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Ranking of AI-Driven Strategies for Optimizing the Health Tourism Supply Chain Using Stratified BWM

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ABSTRACT

Health tourism, as an emerging and strategic sector of the tourism industry, plays a significant role in economic growth, the development of international cooperation, and the enhancement of healthcare service quality. By integrating medical needs with recreational services, this sector holds great potential for attracting international patients. In this context, artificial intelligence technologies—including machine learning, data mining, natural language processing, and recommender systems—offer innovative opportunities to improve the efficiency of the health tourism supply chain. From enhancing patient data management to facilitating travel planning and personalizing services, AI can play a pivotal role in optimizing industry processes. This study aims to identify and rank the most effective AI-driven strategies for optimizing the health tourism supply chain. First, a comprehensive literature review and analysis of domain-specific sources were conducted to extract a set of key strategies. Subsequently, these strategies were evaluated and prioritized using the multi-criteria decision-making method known as the Stratified Best-Worst Method (Stratified BWM). The results revealed that the top three strategies were: "Patient Data Management and Analysis" (A1), "Healthcare supply chain optimization" (A2), and "Customer Experience and Digital Services" (A3). These strategies—by leveraging intelligent data usage, optimal resource allocation, and improved digital engagement with patients—significantly contribute to higher efficiency, customer satisfaction, and service quality. The findings of this research provide valuable insights for policymakers, healthcare managers, and tourism stakeholders in designing targeted programs and promoting the sustainable development of the health tourism supply chain.

1. Introduction

Tourism, as the driving force of the global economy, is no longer a luxury good, but has become a global lifestyle and a vital factor in world trade and economy. It is now the largest and most diverse

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industry in the world, directly impacting national, regional, and global economies. Tourism is a major source of income, employment, private sector growth, and infrastructure development for many countries, especially developing countries with limited economic options [1]. As part of the services sector, tourism contributes cash flows to the economies of countries and is a major source of foreign exchange earnings. The growth of this industry has consistently outpaced the overall growth rate of the world economy over the past fifty years and is projected to grow on average 1 to 3 times faster than Gross Domestic Product GDP [2]. This unique role has made tourism an essential pillar for the sustainability and prosperity of the global economy [3].

As one of the new sub-sectors of the tourism industry, health tourism has found a special place among different countries in the world. In recent decades, demographic changes, increased health-related awareness, and advances in medical technology have led to a significant increase in demand for health-related travel [4]. In addition to medical and surgical services, health tourism also includes healing experiences based on nature, social interactions, and local culture [5]. The importance of health tourism goes beyond its therapeutic and individual dimensions and has wide-ranging impacts on the economy, job creation, development of medical infrastructure, and promotion of the international status of countries [6]. As a source of sustainable income, this type of tourism can play an important role in attracting foreign investment and transferring specialized knowledge [7]. It also paves the way for improving the quality of medical services and standardizing medical centers, which in turn can contribute to improving the domestic health system and increasing public satisfaction [8]. On the other hand, health tourism provides an opportunity to diversify the tourism market and reduce dependence on specific tourist seasons, and by strengthening international cooperation in the field of health, it helps to expand health diplomacy and cross-border interaction [9].

Despite the increasing growth of health tourism as one of the emerging and profitable markets of the tourism industry, the supply chain of this sector still faces fundamental challenges. One of the main challenges is the lack of structural and operational coordination between the various components of the supply chain, including medical centers, tourism service providers, transportation, accommodation facilities, insurance companies, and even government agencies and regulatory bodies [10]. This lack of coordination leads to inconsistencies in timing, quality of services, information transfer, and responsiveness to the needs of health tourists [11]. In many countries, especially developing destinations, there are still no clear institutional and communication frameworks to connect and integrate these sectors, and each sector operates in isolation and insularity [12]. On the other hand, the complexity of human and financial resource management, especially in a situation where health tourists have high expectations of quality, speed, and safety of services, is another challenge that affects the performance of the entire supply chain [13].

Aligning the level of expertise of medical staff with international needs, ensuring safe and rapid patient transportation, designing integrated medical-tourism packages, and providing technological infrastructure for data and information exchange between interested entities require strategic planning and cross-sector investment [14]. If these issues are neglected, the patient-tourist experience will be overshadowed, and the international reputation of the health tourism destination will also be weakened, and it will be difficult to attract capital and tourism [15]. Therefore, addressing these challenges requires a systemic and cross-sectoral approach that can redesign the health tourism supply chain using new technologies, integrated policymaking, and interagency cooperation in a way that both increases its productivity and satisfies domestic and international stakeholders [16].

The role of technology in optimizing the health tourism supply chain has increased significantly in recent years. The emergence of new technologies, especially in the digital domain, has created a

fundamental transformation in the traditional structure of the supply chain and has enabled smart, transparent, and efficient management of resources [17]. Technologies such as the Internet of Things (IoT), blockchain, cloud computing, big data, augmented reality, and artificial intelligence (AI) are among the key tools in this area [18]. Among these technologies, artificial intelligence plays a pivotal and distinctive role as a transformative technology. With the ability to analyze complex data, predict demand, optimize scheduling, and allocate resources, AI can improve coordination between the treatment, service, and transportation sectors in real time [19]. For example, machine learning algorithms and recommender systems can suggest optimal treatment routes for foreign patients or manage treatment capacities and prevent congestion through trend analysis. Also, AI can help improve service quality and increase health tourist satisfaction by processing data related to customer experience. Thus, the targeted use of AI-driven strategies can pave the way to achieving an efficient, smart, and competitive supply chain in the health tourism industry [20].

In this regard, the present study was formed by posing three basic questions: First, what are the key and effective criteria in the health tourism supply chain? Second, what are the most important AI-driven strategies that can optimize this chain? And third, based on the criteria extracted from previous studies, which of these strategies has a higher priority? With the aim of answering these questions, the present study identifies the effective criteria in the health tourism supply chain and ranks AI-driven strategies according to these criteria. To achieve this goal, the Stratified Best-Worst Method (SBWM) has been used; a method that allows for accurate weighting of criteria and prioritization of strategies in the context of a layered structure. The results obtained from this research can provide a scientific basis for decision-making in the field of policy-making, supply chain management, and the development of AI technologies in the health tourism industry, and can be used in the design of integrated and intelligent strategies.

1.1 Key Technological Criteria in Optimizing the Health Tourism Supply Chain

Health tourism, as one of the new and strategic branches of the tourism industry, includes a complex set of diverse factors and criteria that directly or indirectly affect the quality, efficiency, and sustainability of the health service supply chain [21]. These criteria cover various aspects such as the quality of medical services and equipment, the expertise and credibility of medical staff, digital and communication infrastructure, laws and regulations, costs, security and stability of the destination, and the interaction and network cooperation of industry players [19]. A comprehensive and accurate understanding of these criteria and their mutual effects is the key to success in designing and optimizing the health tourism supply chain [17]. This research is dedicated to examining and categorizing these fundamental dimensions with a focus on the technological approach, which has been able to integrate various factors and provide a suitable platform for utilizing new technologies, including artificial intelligence [18].

The different dimensions of these criteria can be categorized into three main areas. First, the area of medical services includes the quality and advancement of medical equipment and the expertise of medical staff. This sector is the backbone of attracting international patients, and its quality directly affects treatment outcomes and patient satisfaction. Second, technological and communication infrastructure, which includes digital networks, information management systems, secure access to medical records, and digital interaction with patients [14]. These infrastructures facilitate the flow of information, improve treatment decisions, and increase the quality of the patient experience. Third, institutional and environmental factors include facilitating laws, total travel cost, security, and political stability of the destination, and cooperation among supply chain players, which provide the

necessary grounds for sustainable growth and competitiveness of health tourism. These dimensions create a dynamic and effective ecosystem in the development of this field.

Finally, the intelligent combination of these dimensions and the use of new technologies, especially AI, can lead to the optimization of health tourism processes. Paying attention to these criteria and implementing strategies based on them will help improve the quality of medical services and patient experience. It will also lead to the sustainability, competitiveness, and targeted development of this industry at the national and international levels [16]. This comprehensive approach paves the way for the formation of an advanced, efficient health tourism supply chain that is responsive to the diverse needs of patients around the world.

1.2 The Role of Environmental Dynamics in Shaping the Health Tourism Landscape

The health tourism industry operates in a highly dynamic and changing environment that shapes its priorities and development trends [21]. These dynamics are the product of a combination of technological developments, changes in consumer behavior, social and political fluctuations, and global health macro conditions, all of which affect how the health tourism supply chain is managed and optimized [15]. A deep and continuous understanding of these changing factors and their impact on the structure and functioning of this industry is of great importance to design flexible, effective, and practical strategies [13].

New technologies, especially artificial intelligence, have provided vast opportunities to improve efficiency, personalize services, and enhance the quality of the patient experience [20]. These technological developments, while facilitating comprehensive and integrated supply chain management, provide the ability to respond to the diverse and complex needs of patients .In contrast, social and political conditions, combined with global health challenges, create instabilities that sometimes affect patient safety and trust [9]. In addition, patients 'increasing awareness of the importance of receiving personalized services has changed the overall outlook on medical travel and created new expectations about the quality and scope of services [5]. This diversity of factors and developments has doubled the complexity of health tourism management and requires careful strategic alignment and collaboration among all stakeholders.

The influential role of these factors in shaping health tourism implies the need to adopt a comprehensive and flexible approach. This approach must simultaneously exploit technological opportunities and be able to deal with the risks arising from environmental changes [11]. Interdisciplinary collaborations and synergies between different relevant sectors, including health, technology, crisis management, and marketing, are key to promoting sustainability and success in this field [12]. Also, the ability to rebuild the destination image in the face of crises and the intelligent use of media and social networks to restore public trust are considered vital solutions. These trends show that health tourism must anticipate possible changes and adjust its strategies based on possible scenarios in order to ensure its resilience and sustainability against complex environmental fluctuations.

Finally, health tourism requires a holistic and multilateral view of environmental impacts and rapid and intelligent adaptation to changes so that it can meet the increasing needs of patients and ensure their mental and physical security. This industry also should maintain its position in the global competitive market and continue the process of sustainable growth with strength and flexibility [16]. Paying attention to changing conditions and designing strategic scenarios to face crises and technological developments are among the vital requirements that can guarantee long-term success and improve the quality of services in this industry.

The remainder of this paper is organized as follows. Section 2 presents the literature review, outlining the key concepts, theoretical foundations, and prior research relevant to the study. Section 3 describes the methodology, which is structured into nine sequential steps to ensure a systematic and transparent research process. Section 4 reports the findings, providing detailed results and analysis. Finally, Section 5 offers the conclusions, highlighting the main contributions, implications, and potential directions for future research.

2. Literature Review

Existing studies in the field of health tourism have presented various perspectives and analyses of this field, indicating its importance in economic and social development. These studies cover various domains, including sustainability in health tourism [10], [22], the selection of providers within the medical tourism supply chain [6], the potential analysis of forest health tourism [14], identifying the criteria affecting the choice of medical destinations [21] and the optimization of health institution selection [13]. Moreover, strategies aimed at enhancing the quality of healthcare services [17], [23] are also of particular interest.

The capability of AI to process vast amounts of patient data, customize treatments, and optimize diagnostic processes has markedly improved the patient experience. For instance, intelligent systems can analyze patient data and recommend optimal treatment options with remarkable accuracy, thus enhancing patient satisfaction and elevating the efficiency of healthcare systems [24], [25], [26], [27]. AI also plays a vital role in resource management and strategic planning within health tourism. By utilizing intelligent algorithms, it is possible to forecast demand for healthcare services and optimize resources [28], leading to cost reductions and increased productivity. Additionally, AI tools such as chatbots and virtual assistants help patients in planning medical trips, booking accommodations, and accessing real-time medical information, all of which contribute to an improved overall experience. AI-driven recommendation systems analyze user behavior and preferences to provide tailored suggestions [29]. Overall, AI serves as an essential tool that acts as a primary driver in the transformation of health tourism, enhancing customer experiences, personalizing services, and streamlining business operations while revolutionizing various facets of this sector [28], [30], [31], [32].

Regarding the methodologies employed for weighting and ranking, the relevant articles utilize various techniques. For example, Fuzzy AHP and TOPSIS are employed to determine the weights of criteria and rank alternatives [1], [11], [33]. Techniques such as F-DEMATEL, SFAHP, F-TOPSIS, and F-SWARA-PROMETHEE have also been used to identify and rank the factors influencing health tourism performance [1], [5], [21], [34], [35], [36], [37]. These methodologies empower organizations and researchers to enhance their performance across various domains, enabling them to utilize precise data analysis for better strategic decision-making [38]. However, the reviewed articles are not without critiques that warrant attention. Many of these works, particularly those utilizing Multi-Criteria Decision-Making (MCDM) approaches, exhibit a lack of flexibility concerning dynamic environmental conditions. For instance, in articles relying on fuzzy methods, there may be insufficient acknowledgment of the rapid changes necessary in response to shifting economic and social contexts [3]. Additionally, some articles have used fixed assumption questionnaires for their analyses, potentially limiting their capacity to respond to changing environmental circumstances. Table 1 shows a summary of related literature.

In this study, we employ the Stratified Best Worst Method (BWM), which considers the importance of indicators in a dynamic environmental context to examine the significance of

alternatives. This methodology is capable of accommodating the changes and variances in factors affecting health tourism amid ongoing digital transformation, allowing for a deeper analysis of the current landscape and future needs while supporting complex decision-making structures. Thus, the adoption of Stratified BWM can provide better solutions for policymakers and decision-makers aiming to optimize the healthcare tourism supply chain. Consequently, the application of Stratified BWM not only enhances the quality of healthcare services but also fosters sustainable development in health tourism. This approach enables policymakers to make more informed decisions in light of changing environmental conditions and to utilize resources in this sector more effectively.

Table 1
Summary of Related Studies

No.	Study	Research Goal	Methodology	Result
1	[10]	Investigating sustainable development in health tourism and identifying drivers	Systematic literature review and bibliometric analysis of 93 articles	Systematization of the existing literature in five areas: Sustainable Tourism Stakeholders, COVID-19 Impact, etc.
2	[11]	Developing a decision-making model for prioritizing medical tourism services	Combining FAHP and TOPSIS for service evaluation and prioritization	Rehabilitation-Physiotherapy has the highest priority, Traditional Eastern Medicine is the second, and Western Medicine is the lowest
3	[13]	Investigating the potential of Kayseri in health tourism and optimizing the selection of health institutions	Using MCDM and goal planning with expert opinions	Providing a mathematical model for assigning patients to health institutions and evaluating the performance of nine institutions
4	[5]	Identifying and evaluating key features and factors for developing health and wellness tourism destinations	Using the 6AsTD framework and the TOPSIS method	Attractions, Accessibility, and Amenities were identified as the main priorities
5	[21]	Determining effective factors in choosing a destination in medical tourism	Using the SFAHP method to determine the criteria importance levels	The most important criteria for choosing a destination: the country's environment, the cost of treatment and services, and facilities
6	[9]	Developing a framework for identifying and prioritizing effective factors in choosing Iranian medical destinations	Using the Fuzzy IPA method	Friends' recommendations and previous experiences were identified as the most important factors for choosing a destination for medical tourists
7	[8]	Investigating the dynamics of the medical tourism supply chain in order to create a robust framework	Developing a multi-objective mathematical formulation and using programming methods for supplier evaluation	Developing resilient strategies that have a significant impact on supply chain profitability (40% increase)
8	[14]	Establishing an evaluation system for the potential of developing forest health tourism	Using TODIM and VIKOR techniques with single-valued nootropic numbers	Creating an SVNN–TODIM–VIKOR technique and investigating the potential for developing forest health tourism

9	[6]	Selection of suppliers and allocation of capacity in the medical tourism service supply chain	Using a fuzzy-based inference system and a fuzzy linear model	Improving cooperation between suppliers and allocating capacity based on medical tourists' preferences
10	[7]	Analyzing sustainability goals in the medical tourism service network	Using the Fermatean Fuzzy MACTOR method	Identifying the major responsibilities of suppliers to achieve sustainability goals
11	[17]	Evaluating the quality and sustainability of dental tourism	Using fuzzy LMAW and LOPCOW methods	Identifying important quality criteria, with an emphasis on social hygiene and cleanliness of clinics
12	[16]	Identifying the main needs of medical tourists and improving services	Using the QFD model and the best-worst method	Identifying key factors, including improving infrastructure and medical standards
13	[4]	Identifying and ranking strategies for developing forest health tourism	Using SWOT, AHP, and QSPM methods	Identifying the best strategies for health tourism development in the Tea and Bamboo Region
14	[1]	Analyzing factors and strategies for implementing sustainable tourism in a green economic structure in China	Using Fuzzy AHP and TOPSIS methods	Identifying Five Criteria and Six Effective Strategies for Sustainable Tourism Development in Guilin
15	[3]	Identifying and prioritizing tourism strategies	Using an antifragile analysis algorithm	Identifying 11 Existing Strategies and Proposing Future Scenarios for Antifragile Strategies
16	[19]	Ranking European countries using MEREC and MARCOS methods in the field of tourism development	Using combined multi-criteria analysis	Identifying Differences in Country Rankings Based on TTDI and the Importance of Criteria

3. Methodology

This section describes the steps of the stratified BWM method. This method consists of 10 steps, including “Problem Description”, “Experts Selection”, “Alternatives Identification”, “Criteria Identification”, “Identifying Possible Scenarios”, “Probability Occurrence and Assessment of Criteria”, “Determining the optimal weights of the criteria”, “Application of BWM to each alternative”, and “Ranking the alternatives”[39], [40], [41]. Figure 1 shows the steps of implementing the Stratified BWM.

Step 1: Problem Description

The first step is to define a precise problem that has several criteria and several alternatives in different conditions or scenarios affecting the importance of the criteria. In such problems, the relative importance of the criteria may change in different scenarios. Decision-making without considering these differences can lead to incorrect results. This method makes the final analysis more accurate, more valid, and tailored to the realities of the problem, especially when changing scenarios play a significant role in decision-making.

Step 2: Expert Selection

For the correct implementation of the Stratified BWM, it is essential to select appropriate experts/decision makers. They should have specialized knowledge, practical experience, and sufficient awareness of the different dimensions of the problem. Careful selection of experts helps to ensure the quality of input data and the validity of the results. The criteria for selecting experts usually include relevant academic and professional background, decision-making experience in the field, and the ability to perform comparative analysis between criteria and alternatives. Also, to cover the diversity of perspectives and reduce bias, an attempt is made to select a mix of experts with different backgrounds (e.g., academic, industrial, or executive). The number of experts should be determined in a way that ensures data adequacy on the one hand and prevents excessive complexity in the analysis on the other.

Step 3: Alternatives Identification

It is necessary to carefully identify and define alternatives that are evaluated and compared based on the determined criteria. The selection of alternatives should be done in a way that covers all reasonable, realistic, and relevant solutions to the problem. This selection should be scientifically based on evidence, previous studies, or expert opinions to prevent possible bias and increase the quality of the analysis. In the Stratified BWM, it is more important to consider the diversity of alternatives because alternatives may perform differently in different scenarios or in different classes of data. Therefore, it is necessary to ensure that the selected alternatives are suitable both in terms of comparability and in terms of their susceptibility to environmental changes or scenario conditions. A precise and comprehensive definition of alternatives provides a platform for more accurate evaluation and more valid decisions.

Step 4: Criteria Identification

Criteria are concepts against which alternatives are evaluated and compared. Criteria identification should be based on a literature review, expert surveys, or exploratory analyses to ensure that all important dimensions of the problem are covered. The selected criteria should have characteristics such as comprehensiveness, non-overlapping, direct relevance to the decision-making objective, and the possibility of measurement. It is also necessary to examine whether the importance or role of these criteria can change in different scenarios, because one of the goals of Stratified BWM is to pay attention to the differences in the importance of criteria in different layers of data or decision conditions. Appropriate and accurate selection of criteria plays a vital role in the accuracy of the final results and directly affects the validity of the decision-making model. If the criteria are incompletely or incorrectly identified, the results of the analysis may not reflect the main realities of the problem.

Step 5: Identifying Possible Scenarios

The fifth step is to identify different scenarios that can affect the importance or performance of decision-making criteria. Scenarios represent different conditions or environments that may arise over time or depending on different situations and cause changes in the prioritization of criteria. Such scenarios can be developed through a thorough review of the relevant literature and industry reports, enabling the extraction of trends, drivers, and key uncertainties. They may also be generated through field investigations and the collection of expert opinions. The goal of this step is to properly consider the dynamic dimensions of the problem in the decision-making process and not limit the analysis to a static situation. Each scenario should have specific characteristics that can explain

potential changes in the importance of criteria or the behavior of alternatives. Accurate and comprehensive identification of scenarios allows the Stratified BWM to optimize decisions by considering possible differences in the future and increases the validity of the results.

Step 6: Probability Occurrence and Assessment of Criteria

6.1 Probability Matrix (probability occurrence of each scenario)

In this step, a probability matrix is formed according to the defined scenarios. This matrix indicates the probability of occurrence of each scenario. These probabilities indicate the weight of each scenario, which helps in a detailed analysis of the impact of each scenario on the final weight of the criteria.

6.2 Selection of the best and worst criteria

In the next step, the best and worst criteria in each scenario must be selected. This step plays an important role in determining the final decision-making results and helps in obtaining the weight of each criterion based on the comparison with the base criterion.

6.3 Pairwise Comparisons

The preferences of the best criterion over other criteria and also the preferences of other criteria over the worst criterion are determined using a scale of 1 to 9 based on Table 2. In each scenario, $2n-3$ comparisons are performed, where n is the number of criteria [42].

Table 2
Comparison Scale

Scale	Description
1	equal importance
2	between equal and moderate
3	moderately more important than
4	between moderate and strong
5	strongly more important than
6	between strong and very strong
7	very strongly more important than
8	between very strong and absolute
9	absolutely more important than

6.4 Calculating the weight of criteria in each scenario

According to the pairwise comparisons performed, the weight of the criteria in each scenario is obtained using Equation 1.

$$\begin{aligned} &min \quad \xi \\ &\left|\omega_B - \omega_j \times bo_j\right| \leq \xi \\ &\left|\omega_j - \omega_w \times bo_j\right| \leq \xi \\ &\sum_{j=1}^{n} \omega_j = 1 \\ &\omega_j \geq 0 \text{ for all j} \end{aligned} \tag{1}$$

6.5 Consistency Ratio

The consistency ratio (CR) is a measure of the degree of consistency of comparative judgments in each scenario. This ratio is calculated separately for each scenario and ensures that the weighting results have reasonable validity. The calculation of CR is based on Equation 2, and if its value is high, there is a need to revise the judgments (Rezaei, 2015).

$$Consistency\ ratio\ (CR) = \frac{\varepsilon}{Consistency\ \ index} \tag{2}$$

Step 7. Determining the optimal weights of the criteria

To determine the optimal weights of the criteria, first, the weights obtained from each scenario are aggregated in the form of a matrix. Then this matrix is multiplied by the matrix of the probability of occurrence of the scenarios. The result of this multiplication determines the optimal weights of the criteria in the final form.

Step 8. Application of BWM to each alternative

In this step, in order to answer the question of which alternative is more suitable for each of the selected criteria, the weighting process is performed. In each criterion, the weight of the alternatives is calculated using the BWM. This step allows for a precise comparison of the alternatives based on each criterion.

Step 9. Ranking the alternatives

To determine the optimal weights of the alternatives, first, the weights obtained from the alternatives are aggregated in the form of a matrix. Then, this matrix is multiplied by the matrix of optimal weights of the criteria. The result of this multiplication determines the final optimal weights of the alternatives.

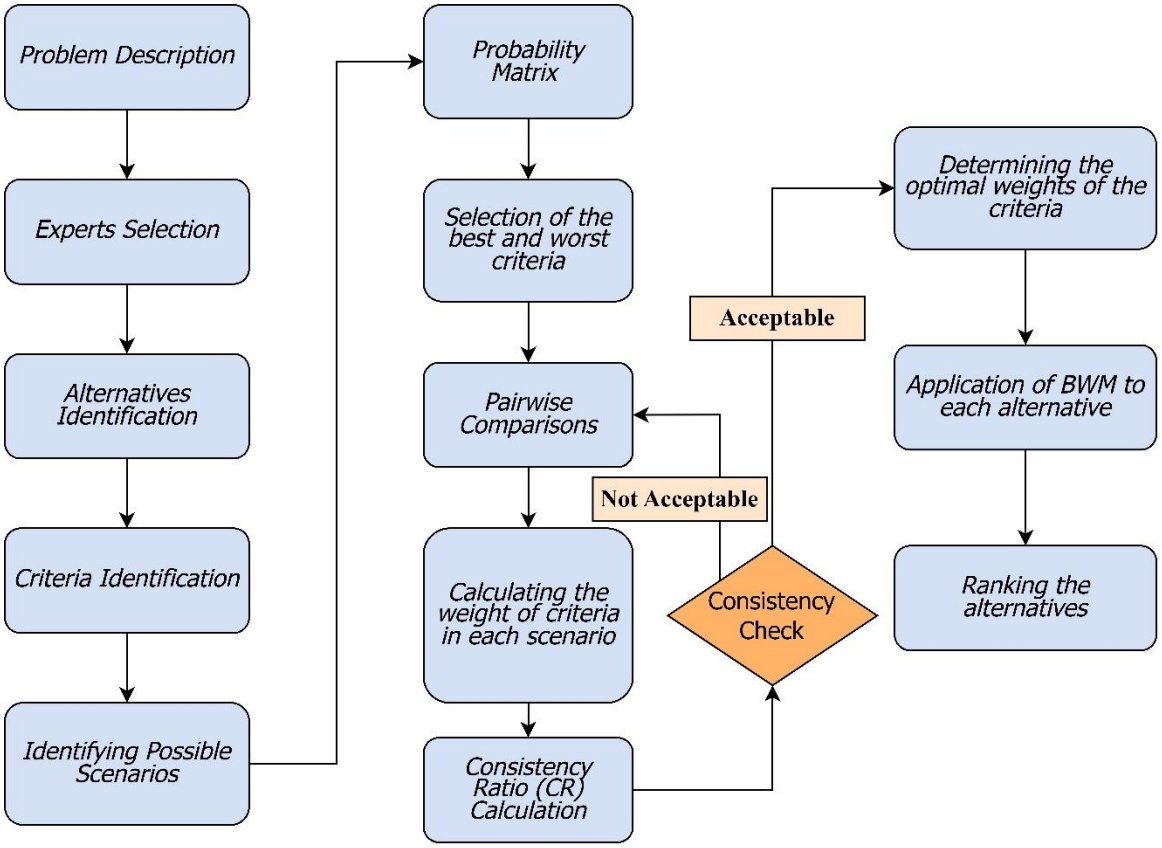

Fig 1. The Steps of Stratified BWM

4. Findings

According to the research problem, alternatives were selected; these alternatives are strategies for improving the health tourism supply chain that are influenced by artificial intelligence (Table 3).

Table 3
Different AI-Driven Strategies (Alternatives)

Code	Strategy	Advantages	Disadvantages
A1	Patient Data Management and Analysis	• Identify health patterns from big data • Accurately predict medical needs • Personalize healthcare services	• Need for advanced data infrastructure and technology • Challenges in maintaining data privacy • Complexity of implementing ML models
A2	Healthcare Supply Chain Optimization	• Intelligently manage healthcare resources and services • Accurately allocate doctors, accommodations, and transportation • Demand forecasting and reducing waste	• Dependence on accurate and up-to-date data • Challenges in coordinating between different healthcare centers • High initial implementation costs
A3	Customer Experience and Digital Services	• Increase health tourist satisfaction • 24/7 support through chatbots	• Difficulty in understanding multicultural patient needs

		• Design personalized travel routes	• Cost of developing and maintaining advanced systems • Risk of recommender errors
A4	Smart Diagnosis and Treatment	• Improve the accuracy of disease diagnosis with deep learning • Help doctors make quick decisions • Enable telemedicine	• Need for large and labeled datasets • Challenges in adopting the technology by some physicians • Concerns about errors in AI systems
A5	Performance Assessment and Monitoring	• Real-time monitoring of patient satisfaction • Improve service quality with sentiment analysis • Make healthcare center performance transparent	• Challenges in accurately analyzing textual and emotional comments • Risk of data bias • Need for human resources to interpret outputs
A6	Data Security and Privacy	• Prevent patient information leaks • Increase international patient trust • Identify security threats with AI	• High cost of implementing security solutions • Technical complexity in encryption and access control • Limitations in data sharing
A7	Smart Marketing to Attract Health Tourists	• Accurately target markets • Analyze user behavior in cyberspace • Increase the effectiveness of advertising campaigns	• Challenges in accessing valid behavioral data • Possibility of privacy violations in personalized advertising • High cost of analyzing market data

Health tourism criteria, based on previous research and expert opinions, are listed in Table 4. These criteria are a summary of important factors in health tourism, which are obtained by combining multiple indicators.

Table 4
Key Criteria for Evaluating the Strategies

Code	Criteria	Brief description	References
C1	Quality and Advancement of Medical Services and Equipment	A combination of service standards, diagnostic technologies, and equipment that directly affect treatment outcomes.	**[4], [16], [17], [43]**
C2	Competence and Credibility of Medical Staff	The level of expertise, experience, and reputation of doctors and other healthcare professionals among domestic and international patients.	**[6], [9], [24]**
C3	Integrated Digital, Transportation, and Accommodation Infrastructure	Availability of stable internet, reservation systems, efficient transportation network, and appropriate accommodation facilities.	**[29], [32], [44], [45]**
C4	Secure and Fast Access to Health Information and Privacy Protection	The ability to share medical records in a timely manner while adhering to data security requirements.	**[28], [46], [47]**
C5	Data Analytical Capacity and Smart Decision-Making	The use of artificial intelligence to predict demand, optimize resources, and provide accurate treatment recommendations.	**[3], [8], [48]**
C6	Digital Patient Experience and Interaction Management	Chatbots, mobile apps, and other tools to personalize services before and after medical travel.	**[9], [12], [49]**

C7	Laws and Tariffs Facilitating Health Tourism	The speed and ease of visa issuance, acceptance of international insurance, and transparent treatment fee structures.	**[9], [50], [51]**
C8	Total Cost of Medical Trip	The total cost of treatment, airfare, and accommodation, and the impact of currency differences on the foreign patient.	**[7], [16]**
C9	Political Stability and Security of the Destination	The level of public security and political risks affects the patient's travel decision and peace of mind.	**[1], [10], [52]**
C10	Network Cooperation Between Health Tourism Actors	The degree of coordination between hospitals, specialized agencies, and other stakeholders to provide integrated services.	**[5], [11]**
C11	Diversity of Specialties and Treatment Options Offered	The range of medical services (from general medicine to specialized surgeries) and the possibility of personalizing the treatment path.	**[2], [9]**
C12	Destination Attractiveness (weather and tourist attractions)	The role of environmental and cultural factors in choosing a destination and improving the recovery experience of the patient and his companions.	**[10], [15], [53], [54], [55]**

To finalize and validate the scenarios, a panel of ten experts was engaged. The panel included four physicians experienced in high-demand health tourism services, three senior hospital managers with expertise in operational planning and patient services, and three specialists in health policy, international regulations, and the medical tourism industry. The experts were selected to provide a balanced combination of clinical, managerial, and policy-oriented perspectives. A description of each scenario, along with its probability of occurrence, is provided in Table 5.

Table 5
Different Scenarios and Their Probability of Occurrence

Code	Scenario	Description	Scenario probability
S1	Rapid growth of international health tourism and increasing global competition	A dramatic increase in the number of international patients and increasing competition between health tourism destinations. Patients are placing more importance on high-quality treatment, the expertise of doctors, and a favorable digital experience to make better choices among multiple options.	35%
S2	Development of artificial intelligence technologies and complete digitalization of the supply chain	Artificial intelligence is being used at all stages of the supply chain, and all processes from data management to travel planning and resource allocation are being carried out intelligently. This increases the role of technology and infrastructure.	30%
S3	Political and health crises in major health tourism destinations	Political uncertainties, security issues, or public health crises such as pandemics increase patients' sensitivity to the security and stability of destinations. Facilitating regulations becomes important to attract patients in these circumstances.	20%
S4	Increasing patient awareness of personalized services and the medical travel experience	Patients are increasingly expecting to receive customized services and an optimal medical travel experience. Attention is increasing on digital interaction, data analysis, and supporting infrastructure to provide services tailored to each individual's needs.	15%

The weights of the criteria were obtained separately in each scenario. For this purpose, in each scenario, the best and worst criteria were determined, and then the opinions of the experts were taken. The opinions of the experts were combined with the arithmetic mean. By combining the opinions of the experts, the final model was determined, and the weights of the criteria in each

scenario were obtained. By multiplying the obtained multiplicative matrix and the probability of occurrence of the scenarios, the final optimal weights were obtained. Using the following model, the weights of the criteria in the first scenario were obtained. In scenario 1, the best criterion is C1 and the worst criterion is C10 (see Table 6). Figure 2 shows the final weight chart of the criteria.

$$
\begin{aligned}
&min \quad \xi \\
&|\omega_1 - \omega_2 \times 4| \le \xi \\
&|\omega_1 - \omega_3 \times 6.3| \le \xi \\
&|\omega_1 - \omega_4 \times 7.5| \le \xi \\
&|\omega_1 - \omega_5 \times 6.5| \le \xi \\
&|\omega_1 - \omega_6 \times 5| \le \xi \\
&|\omega_1 - \omega_7 \times 7.3| \le \xi \\
&|\omega_1 - \omega_8 \times 8| \le \xi \\
&|\omega_1 - \omega_9 \times 8.3| \le \xi \\
&|\omega_1 - \omega_{10} \times 9| \le \xi \\
&|\omega_1 - \omega_{11} \times 7| \le \xi \\
&|\omega_1 - \omega_{12} \times 8.5| \le \xi \\
&|\omega_2 - \omega_{10} \times 5.5| \le \xi \\
&|\omega_3 - \omega_{10} \times 4.5| \le \xi \\
&|\omega_4 - \omega_{10} \times 3.2| \le \xi \\
&|\omega_5 - \omega_{10} \times 4| \le \xi \\
&|\omega_6 - \omega_{10} \times 5| \le \xi \\
&|\omega_7 - \omega_{10} \times 3.4| \le \xi \\
&|\omega_8 - \omega_{10} \times 3| \le \xi \\
&|\omega_9 - \omega_{10} \times 2.3| \le \xi \\
&|\omega_{11} - \omega_{10} \times 3.5| \le \xi \\
&|\omega_{12} - \omega_{10} \times 2| \le \xi \\
&\sum_{j=1}^{n} \omega_j = 1 \\
&\omega_j \ge 0 \text{ for all j}
\end{aligned}
\tag{3}
$$

Solving this model, we obtain the optimal value $\xi^* = 0.069$, and the consistency ratio is 0.013, which is less than its associated threshold [].

Table 6
Weight of criteria in each scenario and optimal weight of criteria

Scenario / Criteria	S 1	S 2	S 3	S 4	Optimal weight of criteria
C1	0.34	0.062	0.3	0.125	0.2164
C2	0.1	0.058	0.083	0.075	0.0803
C3	0.065	0.342	0.062	0.193	0.1667
C4	0.055	0.066	0.051	0.105	0.0650
C5	0.063	0.098	0.052	0.144	0.0835
C6	0.082	0.079	0.07	0.05	0.0739
C7	0.056	0.057	0.057	0.065	0.0579
C8	0.051	0.05	0.067	0.054	0.0544
C9	0.05	0.03	0.12	0.043	0.0570
C10	0.03	0.052	0.053	0.041	0.0429
C11	0.06	0.055	0.048	0.073	0.0581
C12	0.048	0.051	0.037	0.032	0.0443

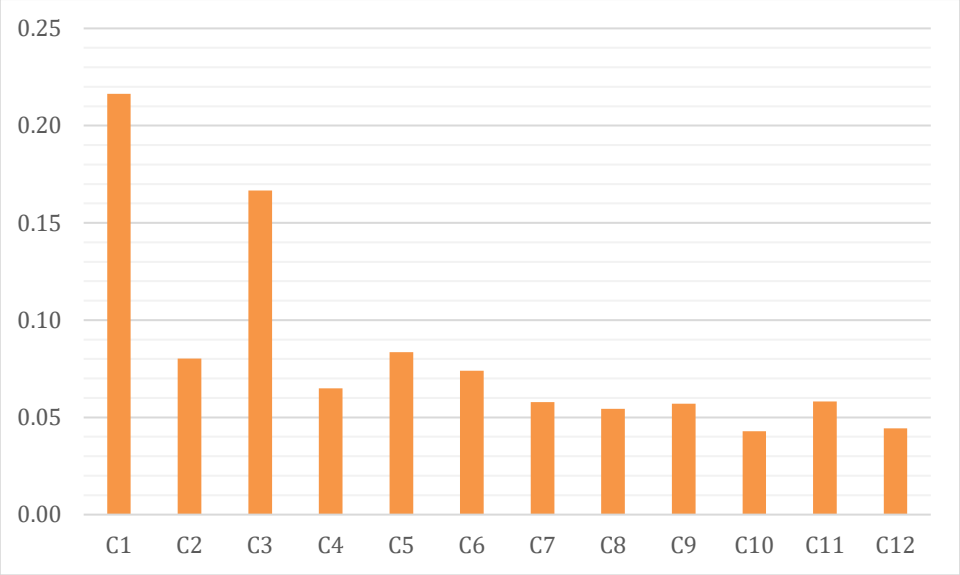

Fig 2. Optimal Weight of Criteria

To obtain the final weight of the alternatives, the weights of all alternatives in each criterion were obtained separately. The matrix multiplication of these weights with the final weight of the criteria gave the final weight of the alternatives (see Table 7). Figure 3 shows the final weight chart of the alternatives.

Table 7
Final Weight and Final Ranking of Alternatives

Criteria	A1	A2	A3	A4	A5	A6	A7
C1	0.29	0.23	0.12	0.036	0.099	0.11	0.115
C2	0.2	0.245	0.123	0.113	0.067	0.082	0.17
C3	0.123	0.165	0.231	0.143	0.08	0.098	0.16
C4	0.132	0.153	0.112	0.174	0.173	0.137	0.119
C5	0.221	0.182	0.132	0.153	0.184	0.078	0.05
C6	0.163	0.142	0.251	0.098	0.073	0.137	0.136
C7	0.152	0.193	0.18	0.125	0.08	0.11	0.16
C8	0.29	0.143	0.117	0.084	0.066	0.14	0.16
C9	0.234	0.14	0.12	0.066	0.053	0.093	0.294
C10	0.16	0.21	0.126	0.12	0.11	0.15	0.124
C11	0.194	0.2	0.154	0.13	0.07	0.09	0.162
C12	0.2	0.13	0.17	0.09	0.07	0.08	0.26
Final Weight of Alternatives	0.203	0.186	0.157	0.104	0.095	0.107	0.148
Final Ranking of Alternatives	1	2	3	6	7	5	4

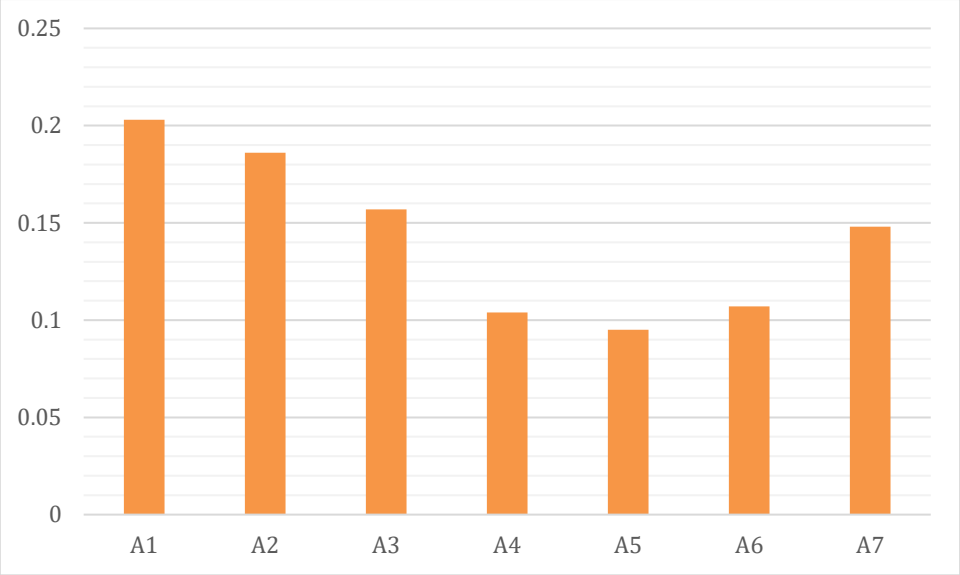

Fig 3. Optimal Weight of Alternatives

5. Conclusions

This research aimed to examine and rank AI-driven strategies to optimize the health tourism supply chain. To achieve this goal, 12 critical criteria, recognized for their substantial influence on enhancing efficiency and service quality within the health tourism domain, were systematically identified. Based on four different scenarios, the final weight of these criteria was determined. These scenarios include "Rapid growth of international health tourism and increasing global competition" (S1), "Development of artificial intelligence technologies and complete digitalization of the supply chain" (S2), "Political and health crises in major health tourism destinations" (S3), and "Increasing patient awareness of personalized services and medical travel experience" (S4).

The findings demonstrate that "Quality and Advancement of Medical Services and Equipment" (C1), with a weight of 0.2164, holds preeminent significance in this intricate process. Following closely, "Integrated Digital, Transportation, and Accommodation Infrastructure" (C3) secured the second position with a weight of 0.1667, while "Data Analytical Capacity and Smart Decision-Making" (C5) ranked third at 0.0835. Furthermore, other noteworthy criteria such as "Competence and Credibility of Medical Staff" (C2), weighing 0.0803, and "Digital Patient Experience and Interaction Management" (C6), at 0.0739, were positioned fourth and fifth, respectively, underscoring their crucial contribution to elevating healthcare service delivery processes.

Based on the optimal and definitive criteria weights, the alternatives were subsequently ranked. The foremost priority emerged as "Patient Data Management and Analysis" (A1), carrying a weight of 0.203. This alternative empowers medical institutions to meticulously collect and analyze patient data through sophisticated AI technologies, thereby facilitating the provision of superior quality healthcare services. Through the analysis of this data, clinicians will be equipped to render more precise diagnoses and deliver personalized treatments, which can profoundly enhance the overall patient experience.

The second alternative, "Healthcare Supply Chain Optimization" (A2), weighted at 0.186, is designed to refine processes and mitigate operational costs within health tourism. By strategically managing supply and demand, this alternative enables accurate forecasting of treatment requirements and necessary resources, simultaneously streamlining coordination among all

stakeholders, including hospitals, physicians, and accommodation providers. This process is instrumental in minimizing resource and time wastage, ultimately fostering improved service outcomes for patients. The third alternative, “Customer Experience and Digital Services” (A3), with a weight of 0.157, accentuates the critical importance of patient engagement with healthcare services. Leveraging advanced technologies such as customer experience management systems and conversational agents, patients can readily access information, receive consultations, and utilize services. Such seamless interaction is poised to significantly enhance patient satisfaction with the treatment journey and exert a considerable influence on attracting new clientele.

Considering the key criteria identified in this research, the amelioration of health tourism fundamentally necessitates a concerted focus on the quality of services and the advancement of medical equipment. Healthcare institutions must proactively invest in cutting-edge technologies and continually elevate the caliber of medical equipment. This strategic imperative will contribute to enhanced treatment efficacy and cultivate greater patient trust. Concurrently, the development of integrated digital infrastructures encompassing transportation and accommodation must be prioritized to facilitate the streamlined orchestration of services. Digital infrastructures further possess the potential to foster greater synergy between disparate healthcare and tourism domains, thereby culminating in the provision of more comprehensive and harmonized services.

Based on the results of this research, administrators are strongly advised to implement robust systems for the collection and analysis of patient data, enabling the delivery of highly personalized and patient-centric services. The optimization of the treatment supply chain also warrants diligent attention to reduce resource and time inefficiencies, thereby facilitating the patient treatment process. Furthermore, elevating the digital dimension of customer experience by strategically employing technologies such as conversational agents and mobile applications can profoundly enhance patient engagement with healthcare services. These collective actions are poised to significantly elevate service quality and foster a positive patient experience within the health tourism industry. Overall, these alternatives, by presenting innovative and intelligent solutions, contribute substantially to addressing patient needs and elevating the quality of services in the health tourism sector.

Author Contributions

Conceptualization, KM.J, M.S., F.K., S.R., and S.K.; methodology, M.S., F.K., and S.K.; software, F.K., and S.R.; validation, KM.J, M.S., and S.R.; formal analysis, KM.J; investigation, F.K., and S.K.; resources, S.R.; data curation, S.R., and S.K.; writing—original draft preparation, KM.J, and M.S.; writing—review and editing, S.R., and S.K.; supervision, S.K. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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