- A dataset will be formed with real data received from app users that can be made available to the public to improve their business and can be used for research purposes.
- The app has the facility of searching for tourism stakeholder details; selecting a tourist destination and navigation for the destination are available with the approximate time required to reach the destination. If the user changes the route by mistake, the app recalculates and the updated route is assigned to navigate. Voice navigation was also supported from the start until the user reached the destination.
- After registration and login, the user can easily add information about their business. Some information is available to other users only after approval from the authorities.
- The *Ministry of Heritage and Tourism* tracks tourists according to necessity. When a tourist is registered in an app and travels to a destination along with the authorized tourist guide, all information of the tourist and the tourist guide will be available with the MoHT. As a result, tourists are more secure than unregistered or unguided travel to a new destination. Regarding the tourist's safety measure, the MoHT can make an alert message to the tourist or tourist guide about the upcoming unpleasant weather through SMS or any other social media platform connected to the app. This can enhance tourists' safety and security.

- By analyzing the data received from the users through the app using Multiple-Linear – Regression, MoHT can make the future plan of infrastructure development or promotion of a tourist site.
- The mathematical model can be used to predict any component (no. of tourists, natural environmental conditions, and fund investments) when other components are known.

Comparison of the Work with Existing Research Works

In the literature, the authors did not observe much work similar or specific to the area where there is a common platform that can connect individual tourism stakeholders, or the availability of any numerical result and its comparison. However, in [5-8], different recommendation systems are mentioned where some authors developed mechanisms to filter the information while searching, some other authors developed the RS that will check the user's choice and preferences and based on the selection criteria, RS filters the data.

Some recommendation systems divide filtering approaches into three different categories: $content-based\ filtering$, $collaborative\ filtering$, and $hybrid\ filtering$. In our research work, the focus is not on user recommendation; instead, it attempts to connect different tourism stakeholders through mobile applications.

Advantages of the Proposed Model over the Existing Research

The advantages of the proposed model are:
- It provides a single platform to connect all the different stakeholders.
- One stakeholder can communicate with another within the mobile app.
- All data from different stakeholders are stored in a single database, which can be useful for data analysis.

Conclusion

The developed mobile application can make life easier for tourism stakeholders and increase the safety and security of tourists, a common platform

- The *Ministry of Heritage and Tourism* can take necessary measures by analyzing the reviews collected through the mobile app.
- The proposed mathematical model can be used for predicting tourists at a destination.
- Explore seamless navigation between two destinations, providing the shortest distance and estimated travel time, accompanied by clear voice guidance for an enhanced user experience.

Practical Implications of the Findings

The findings of this study can be useful for tourism stakeholders, authorities, and businesses as follows:
- Tourism stakeholders can use the navigation features of the app, search for information about other stakeholders, and contact each other directly with the app. The review and rating features of the app about a tourism entity will help tourists decide on their destination and other related components.
- The authorities can track the popularity of a tourist site and the experience of a tourist with other stakeholders in the form of reviews and ratings. As a result, the authority can allocate a budget to invest more in the infrastructure development of the tourist destinations that are in high demand. Moreover, at less popular sites, MoHT can promote the features and natural beauties of the location to attract visitors.
- From a business point of view, the findings of the study can be used by every related business entity to improve their business; for example, season-based small-scale businesses can be started and enhanced; for example, if an onsite restaurant manager sees the app that the frequency of Western visitors is more in number on the site, the manager will make arrangements of foods of their choice. A similar treatment can be useful in large-scale businesses, such as high-rated hotels and transport industries, to attract more visitors and attain maximum satisfaction.

for bringing together at one place all scattered tourism stakeholders. Necessary minimal features are added to the app, and many more features are left

for future development. The minimal mathematical model of tourism includes three major components: tourists, natural resources, environment, and fund or capital investment. In future work, the model can be applied to real data and its accuracy can be measured.

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Authors' Declaration

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are ours. Furthermore, any Figures and images, that are not ours, have been included with the necessary permission for re-publication, which is attached to the manuscript.
- No animal studies are present in the manuscript.
- No human studies are present in the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee at University of Technology and Applied Sciences, Oman.

Authors' Contribution Statement

D. I. M., S. K. V., R. P., and R. S. contributed to the conception, design, data acquisition and implementation of the research work, to the analysis of the results and to the writing and proof reading of the manuscript.

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قدير النمو السياحي في مواقع الوجهات السياحية: معادلة رياضية ونموذج الاتصال من خلال تطبيقات الهاتف المحمول

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الخلاصة

لقد سعى باحثو العلوم الاجتماعية إلى عرض الأدبيات المختلفة لأنظمة التوصية المتنقلة الفردية لمساعدة أصحاب المصلحة في قطاع السياحة. إن التحدي المتمثل في صياغة معادلة رياضية للتنبؤ بالنمو السياحي في مواقع محددة ينشأ بسبب الظروف البيئية المتنوعة الفريدة لكل وجهة. يسعى هذا البحث إلى تطوير نموذج لتطبيقات الهاتف المحمول يعزز الاتصال بين أصحاب المصلحة الرئيسيين في مجال السياحة. داخل التطبيق، يمكن لأصحاب المصلحة استرداد المعلومات حول الآخرين بسهولة والتفاعل مباشرة مع السلطات ذات الصلة دون الخروج من التطبيق. يوفر التطبيق أيضًا إرشادات ملاحية للوجهات السياحية. وتستكشف الدراسة معدل النمو النوعي للسياح، بافتراض تضاعف أعداد السياح بعد فترة زمنية محددة. في حين أنه قد يكون هناك نمو هائل نمو مبدئي في أعداد السياح في الوجهة، إلا أن العدد يستقر في النهاية. تم استخدام معادلة مونود مع المعادلة السياحية للحصول على تمثيل شامل في هذه الدراسة. بالإضافة إلى ذلك، يتعمق البحث في التحليل الرسومي لشروط الجدوى التي يقترحها نموذج الاتصال الخاص بـ Casagrandi و Rinaldi. ومن الضروري ملاحظة أن هذا التحليل يظل مجردًا، وأن إنشاء نموذج رياضي قابل للتطبيق عالميًا لكل وجهة يكاد يكون مستحيلًا.

الكلمات المفتاحية: نموذج السياحة المصغر، تطبيق الهاتف المحمول، معادلة مونود، السياحة، أصحاب المصلحة في السياحة، اتصال أصحاب المصلحة في السياحة.