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Scenario-Based Robust Decision-Making in Health Tourism Service Supply Chains

Amirhossein Saffarinia[1], Mohammad Reza Fathi[2], Mohammad Javad Pahlevanzadeh[3] and Samaneh Raeesi Nafchi[4]✉

1. Department of Management and Accounting, College of Farabi, University of Tehran, Iran. E-mail: Saffarinia14@gmail.com
2 .Department of Management and Accounting, College of Farabi, University of Tehran, Iran. E-mail: Reza.fathi@ut.ac.ir
3. Department of Management and Accounting, College of Farabi, University of Tehran, Iran. E-mail: J.pahlevanzadeh@ut.ac.ir
4. Corresponding author, Assistant Professor of Industrial Management, Shiraz University of Technology-Lamerd Higher Education Center, Fars, Iran. E-mail: raeesi@sutech.ac.ir

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ABSTRACT

Health tourism is a dynamic sector of Iran's economy with strong potential in the religious city of Qom. This study develops plausible future scenarios for the health tourism service supply chain and identifies suitable strategies using Robustness Analysis (RA). A mixed qualitative–quantitative design is employed. First, key influencing factors are identified through expert interviews and a literature review. Next, alternative scenarios are constructed and evaluated using a weighted decision-matrix that simultaneously accounts for system complexity and environmental uncertainty in a participatory decision-making setting. The analysis yields seven distinct scenarios derived from eight key factors, ranging from an ideal future characterized by sustainable development and attraction of religious markets to a pessimistic future marked by sanctions-driven stagnation and multiple crises. The RA results indicate that vertical integration and market development perform best under favorable conditions, whereas retrenchment and heterogeneous diversification are more effective under crisis conditions. The proposed weighted RA decision matrix provides a practical decision-support tool for policymakers and healthcare managers in Qom to select resilient strategies across diverse environmental futures.

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1) Introduction

As an emerging industry, health tourism offers significant opportunities for developing countries such as Iran. This sector can diversify tourism offerings, increase revenue, and create jobs (Ba et al., 2023; Dunets et al., 2020; Kiss, 2015; Oltean et al., 2020; Tsekouropoulos et al., 2024; Wang et al., 2023). However, successful development of health tourism requires appropriate infrastructure, skilled human resources, and effective marketing (Lee & Kim, 2015; Wong & Sa'aid Hazley, 2020; Yıldız et al., 2023). Health tourism can serve as a tool to advance shared global health goals while simultaneously providing commercial opportunities and prestige for destination countries. Governments leverage health tourism as a tool for global health diplomacy to achieve common objectives such as access to affordable treatments and promotion of healthcare quality. Health tourism strategies can enhance commercial opportunities and prestige for host countries (Farber & Taylor, 2023).

The commodification of specific health interventions within health tourism can lead to increased prices and reduced accessibility for local populations (Farber & Taylor, 2023). Health tourism may exacerbate global health inequalities, with wealthier countries accessing higher-quality care while poorer countries are deprived of it (Farber & Taylor, 2023). The health tourism industry, particularly medical tourism, is a complex and dynamic sector influenced by a wide range of dimensions and drivers. Understanding these factors is crucial for various stakeholders, including governments, healthcare providers, and travel agencies, to develop effective strategies for attracting medical tourists and fostering industry growth (Malhotra & Dave, 2024).

Prior studies in this field have shifted their emphasis over time. Initially, the focus was on demand and tourist behavior; subsequently, it shifted to the development and promotion of health tourism destinations, and more recently, it has concentrated on policies and their impacts (Zhong et al., 2021). To attract health tourists, it is essential to examine factors such as accessibility, treatment options, quality of medical facilities, travel planning, security assurance, and government policies (Ding, 2024; Ibrahim et al., 2020; Pinos Navarrete & Shaw, 2021; Nilashi et al., 2019; Yazdi & Barazandeh, 2016). Furthermore, in the development and promotion of this type of tourism, topics such as child vaccination, oral hygiene, legal frameworks, evaluation systems, entry and exit systems, and macroeconomic policies require more attention. The most critical aspect in promoting health tourism is meeting or exceeding the expectations and needs of tourists. On the other hand, formulating appropriate policies and supportive frameworks for this type of tourism is essential (Butler & Szromek, 2019). It is important to note that health tourism can negatively impact healthcare service provision for local residents in poorer countries, where tourists from wealthier countries may benefit at the expense of local communities (Farber & Taylor, 2023). However, if successfully managed, this type of tourism can be a driving force for economic development in countries that provide such services.

Complexity and uncertainty, especially in turbulent environments, coupled with numerous often contradictory indicators, rapid and unpredictable environmental changes, and the long-term consequences of decisions, highlight the need for more efficient tools for managers (Sorourkhah, 2024). Additionally, in some scenario planning approaches, the number of scenarios is too limited to adequately represent future uncertainty, and in Multi-Attribute Decision Making (MADM) methods, computational complexity problems arise with an increasing number of elements (Sorourkhah, 2024). Researchers emphasize that the selection of an appropriate strategy depends on the extent of future environmental changes (Büyüközkan et al., 2021). Given the uncertain and fast-paced nature of today's environments, selecting a robust strategy to cope with a changing environment is of paramount importance (Sorourkhah et al., 2017).

Health tourism in Qom, given its unique advantages such as sacred sites, medical infrastructure, and growing demand from pilgrims, possesses high potential for development. However, uncertain factors such as political-economic changes, advancements in medical technology, and demand fluctuations have made planning in this area difficult. This article aims to delineate possible scenarios and identify strategies resilient to uncertainties by employing robustness analysis.

Planning for the development of health tourism in Qom faces numerous structural and environmental challenges including:

Demand Uncertainty: Fluctuations in the number of international pilgrims and patients influenced by political, economic, and health factors (e.g., pandemics).

Increasing Competition: The emergence of new health tourism destinations in the region and globally impacting Qom's competitive position.

Dependence on Existing Infrastructure: Limitations in the development of medical centers and supporting services in case of sudden demand growth.

In an era of increasing complexity and uncertainty, decision-making in socio-economic domains, such as health tourism, requires methods that can anticipate and analyze a range of possible futures. Robustness analysis (Driouchi et al., 2009; Grimm & Berger, 2016; Namen et al., 2009; Namen et al., 2010; Schupbach, 2018; Sorourkhah & Edalatpanah, 2022; Wang et al., 2021), as one of the soft operations research (Soft OR) methods, focusing on reducing ambiguity and structuring the problem without seeking an absolute optimal solution, is an effective tool for addressing such challenges. This method assists policymakers in designing flexible strategies under uncertainty by identifying decision points, sequential decisions, and probable futures. Therefore, classical operations research methods (such as linear optimization) are unable to provide practical solutions in this area due to their oversimplification of complex realities. In contrast, robustness analysis, by inherently accepting uncertainty and focusing on strategy flexibility, provides a set of possible decisions instead of a definitive answer.

The main questions of this research are: How can future scenarios for health tourism in Qom be analyzed and robust strategies designed using this method? Given the decision-making level and the health tourism supply chain network, what scenarios and strategies can be defined for health tourism in Qom? Which strategies demonstrate greater robustness under conditions of uncertainty?

2) Theoretical Foundations

The tourism industry is one of the most competitive sectors globally. Health tourism encompasses elements of tourism pathways designed to restore individuals' physical, mental, and psychological well-being. Tourism programs can also include educational and sports entertainment elements. The impact of natural environmental factors on human health and livelihood is evident (Dunets et al., 2020). Instability and conflict, political mismanagement and corruption, funding shortages, limited infrastructural development, low service quality, and inadequate marketing are among the main challenges to health tourism development in the Balkans. Cooperation among the public, private, and academic sectors is essential to overcome these challenges and develop health tourism in this region (Kiss, 2015).

With the spread of globalization and increasing international travel, health tourism is becoming a growing industry. Nurses, as the frontline of healthcare, play a key role in providing quality services to health tourists. However, providing effective care to patients from diverse cultures requires intercultural awareness and sensitivity from nurses (Yıldız et al., 2023).

Health tourism brings significant economic benefits to host countries, including job creation, increased revenue, and infrastructure development (Ba et al., 2023; Butler & Szromek, 2019; Oltean et al., 2020; Tsekouropoulos et al., 2024; Wong & Sa'aid Hazley, 2020; Wang et al., 2023). However, health tourism can also create sustainability challenges, such as pressure on natural resources, increased waste generation, and negative impacts on local communities. The value created by tourism companies often does not include benefits for society. Instead, among current priorities, benefits are for tourists and the companies themselves (Butler & Szromek, 2019). Additionally, hotels and other tourism service providers must collaborate with clinics and hospitals to offer comprehensive health tourism packages to tourists (Ba et al., 2023). Factors such as social status, traffic conditions, human resource status, industrial structure, industrial infrastructure, consumer demand, and employment demand have a direct positive impact on the development of health tourism in China. Furthermore, industrial structure and industrial infrastructure have a positive indirect effect, and overall, industrial structure, industrial

infrastructure, and economic conditions have a total positive impact on the development of health tourism in China (Wang et al., 2023).

Some barriers in medical tourism include administrative complexities, high healthcare costs, and the lack of a comprehensive strategy for medical tourism development. Solutions to overcome these challenges and enhance Central Macedonia's position as a tourism hub include: developing services in medical specialties with lighter infrastructure, focusing on specific target markets, offering green health and wellness packages, creating a digital platform to connect medical tourists, medical centers, accommodation facilities, and paying attention to domestic medical tourism (Tsekouropoulos et al., 2024).

Multiple demand-side factors influence the growth of medical tourism, including rising healthcare costs in developed countries, increasing income and living standards in emerging markets, and growing awareness of medical tourism options (Malhotra & Dave, 2024). Several supply-side factors also affect the competitiveness of medical tourism destinations, including the quality of healthcare, the price of services, tourism infrastructure, and government policies. Numerous contextual factors also influence the medical tourism industry, including global trends such as globalization, technological advancements, and demographic changes (Malhotra & Dave, 2024). Key drivers of the medical tourism industry include: price differences, access to quality care, shorter waiting times, and the patient experience. One of the main drivers of medical tourism is the price difference between healthcare costs in developed and emerging countries. Patients can achieve significant cost savings by traveling to medical tourism destinations. Access to quality care is another factor attracting medical tourists. Many medical tourism destinations have advanced healthcare facilities and experienced surgeons and specialists. Shorter waiting times for examinations and treatments are another factor attracting medical tourists. In many developed countries, patients may have to wait months or even years for specific treatments, while in medical tourism destinations, they can receive treatment quickly. The patient experience is also a key factor in the medical tourism industry. Medical tourism destinations strive to provide patients with a positive and comfortable experience, which includes a range of services such as translation, transportation, and accommodation (Malhotra & Dave, 2024).

Complexity arises from the multiplicity of criteria and the interrelationship between them, while uncertainty refers to the ambiguity of judgments and future uncertainties. Although Multiple-Criteria Decision-Making (MCDM) methods assist decision-makers in selecting the best alternative and consider the interrelationships between criteria, they do not address uncertainty. Fuzzy set theory can manage the uncertainty arising from the ambiguity of human thoughts and language in decision-making, but MCDM or Fuzzy Multi-Criteria Decision-Making (FMCDM) methods cannot formulate probable futures because they use current information and judgments to collect data. In the real world, however, choosing a method that can cope with an uncertain environment and reduce its impact on outcomes would be highly effective (Sorourkhah & Edalatpanah, 2022). Soft Operations Research (Soft OR) methods, such as robustness analysis, the strategic choice approach, etc., can cope with future uncertainty, but many of them are unable to manage complexity (Sorourkhah & Edalatpanah, 2022). In decision-making environments with uncertainty, robustness analysis serves as a reliable tool for evaluating the consequences of an initial decision over time (Anvari et al., 2017). Robustness analysis provides a basis for logical analysis and rational decision-making when a high degree of uncertainty, indeterminacy, and even inexperience and ignorance encompass the main decisions associated with it (Namen et al., 2010). While classical strategy selection approaches are suitable for rigid environments and Multi-Attribute Decision Making (MADM) models for complex environments, robustness analysis (RA) produces more reliable results when facing turbulent environments (Sorourkhah, 2024).

Robustness analysis is rooted in flexible planning approaches and decision theory under uncertainty. Unlike traditional operations, research paradigms that emphasize single-solution optimization, this method originates from Lindblom's incrementalism and the idea of robust design. Its key foundations include:

Plurality of Futures: Not relying on a definitive forecast and examining several probable paths.

Focus on Adaptability: Evaluating strategies based on their ability to perform well under various conditions.

Sequential Decisions: The possibility of adjusting strategies as new information emerges.

3) Empirical Background

Lee and Kim (2015) investigated the success factors of health tourism in Asian tourist cities. They first provided a clear definition of health tourism and divided it into two main subcategories: medical tourism and health and wellness tourism. This research, using a grounded theory approach and a combination of comprehensive literature reviews and practical data from three different cities, sought to identify factors influencing health tourists' decision-making when choosing a destination. Yazdi and Barazandeh (2016) conducted a descriptive-correlational study to identify and prioritize barriers to health tourism development in Iran. After reviewing relevant literature and consulting experts in the health tourism industry, four criteria – price, quality, accessibility, and appropriate time – were selected as the most important factors. Nilashi et al. (2019) examined the factors influencing the adoption of medical tourism in Malaysia. This research aimed to identify various factors affecting the development of medical tourism in Malaysia. To elucidate the interrelationships among factors and determine their relative importance in the decision-making model, two multi-criteria decision-making (MCDM) methods were used: Decision Making Trial and Evaluation Laboratory (DEMATEL) and Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (Fuzzy TOPSIS).

Wong and Sa'aid Hazley (2020) investigated how advancements related to connected healthcare (such as mobile healthcare technology and digital health) can significantly and almost in real-time reduce the distance between healthcare providers worldwide and their potential patients. Ibrahim et al. (2020) explored the future of remote psychiatric service delivery in India. They believe that technology is revolutionizing all fields, and mental healthcare is no exception. Furthermore, the COVID-19 pandemic has created both a need and an opportunity to use technology to improve access to mental healthcare. Oltean et al. (2020) examined the marketing aspects of dental tourism and its role in sustainable development in Romania. This study, using random sampling and an online questionnaire, sought the perspectives of 160 dental clinics and 32 travel agencies on dental tourism. Zhong et al. (2021) conducted a comprehensive review of the health, medical, and wellness tourism literature from 1970 to 2020. By analyzing 802 articles from reputable academic databases, they identified three main themes in this area: market (demand and tourist behavior), destination (development and promotion), and development environment (policies and impacts). Büyüközkan et al. (2021) explored health tourism strategy selection using a hybrid approach of SWOT analysis and Hesitant Fuzzy Linguistic AHP-MABAC (HFL-AHP-MABAC) methods in Istanbul, Turkey. Pinos Navarrete and Shaw (2021), focusing on the Spanish model, investigated spa tourism opportunities as a key strategy to aid recovery from COVID-19.

Farber and Taylor (2023) examined how governments use health tourism as a tool for global health diplomacy in the post-pandemic era. Ba et al. (2023) investigated the feasibility of developing health tourism in Senegal's coastal region as a way to specialize the country's tourism industry. In this study, interviews with socio-economic actors and structured questionnaires were conducted, and information was collected from two groups: 21 samples from private clinics and 31 samples from hotels. The obtained data were analyzed using descriptive analysis. Yıldız et al. (2023) studied the effect of intercultural sensitivity and ethnocentrism on nurses' awareness of health tourism. This quantitative cross-sectional study was conducted among 386 nurses in Turkey. The intercultural sensitivity scale, ethnocentrism scale, and health tourism awareness scale were used to collect data. In this study, machine learning algorithms were used to predict the health tourism awareness variable. The random forest algorithm was identified as the best algorithm for this purpose. Malhotra and Dave (2024) explored the dimensions and drivers of the medical tourism industry using a qualitative systematic review approach. Ding (2024) investigated tourists' choices for sustainable hot springs tourism in the post-COVID-19 pandemic period in Colorado. This study estimates the impact of sustainability-related attributes on the choices and willingness of Colorado hot springs tourists during this period.

Namen et al. (2009) investigated the use of robustness analysis (RA) for sustainable community development. This article offers alternatives for improving the living conditions of poor communities based on self-management and sustainability in food production. In this regard, a complex decision-making process is inevitably involved, and a soft OR approach, specifically robustness analysis, was used for its analysis. Driouchi et al. (2009) introduced a robustness framework for monitoring real options in the face of uncertainty. Relying on the principles of robustness analysis and scenario planning, they demonstrated how decision-aiding tools can facilitate participation in project structuring and achieve effective decision-making through real options reasoning. Namen et al. (2010) examined the use of robustness analysis for planning actions in a poor Brazilian community. This project focused on food production and agriculture and was based on a participatory approach that included both community-driven development and sustainability in food production. Grimm and Berger (2016) addressed the concept of robustness analysis and "deconstructing" computational models for ecological theory and applications. They stated that the design of computational models is path-dependent, meaning that choices made at each stage of model development limit the available choices in subsequent stages.

Anvari et al. (2017) combined robustness analysis and fuzzy screening to formulate a Robust Strategic Planning Model for a service logistics network. Sorourkhah et al. (2017) applied weighted robustness analysis for strategy selection at the Saipa Automotive Industries Research and Innovation Center. Schupbach (2018) discussed the logic of robustness analysis as an explanatory reasoning. Wang et al. (2021) simulated the migration of wind-borne pests and emphasized "deconstructing" the representation of the emigration process. These researchers presented the results of a robustness analysis where the migration representation in a predictive model of regional infestations of North American sorghum (Sorghum bicolor) fields by the sugarcane aphid (Melanaphis sacchari) was systematically deconstructed. Fathi et al (2022) examine tourism supply chains through the lens of strategic orientation, arguing that firms' overarching strategic postures are closely tied to higher agility and resilience in the tourism supply chain. Their study positions strategic orientation as an upstream managerial driver that shapes how tourism organizations respond to disruptions and volatility, supporting the view that resilience is not only operational but also strategically enabled. Building on this stream, Fathi et al (2025) focus on a health-tourism context (dental tourism) and develop a green supply chain network perspective, emphasizing the need to design health tourism service networks in a way that simultaneously addresses economic and environmental considerations. Together, these studies reinforce the importance of combining strategy-level drivers (that strengthen resilience and agility) with network-level design thinking (that structures health tourism service supply chains), which aligns with scenario-based and robustness-oriented decision-making approaches in health tourism service supply chains. Sorourkhah and Edalatpanah (2022) addressed the challenge of selecting the best option in today's world, which is often accompanied by complexity and uncertainty. This research uses a combination of the Matrix Approach to Robustness Analysis (MARA) and Fuzzy DEMATEL-based ANP (FDANP). Sorourkhah (2024) discussed the challenges of strategic decision-making in turbulent environments. This research considers conventional tools, such as the Quantitative Strategic Planning Matrix (QSPM) and Multi-Attribute Decision-Making (MADM) methods, which often rely on past information, to be insufficient for dealing with a turbulent future. In this method, alternative strategies are first defined using SWOT analysis. Then, future scenarios are determined using a matrix approach. Subsequently, illogical scenarios are eliminated using Interpretive Structural Modeling (ISM), and finally, strategies are evaluated by implementing robustness analysis. Fathi et al. (2024) addressed the prediction of energy carrier production and consumption in the supply chain and strategy selection using a robustness analysis approach in the National Iranian Copper Industries Company.

4) Methodology

The present research is applied in its objective. Given the research topic of predicting health tourism strategies in Qom, Qom Province has been selected as the case study. Data collection instruments include document and archival analysis and expert interviews. The research methodology is based on a quantitative and robustness analysis approach.

Robustness analysis (RA) is a soft operations research method designed to structure complex problems with high uncertainty. This method helps decision-makers identify robust and flexible options under ambiguous conditions. Robustness analysis focuses on future scenarios, evaluating the resistance of strategies to unpredictable changes. This method is particularly applicable in dynamic environments such as the automotive industry, where technological and market changes necessitate stable strategies. In practice, robustness analysis is conducted by mapping matrices that quantify the relationship between initial decisions and their outcomes across different scenarios.

Key advantages of robustness analysis include:

Flexibility: The ability to adapt strategies to changing scenarios.

Support for Group Decision-Making: Facilitating stakeholder participation in complex environments.

Risk Reduction: Identifying options that have the highest compatibility with probable futures.

The classical robustness analysis method faced limitations such as examining a limited number of scenarios and neglecting the weighting of influencing factors. To address these shortcomings, the "weighted robustness analysis" approach was developed, which increases the accuracy of evaluations by assigning importance coefficients to influencing factors. For example, in the Saipa Research Center study, this approach enabled the prioritization of innovation strategies by simultaneously considering complexity and uncertainty (Sorourkhah et al., 2017).

Weighted Matrix Robustness Analysis Approach

Researchers point to three significant weaknesses in the classical robustness analysis method: first, the ambiguity of scenarios and the examination of only a few of them; second, the lack of attention to weighting criteria in evaluating the results of certain decisions within scenarios; and third, the lack of attention to the importance of factors forming future scenarios. To address these deficiencies, a weighted matrix approach to robustness analysis is presented in this research (Sorourkhah et al., 2017).
In the proposed approach, based on the widely used PESTEL (political, economic, social, technological, environmental, legal) macro-environmental analysis technique, environmental factors were classified, and six important indicators were used to design various future scenarios. This research shows that these factors are fundamental, and changes in them, especially over the long term, can lead to transformation and change in the health tourism industry. Unlike other approaches that pre-determine whether a criterion is favorable or unfavorable, the robustness analysis approach conducts this analysis within a temporal context, and by considering future scenarios, which leads to more diverse and appropriate outputs for the organization (Sorourkhah et al., 2017). This approach involves various steps, some of which are developed within the research methodology and illustrated in the figure below.

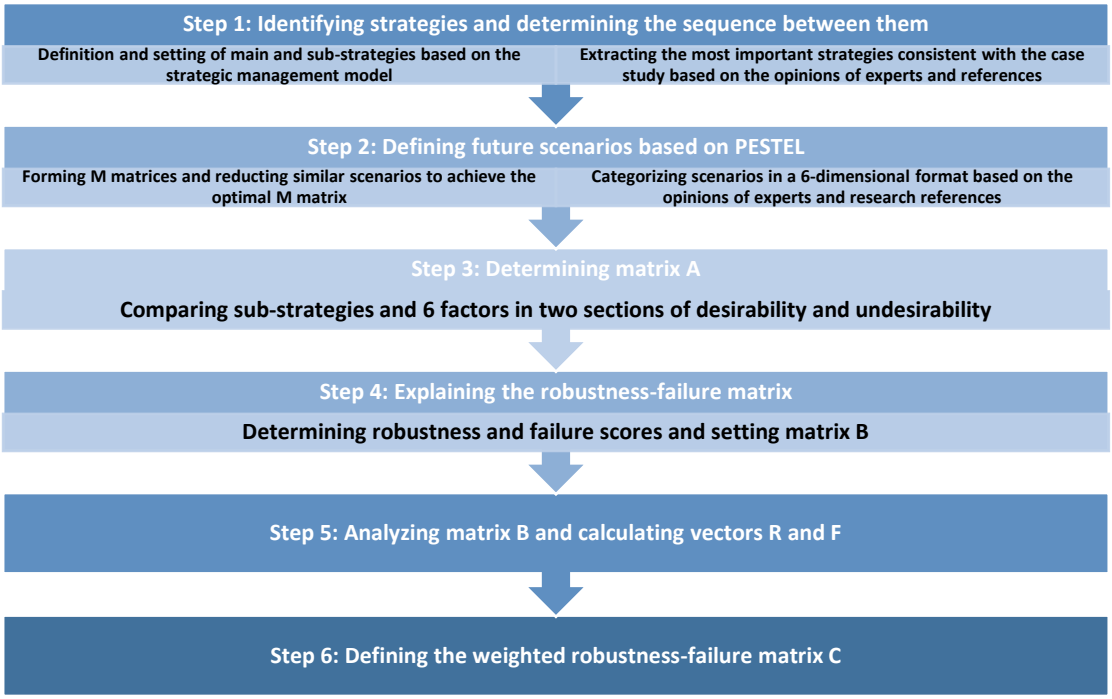

Figure 1. Research Methodology Based on the Weighted Matrix Robustness Approach

5) Findings

The weighted matrix robustness analysis approach was examined based on the following steps:

Step 1: Identification of Strategies and Determination of Their Sequence

This step is based on the principles of strategic management and marketing. These strategies are divided into two categories: main strategies and sub-strategies. First, the main strategies (MS_i: i = 1.2. … . r) are identified. The main strategies include four types: Aggressive (MS_1), Competitive (MS_2), Collaborative (MS_3), and Conservative (MS_4). Each main strategy encompasses a number of sub-strategies ($Sj : j = 1.2. \dots m$).

$$MS_i = S_{j1} + S_{j2} + \cdots + +S_{ji}$$
$$(i = 1.2. \dots . r)$$

The sub-strategies are as follows:

- **Vertical Integration (S_1):** Establishing ownership or increasing control over the purchasing, sales, distribution, and supply system. This involves creating a complete and continuous service supply chain from the admission to the discharge of international patients, either through direct ownership by a holding company including medical hotels, transfer centers, and specialized clinics, or by an overarching organization.
    - In this scenario, the origin and destination of all services are specified and customized, and patients receive all services as a package upon order placement.
    - This coordination requires the establishment of a new official department or entity called "Health Tourism Service Management" to control and supervise this chain.
    - Creating an integrated reservation platform to control all stages from booking to patient discharge can be among the measures for integration.
    - Ownership or control of medical equipment manufacturing centers (upstream integration) and establishing dedicated logistics centers (downstream integration).

- **Horizontal Integration (S_2):** Acquiring ownership or increasing control over competitors.
    - Merging with neighboring private hospitals, such as hospitals in Arak or Tehran, or collaborating with international clinics in Turkey to create an integrated network, similar to hotel or hospital chains.
- **Concentric Diversification (S_3):** Adding new and related products and services.
    - Establishing rehabilitation centers for elderly pilgrims, religious psychological counseling centers, and developing traditional medicine services (Iranian-Islamic) alongside existing hospitals.
- **Horizontal Diversification (S_4):** Adding new and unrelated products and services for current customers.
    - Establishing an acupuncture center to attract Chinese tourists, eco-tourism, and wellness centers (such as hydrotherapy and massage therapy) alongside existing services, and developing wellness tourism centers and recreational tourist centers.
    - Construction of recreational tourism centers: developing non-medical but complementary facilities (such as health spas).
    - Targeting new markets (non-religious tourists with luxury services).
- **Conglomerate Diversification (S_5):** Adding new and unrelated products and services.
    - Outsourcing surplus sections of medical and recreational centers to non-medical businesses, such as organic product stores or Qom souvenirs, and investing in the construction of mixed-use commercial-medical complexes.
    - Establishing educational/research centers: investing in indirect areas (such as a health tourism university).
- **Joint Venture/Partnership (S_6):** Forming an organization from one or two organizations to achieve common goals.
    - Tripartite cooperation between Qom University of Medical Sciences, Astaneh (custodianship of the shrine), and a foreign company to establish a specialized hospital.
    - Cooperation and partnership with international bodies to obtain standard certifications.
    - Formation of a Qom-Mashhad health tourism consortium.
    - Partnership with digital health startups to develop online booking platforms.
    - Concluding international agreements: collaborating with foreign companies for hospital management.
    - Cooperation with transportation organizations and the Ministry of Roads and partnership with railway companies for high-speed rail.
    - Collaboration with global insurers to cover crises.
    - Partnership with universities for crisis management research.
- **Retrenchment (S_7):** Grouping and reviewing costs to cover a downward trend in sales.
    - Closing inefficient sections of old hospitals and focusing on profitable specialties, outsourcing some high-cost services such as transportation, catering, and cleaning.
    - Crisis management: optimizing costs in emergency situations, including establishing backup and alternative hospitals or treatment centers for crisis situations (e.g., pandemics) or constructing smart quarantine centers with basic equipment.
    - Contingency reserve: medical equipment and drug warehouses for emergencies (e.g., storing oxygen and vital drugs in strategic centers).

- **Divestiture (S_8):** Selling an independent unit or part of the organization.
  - Selling residential units belonging to medical centers and converting them into health hotels or divesting unused land.
  - Building an international airport: may require divesting parts to the private sector.
- **Market Development (S_9):** Offering current services and products to new geographical areas.
  - Targeting new markets, such as African countries, for infertility treatment services.
  - Branding Qom: transforming the city into a global religious health destination.
- **Market Penetration (S_{10}):** Increasing market share for current products.
  - Increasing market share through targeted advertising on Arabic social media and satellite channels.
  - Completion of the metro and public fleet: facilitating access to increase usage by existing tourists.
- **Product Development (S_{11}):** Increasing sales by improving the quality of current products.
  - Acquiring advanced medical equipment: upgrading existing services (e.g., robotic surgery).
  - Designing attractive health packages, specifically for foreign pilgrims of the Holy Shrine of Lady Fatimah Masumeh (PBUH) (e.g., pilgrimage-treatment packages).
  - Designing innovative plans, such as smart hospitals, electronic medical records, and eco-friendly hotels.

Broadly, the main strategies are:

Aggressive Strategy (MS1)

An aggressive strategy aims for rapid growth and expansion, often involving significant investment and a proactive approach to market opportunities. This typically includes strategies like market penetration, market development, and product development. It also involves pursuing vertical and horizontal integration to gain greater control over the supply chain and market share.

$$MS_1 = S_1 + S_2 + S_3 + S_8 + S_9 + S_{10}$$

Competitive Strategy (MS2)

A competitive strategy focuses on gaining a sustainable competitive advantage in the market. This might involve differentiation through service quality, cost leadership, or focusing on niche markets. Key sub-strategies here could include product development to enhance offerings, market penetration to capture more existing market share, and carefully selected horizontal integration to gain an edge over rivals.

$$MS_2 = S_3 + S_4 + S_5 + S_6$$

Collaborative Strategy (MS3)

A collaborative strategy emphasizes partnerships and alliances to achieve common goals. This is particularly relevant in complex environments, such as health tourism, where various stakeholders are involved. Core sub-strategies include joint ventures/partnerships with other organizations, international collaborations, and forming consortia to leverage combined strengths. This approach also supports vertical integration by aligning different parts of the supply chain through cooperation rather than just ownership.

$$MS_3 = S_3 + S_5 + S_4 + S_8$$

Conservative Strategy (MS4)

A conservative strategy prioritizes stability, risk reduction, and efficient resource management, especially in uncertain or turbulent environments. This often involves a focus on internal efficiency and careful resource allocation. Key sub-strategies here are retrenchment (cost reduction and operational streamlining), divestiture of non-core assets, and sometimes, conglomerate diversification to spread risk across unrelated ventures.

$$MS_4 = S_2 + S_8 + S_9 + S_{10} + S_{11}$$

Step 2: Defining Future Scenarios

The second step involves defining future scenarios, which are categorized using the PESTEL framework across six domains: political, economic, social, technological, environmental, and legal. Therefore, scenarios are organized as an ordered sextuple as follows:

$$Sn_i = P_i + Ec_i + So_i + T_i + En_i + L_i$$
$$(i = 1.2 \dots . f)$$

where P represents Political factors, E denotes Economic factors, S stands for Social factors, T represents Technological factors, E′ is Environmental factors, and L represents Legal factors.

Table 1. Factors, Indicators, and States based on the PESTEL Method

Factor	Indicator	State
Political	Pi	"$i = 1.2 \dots p$"
Economic	Ec_i	"$i = 1.2 \dots c$"
Social	SO_i	"$i = 1.2 \dots s$"
Technology	T_i	"$i = 1.2 \dots t$"
Environmental	En_i	"$i = 1.2 \dots n$"
Legal	L_i	"$i = 1.2 \dots l$"

The scenario matrix is a 6×q matrix defined by arranging the Sni values as columns. At this stage, each indicator has several states, and scenarios are formed by creating possible combinations of different states. Therefore, health tourism experts, after reviewing various combinations, identify more important and prioritized combinations as possible scenarios.

Table 2. Influencing Indicators and States

Factor	Sub-factor	Indicator	State	Number
Political	Stability or instability of health diplomacy	Extent of international health agreements	Growth in the number of agreements with target countries	1
			Maintenance of existing international agreements	2
			Suspension of all agreements due to sanctions or tensions	3

Economic	Growth or stagnation of health tourism market	Annual growth rate of foreign exchange revenues and investment in logistics and infrastructure	Rial growth, economic stability, and increased investment in infrastructure and foreign currency earnings	1
			High inflation, currency fluctuations, and outflow of investment in infrastructure and foreign currency earnings	2
Social	Cultural acceptance or resistance	Diversity of health tourist nationalities	Growth in acceptance of non-religious or culturally diverse countries	1
			Growth in acceptance of religious or culturally similar countries	2
	Management of specialized human resources	Number of human resources	Attraction and training of specialized and multilingual personnel	1
			Exodus or migration of specialized and multilingual personnel	2
	Health and security crises	Extent and intensity of crises	Decrease or control of health, social, and security crises at origin or destination	1
			Increase in health, social, and security crises at origin or destination	2
Technology	Advancement or lag in medical technology	Number of centers equipped with first-tier technologies	Technology change and development of advanced and up-to-date treatment and accommodation centers of competitors, and internet and digital infrastructure	1
			Utilization of existing capacities and technologies	2
Environmental	Sustainability or environmental degradation	Environmental quality index	Improvement of water resources, reduction of air pollution and waste	1
			Shortage of water resources, increase in air pollution and waste	2
Legal	Transparency or regulatory complexity	Regulatory efficiency	Reduction of bureaucracy and visa issuance time, and approval of supportive laws	1
			Increase in restrictions and requirements for visa issuance and entry of foreign nationals	2

Therefore, the seven distinct and key scenarios for Qom health tourism are:

- **Scenario 1:** Sustainable Development with Attraction of Religious Markets: A combination of growth in agreements, economic stability, and environmental improvement.
- **Scenario 2:** Sanction-Induced Stagnation: The most pessimistic state with suspension of agreements and multiple crises.
- **Scenario 3:** Attracting Non-Religious Tourists with Advanced Technology: Focus on new markets with advanced technology.
- **Scenario 4:** Stable Situation with Environmental Challenges: Maintaining the current status quo without significant changes.
- **Scenario 5:** Multiple Crises: A combination of economic, political, and environmental threats.
- **Scenario 6:** Ecological Development: Emphasis on improving environmental conditions.
- **Scenario 7:** Foreign Investment-Oriented: Attracting international capital for development.

Therefore, matrix M consists of a column of selected scenarios, showing different states for rows of various indicators.

$$M = \begin{bmatrix} 1 & 3 & 2 & 2 & 3 & 1 & 1 \\ 1 & 2 & 1 & 2 & 2 & 1 & 1 \\ 2 & 1 & 1 & 2 & 1 & 2 & 1 \\ 1 & 2 & 1 & 1 & 2 & 1 & 1 \\ 1 & 2 & 1 & 1 & 2 & 1 & 1 \\ 1 & 2 & 1 & 2 & 2 & 1 & 1 \\ 1 & 2 & 1 & 1 & 2 & 1 & 1 \\ 1 & 2 & 1 & 2 & 2 & 1 & 1 \end{bmatrix}$$

Step 3: Determining the Desirability or Undesirability of Strategies for Each Strategy

Two ordered sextuples, S_j^+ and S_j^-, are considered. Matrix A is the strategy condition matrix, which takes values in columns of indicators and rows of desirable and undesirable sub-strategies.

$A = [S_1^+ + S_1^- + S_2^+ + S_2^- + \cdots + S_m^+ + S_m^-]$

The following matrices show the desirable (A^+) and undesirable (A^-) states for strategies and factors, respectively.

$$A^+ = \begin{bmatrix} 1 & 2 & 0 & 1 & 2 & 1 & 0 & 1 & 2 & 1 & 2 \\ 1 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 2 & 2 & 1 & 1 & 2 & 2 & 2 & 1 & 2 & 2 & 2 \\ 1 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 1 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 1 & 2 & 2 & 1 & 2 & 1 & 2 & 1 & 2 & 1 & 2 \\ 1 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 1 & 2 & 2 & 1 & 2 & 1 & 2 & 1 & 2 & 1 & 2 \end{bmatrix}$$

$$A^- = \begin{bmatrix} 3 & 3 & 0 & 3 & 0 & 3 & 0 & 3 & 0 & 3 & 0 \\ 2 & 2 & 0 & 2 & 0 & 2 & 1 & 2 & 0 & 2 & 0 \\ 0 & 0 & 2 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 2 & 2 & 0 & 2 & 0 & 2 & 0 & 2 & 0 & 2 & 0 \\ 2 & 2 & 0 & 2 & 2 & 2 & 0 & 2 & 0 & 2 & 2 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 2 & 2 & 0 & 2 & 0 & 2 & 0 & 2 & 0 & 2 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Step 4: Elucidating the Robustness-Inability Matrix

The matrix in question has m rows and q columns, where each row represents a sub-strategy S_j with $j = 1.2 \ldots n$ and each column represents a scenario S_{ni} with $i = 1.2 \ldots . q$. To determine the value of the $(i.j)$ component of this matrix, the ordered sextuple S_{ni} must be compared with the sextuples S_j^+ and S_j^-. If Sni matches S_j^+, a positive score is assigned, and each match of S_{ni} with S_j^- is considered a negative score.

$$B = \begin{bmatrix} -3 & 0 & 1 & 1 & 4 & 1 & 1 & 1 \\ -3 & 7 & 8 & -4 & 3 & 6 & -4 & 7 \\ 4 & 0 & 1 & 2 & 4 & 1 & 2 & 1 \\ -3 & 8 & 7 & -4 & 2 & 7 & -4 & 6 \\ -1 & -2 & 0 & 1 & 3 & -2 & 1 & 0 \\ -3 & 7 & 8 & -5 & 3 & 6 & -5 & 7 \\ -3 & 0 & 1 & 1 & 4 & 1 & 1 & 1 \\ -3 & 8 & 7 & -4 & 2 & 7 & -4 & 6 \\ -2 & 1 & -1 & 3 & 1 & 1 & 3 & -1 \\ -3 & 4 & 5 & -3 & 6 & 5 & -3 & 5 \\ -3 & 7 & 8 & -5 & 3 & 6 & -5 & 7 \end{bmatrix}$$

Step 5:

Specifically, in the classical approach (Rosenhead, 2010), two m-dimensional vectors R and F are defined, representing the robustness and inability levels of the sub-strategies S_j for j = 1,…,m, respectively. The j-th component of vector R (i.e., R_j) is equal to the ratio of the number of positive entries in the j-th row of matrix B to the total number of entries in that row (q), and the j-th component of vector F (i.e., F_j) is considered the ratio of the number of negative entries in the same row to q. Finally, for each main strategy MSi with I = 1,…,r, a robustness level is defined, which is equal to the sum of the components of vector R corresponding to the sub-scenarios related to this main scenario. An inability level is also obtained, which is the sum of the components of vector F related to the sub-strategies dependent on this main scenario. The selection of the superior main strategy is made by comparing the obtained levels of robustness and inability.

Table 3. Robustness and Inability Scores for Sub-Strategies

Robustness	Inability	Strategy
0.75	0.125	Strategy 1
0.625	0.375	Strategy 2
0.75	0.125	Strategy 3
0.625	0.375	Strategy 4
0.375	0.375	Strategy 5
0.625	0.375	Strategy 6
0.75	0.125	Strategy 7
0.625	0.375	Strategy 8
0.625	0.375	Strategy 9
0.625	0.375	Strategy 10
0.625	0.375	Strategy 11

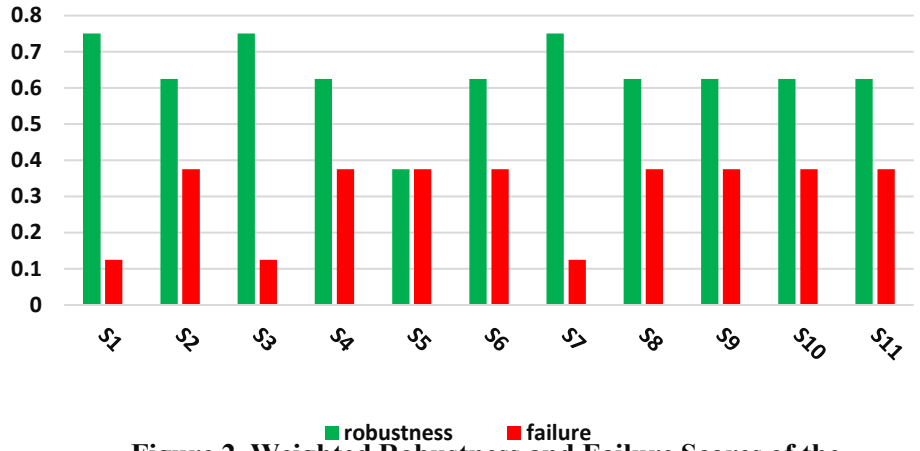

Figure 2. Weighted Robustness and Failure Scores of the Main Strategies

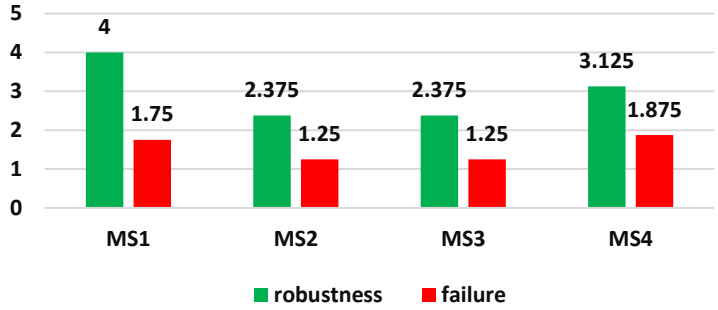

Figure 3. Robustness and Weakness Scores of the Main Strategies

Step 6:

The output obtained from the previous steps faces two important limitations due to not considering the weight of the criteria used. The first limitation is that it is not possible to determine the conditions of some entries in matrix B due to their zero values, and the second is that the robustness and inability scores of the main strategies are likely to be close, and these scores deviate from reality. To address these shortcomings, in the final stage of the proposed approach, the weighted robustness-inability matrix C is introduced, which is formed by considering matrices A, M, and the weight vector w. Similar to matrix B, to determine the (j,i) entry of matrix C, the ordered sextuple Sni must be compared with the ordered sextuples S_j^+ and S_j^-. The difference here is that for each match of S_{ni} with S_j^+, a positive score equal to the weight of the corresponding criterion is assigned, and for each match of S_{ni} with S_j^-, a negative score equal to the criterion's weight is considered. As before, the output of this stage includes a robustness level and an inability level for each main strategy MS_i with i = 1,…,r, based on which the superior main strategy can be selected.

Table 4. PESTEL Factor Weights Based on Expert Opinion

Factor	Legal	Environmental	Technological	Social (1)	Social (2)	Social (3)	Economic	Political
Weights	0.15	0.03	0.07	0.15	0.08	0.1	0.15	0.25

To enhance transparency in the weighting procedure, the PESTEL factor weights were elicited from a panel of domain experts familiar with health tourism in Qom. Experts provided importance judgments for each factor, and the final weights were obtained by aggregating expert inputs and normalizing them so that the weights sum to one. These weights were then applied in the weighted robustness–inability matrix to score the matches between each strategy's desirable/undesirable conditions and the states observed in each scenario. Based on the above weights, new robustness and inability scores can be calculated. Based on the results obtained, it can be stated that sub-strategies 2, 6, and 11 have the highest robustness, while sub-strategies 1, 5, 7, and 9 have the lowest inability. Main strategy 4, the conservative strategy, has also the highest robustness and the lowest inability.

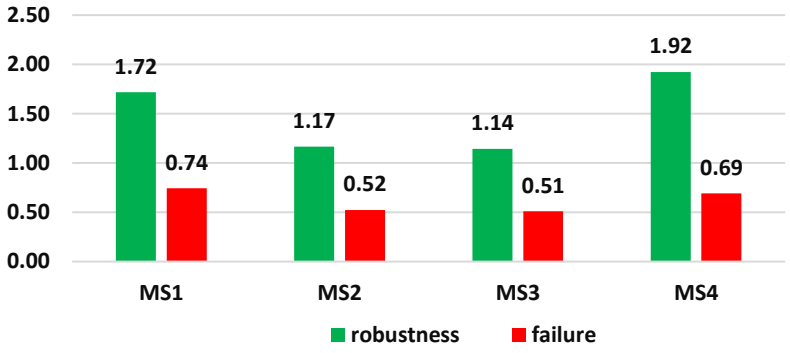

Figure 4. Weighted Robustness and Failure Scores of the Main Strategies

6) Discussion and Conclusion

This study aimed to identify and evaluate optimal health tourism service supply chain strategies in Qom using a robustness analysis approach. The current research sought to address the key question of which strategies can be most effective in developing this sector under various environmental conditions. The research was conducted based on the PESTEL method and the weighted matrix robustness approach in three main stages: identifying key influencing factors through expert interviews and reviewing upstream documents, formulating probable scenarios using the robustness analysis method, and quantitatively evaluating strategies within a weighted framework and calculating robustness and inability indices.
The provision of a combined weighted robustness analysis framework for health tourism, the design of a multi-criteria decision matrix tailored to the specific conditions of the religious city, the development of flexible scenarios with dynamic update capability, and the development of a weighted matrix approach with the calculation of the reduction matrix are among the most important innovations of this research.

The findings of the evaluation of Qom's health tourism strategies in the weighted robustness analysis section showed a clear distinction between the performance of different strategies. Strategy 4 (Conservative) was identified as the most effective strategy, with a robustness score of 1.92 and an inability score of 0.69, indicating its relatively higher resistance and lower vulnerability in changing environmental conditions. Strategy 1 (Aggressive) ranked second with a robustness score of 1.72, while its inability score of 0.74 indicates greater sensitivity to external factors. Strategies 2 (Competitive) and 3 (Collaborative), with close robustness scores (1.17 and 1.14, respectively) and very low inability scores (0.52 and 0.51), indicated the suitable potential of these strategies for medium-risk conditions.

The research indicates that Qom's health tourism system requires a combined and intelligent approach. The findings confirm that, in the current situation, the conservative strategy should be considered as the core strategy due to its relatively higher stability and controlled vulnerability. However, targeted integration of this strategy with elements of an aggressive strategy (for high-growth

potential sectors) and competitive-collaborative strategies (for improving regional cooperation) can lead to a desirable balance between risk and opportunity. This research emphasizes the importance of strategic flexibility and designing responsive scenarios adapted to environmental fluctuations. The results can serve as a decision-making framework for healthcare policymakers and managers of Qom's medical centers in formulating short-term and long-term operational plans.

It is suggested that in future studies, this analysis be further developed by considering supplementary qualitative indicators and focusing on specific regional dynamics. It is recommended that an expert working group be formed in the executive domain to implement the optimal combination of strategies and take responsibility for designing an intelligent monitoring system for key indicators. Qom, as a religious, tourism, and health city, adds complex dimensions to the problem. Therefore, it is suggested that, for the development of future research, other cities with environmental, political, and commercial potentials be examined. Furthermore, the use of dynamic modeling and system dynamics can be highly beneficial. This research, by providing a systematic framework, has taken an important step towards enhancing strategic management of health tourism in the region. The findings indicate that success in this area requires an intelligent combination of different strategies with attention to environmental dynamics.

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