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Design of a Green Dental Tourism Supply Chain Network: A Case Study of Qom Province

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Abstract

Supply chain network design entails strategic decisions that critically shape the operational framework of a supply chain. The purpose of this study is to develop and optimize a green dental tourism supply chain network using metaheuristic algorithms. This applied research combines field surveys and library-based methods for data collection. Empirical data were obtained from dental clinics and three- and four-star hotels in Qom Province, forming the basis for model implementation. The proposed network integrates environmental considerations and seeks to minimize total supply chain cost. A multi-objective optimization model is formulated and solved using two algorithms: NRGA (Non-dominated Ranked Genetic Algorithm) and NSGA-II (Non-dominated Sorting Genetic Algorithm II). The comparative analysis demonstrates that NSGA-II achieves more efficient solutions and superior ranking of Pareto-optimal fronts across the model's multiple objectives. This study advances the design and optimization of sustainable dental tourism supply chains, providing practical insights for policymakers and industry stakeholders aiming to promote environmentally responsible and economically viable tourism services.

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Introduction

Tourism is one of the world's largest industries and a major source of foreign exchange revenue for many governments. Health tourism, a vital sub-sector of this industry, has emerged as a global phenomenon that enables patients to access high-quality medical services at lower costs and with shorter waiting periods (Lashkarizadeh, 2007). It involves travel by individuals seeking specific medical procedures while also enjoying traditional tourism activities (Nikrafta & Hosseini, 2017). Health tourism fosters socio-cultural exchange and strengthens international collaboration and communication. Given the globalization of trade in healthcare services, health tourism now serves as one of the main drivers of competitive advantage for countries with strong medical sectors.

One specialized form of supply chain is the health and medical tourism supply chain. Managing this chain is essential for maintaining domestic tourism performance and sustaining it during economic or political crises. Effective logistics management ensures a smooth flow within the supply chain, which is crucial for hospitals and tourism companies alike. Efficient tourism logistics positively affect organizational performance, emphasizing the need for managers to focus on value chain optimization to achieve higher customer satisfaction (Setthachotsombut & Sua-iam, 2020). Trust, commitment, and interdependence enhance coordination and information sharing within the medical tourism supply chain, improving overall efficiency and financial outcomes (Lee & Fernando, 2015). Sound financial management is a cornerstone of integration in this supply chain (Chung & Chang, 2018). Government financial incentives for private enterprises can lower operational costs in medical centers and accommodations, fostering better supply chain alignment and increased profitability. Advertising also substantially influences chain profitability. When tourists travel with companions, supply chain shortages decrease, and profits rise (Ahmadimanesh et al., 2019). Tourist numbers, medical center capacity, and stakeholder profits are key determinants of the network's overall financial success.

Applying open innovation principles encourages stakeholder collaboration, knowledge exchange, and joint problem-solving, leading to supply chain improvement (Dinkoksung et al., 2023). Economic and environmental objectives often conflict; improving one may compromise the other (Ghalandari et al., 2023). Green supply chain management integrates environmental concerns throughout all supply chain processes to enhance sustainability (Faris & Maan, 2020). Green practices encompass design, procurement, production, packaging, logistics, and reverse logistics (Tseng & Chiu, 2012). Studies show that poor environmental performance often stems from prioritizing economic goals and the high cost of waste management associated with reverse logistics (Faris & Maan, 2020).

Dental Tourism (DT) is a rapidly expanding segment of health tourism in which patients travel internationally for dental care (Conti et al., 2014). Factors influencing investment and destination choice include clinic reputation, certifications, dentist qualifications, and treatment costs (Ahmadimanesh et al., 2021). Tourists are primarily motivated by service quality, information accessibility, and cost savings (Jaapar et al., 2017). Service quality involves professional conduct, facility standards, and clinical care, while information access relates to details about services and costs. Cultural compatibility, affordability, and supportive service systems also contribute to patient satisfaction (Akbar et al., 2021). Dental tourism providers should train their staff in language skills and service excellence and ensure a welcoming, stress-free clinic environment. Satisfaction is further influenced by affordability, personal referrals, testimonials, efficient treatment, and local hospitality (Wongkit & Boonyanmethaporn, 2020).

Nevertheless, dental tourism presents ethical challenges concerning patient autonomy, safety, continuity of care, informed consent, and professional responsibility (Conti et al., 2014). Dentists may face legal and ethical dilemmas in providing follow-up or restorative treatments to returning patients. There are also concerns that dental tourism can reduce local clinic income and erode public trust in domestic dental services (Lovelock et al., 2018). In some cases, inadequate treatment and lack of follow-up care lead to patient dissatisfaction and ethical complications within this evolving global industry. Iran possesses exceptional potential to emerge as a leading hub for health tourism in the region, supported by its rich cultural heritage, diverse natural resources, and specialized human expertise. The holy city of Qom, positioned at the crossroads of major provincial routes and in close proximity to the capital, enjoys unique advantages in medical and tourism infrastructure, particularly in the field of dental tourism. The main objective of this study is to design a green dental tourism supply chain network in Qom Province. The research introduces an innovative approach by integrating environmental considerations into the dental supply chain, transforming it into a green supply chain. A bi-objective mathematical model is proposed: the first objective minimizes overall supply chain costs, while the second minimizes carbon dioxide emissions.

Health tourism, as a key sub-sector of the broader tourism industry, involves travel for medical services, preventive care, and rehabilitation outside one's country of residence. It contributes to employment, income growth, infrastructure development, public health promotion, and cultural exchange (UNWTO, 2019). Health tourism encompasses diverse services such as medical and dental treatments, cosmetic surgeries, traditional medicine, rehabilitation, and elderly care. Motivations range from seeking affordable, high-quality medical services and specialized expertise to combining treatment with recreation and leisure. Structurally, the healthcare tourism system includes health tourism and medical tourism (Asadi & Daryaei, 2011).

From an economic perspective, health tourism operates as an industry influenced by service demand, treatment costs, destination competition, and local economic impacts (Gössling et al., 2012). Its management dimension focuses on planning, organizing, and controlling operational activities—especially marketing, branding, service quality, and tourist satisfaction. Governments are deeply involved in health tourism management since the sector strengthens economic performance, global visibility, and international reputation (Kliuchnyk et al., 2023).

From a sociological standpoint, health tourism shapes social interactions and lifestyles, emphasizing equitable benefit distribution and the protection of local cultural identity (Sharpley, 2018). Psychologically, it examines tourists' motivations, satisfaction levels, and the mental health effects of travel and treatment (Gössling et al., 2020).

One key configuration within this field is the Health Tourism Supply Chain (HTSC), which enhances a destination's capacity to offer high-quality, cost-effective services—thereby attracting international patients, particularly to developing countries (Loh, 2015). Although HTSC and Medical Tourism Supply Chain (MTSC) are conceptually related, MTSC is often understood as a complex network involving various stakeholders: patients, healthcare providers, insurance firms, travel agencies, and other intermediaries. Its performance depends on demand dynamics, service supply, multi-actor collaboration, and technological integration (Fernando & Khei, 2015).

Logistics management underpins this system by optimizing cargo distribution, route design, vehicle utilization, and transport efficiency. Governmental involvement in establishing robust logistical infrastructure is crucial for tourism growth. Furthermore, in today's dynamic market environment, the adoption of innovative technologies tailored to evolving conditions generates strong competitive advantages (Kazakov et al., 2023).

A green supply chain refers to a network that prioritizes environmental initiatives and sustainability practices (Soleimani et al., 2017). In recent decades, the term green supply chain has emerged from the combination of "green" and "supply chain," denoting the integration of environmentally conscious policies throughout supply chain operations. This approach emphasizes pollution reduction and the mitigation of environmental issues at both individual and organizational levels (Zhu et al., 2007). Evidence suggests that environmental concern and tourists' intentions regarding sustainable travel strongly and positively influence environmentally responsible tourism behavior (Ibnou-Laaroussi et al., 2020). Green tourism, in turn, promotes environmental preservation and socio-cultural benefits within local communities (Anh et al., 2024).

Health tourism comprises several branches. Medical tourism focuses on complex and specialized medical treatments (Gössling et al., 2012), whereas wellness tourism involves short-term, preventive, and outpatient services promoting health and well-being through activities such as hydrotherapy, yoga, and meditation. Dental tourism, as a distinct branch, refers to patients traveling abroad to access dental care. This form of tourism is particularly attractive due to lower treatment costs, high-quality services, and the added leisure benefits of travel (Gössling et al., 2012). Typical treatments include examinations, scaling, restorations, extractions, implants, orthodontics, and other dental procedures (Su & Hsu, 2013).

Fathi et al. (2016) developed a closed-loop supply chain model incorporating environmental factors. Using library research and expert questionnaires, they proposed a fuzzy multi-objective mixed-integer programming model aimed at minimizing cost, environmental impact, and delivery time.

Conti et al. (2014) analyzed ethical concerns in dentist–patient relationships within dental tourism, while Lee and Fernando (2015) examined factors influencing the performance of Malaysia's medical tourism supply chain. Their findings illustrate how collaboration and stakeholder coordination shape the supply chain's effectiveness.

Seles et al. (2016) explored how institutional pressures can intensify the green bullwhip effect, and Ferreira et al. (2017) investigated the link between environmental management maturity and the adoption of green supply chain practices. Their multi-case analysis in Brazil produced a framework for assessing green supply chain maturity. Rahman and Zailani (2017) evaluated the effectiveness and feasibility of the Muslim-friendly medical tourism supply chain in Malaysia.

Jaapar et al. (2017) studied dental tourists' motivations and satisfaction levels in Malaysia through surveys conducted across twelve clinics. Romão et al. (2017) analyzed wellness tourism development in Hokkaido, Japan, using multi-criteria decision-making and strategic choice analysis. Similarly, Lovelock et al. (2018) examined dentists' experiences in dental tourism, identifying scenarios for diversifying healthcare services toward international markets. Chung and Chang (2018) designed a framework to evaluate sustainability strategies in Asian medical tourism supply chains using Delphi and Analytic Network Process (ANP) methods.

Mathematical modeling studies have also expanded this field. Ahmadimanesh et al. (2019) developed a dental tourism supply chain model for six cities in Iran's Mazandaran Province to optimize medical center location, service allocation, and capacity, balancing profit and efficiency. Their model connected three key supply chain components: tourists (demand), medical centers (service providers), and accommodation facilities (support centers).

Setthachotsombut and Sua-Iam (2020) analyzed tourism value chain management in Thailand, while Ibnou-Laaroussi et al. (2020) assessed the influence of green tourism practices on international tourist behavior. Wongkit and Boonyanmethaporn (2020) presented field insights on dental tourism in Thailand, highlighting provider–patient interaction patterns. Akbar et al. (2021) examined how information access, service quality, cost savings, and cultural alignment affect dental tourist satisfaction. Ahmadimanesh et al. (2021) then used hybrid MCDM methods—DANP and VIKOR—to prioritize investment sites for dental tourism.

Kazakov et al. (2023) focused on logistics management in health resorts, emphasizing digital infrastructure development for performance enhancement. Dinkoksung et al. (2023) applied an open innovation approach to optimize profitability within medical and wellness tourism supply chains, whereas Chowdhury et al. (2023) explored resilience strategies under extreme disruptions using the Dynamic Capabilities View and fuzzy-set qualitative comparative analysis. Dev (2023) used wellness tourism initiatives to empower women in developing economies. Anh et al. (2024) further advanced green tourism research by modeling profitability optimization for integrated medical and wellness services—combining health assessment, dentistry, beauty, and spa care to enable sustainable supply chain cooperation among industry stakeholders.

Materials and Methods

Given that this study aims to design a green dental tourism supply chain network in Qom Province, it is categorized as applied research in terms of its objectives. Based on the type of data, the research is quantitative, and regarding its data collection approach, it is classified as descriptive research. Both field and library-based methods were employed for data collection. Qom stands as one of Iran's primary religious tourism destinations, and in recent years, increasing attention has been directed toward developing health tourism in this city. Although limited infrastructure—particularly in the accommodation sector—was previously one of Qom's main challenges, current observations indicate that the demand from health tourists visiting Qom and Mashhad is now nearly equivalent. This city holds significant potential due to its strategic geopolitical position, logistical advantages, and qualified workforce (Figure 1).

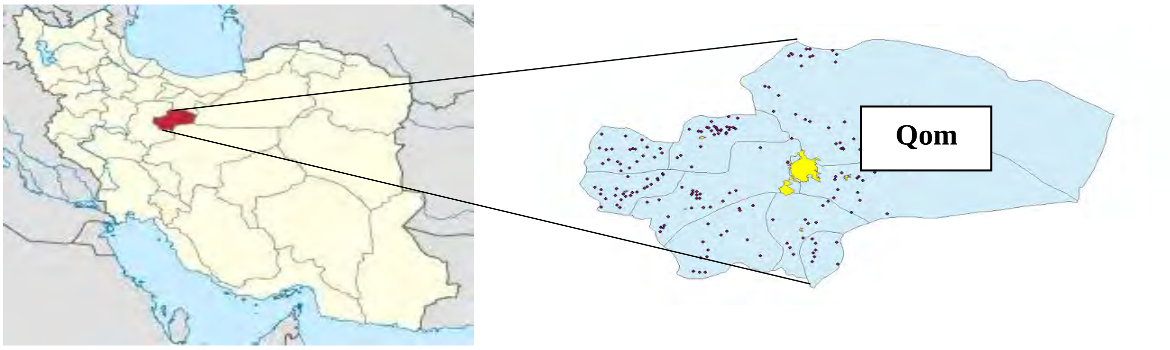

Figure 1. Location of Qom province and city

In this study, the required data were gathered through field research conducted in dental clinics and three- and four-star hotels located in Qom Province. These data were subsequently applied in the model-solving process. The case study encompasses three key components: medical service providers (clinics), three- and four-star hotels, and customer groups. Specifically, seven treatment centers were selected to represent dental service providers, while six hotels were identified for accommodating dental tourists within Qom Province (Figure 2).

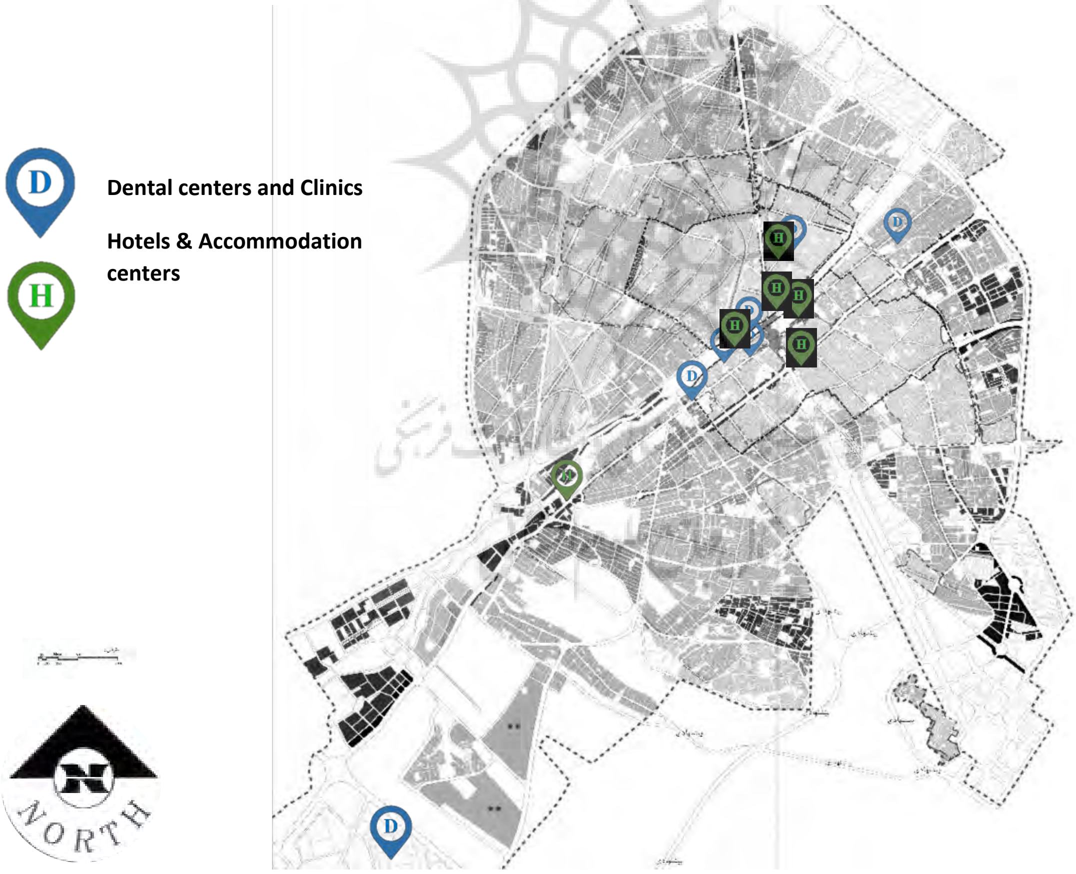

Figure 2. Location of candidate dental centers and hotels in the city

There are three types of dental services and two quality levels for hotels. The three types of dental services that have been most popular with tourists include oral surgery and dental implants, dental restoration, and orthodontics. The names of the selected treatment centers and hotels in Qom province are provided in Table (1) and Table (2), respectively.

Table 1. Dental clinics and centers

Row	Dental Clinics and Centers Name
1	Salamat Dental Clinic
2	Hakim Dental Clinic
3	Mehregan Dental Clinic
4	Sina Dental Clinic
5	Mina Dental Clinic
6	Pardis Dental Clinic
7	Quran and Etret Dental Clinic

Table 2. Hotels and accommodation centers

Row	Name of hotels and accommodation centers
1	Qom International Hotel
2	Raspina Hotel
3	Khordish Hotel
4	Olympic Hotel
5	Mahsan Hotel
6	Parsia Hotel

In this research, a three-echelon forward supply chain is considered. These echelons include customers, accommodation centers (hotels), and treatment centers (clinics). For the design of the proposed supply chain, it is assumed that tourists travel to another country to receive their dental services. The destination country should respond to the demand of tourists by providing suitable accommodation and treatment centers and generating income through this. In the destination country, there are a number of candidate accommodation and treatment centers that require start-up costs to continue their operations. The final capacity of the treatment centers is considered as a decision variable. Therefore, based on the existing demand, it is determined whether the capacity of existing services will be increased, or new services will be added by incurring specific additional costs, or there will be no capacity increase in the model. The two main objectives of the proposed model are to minimize the total costs of the supply chain and to minimize greenhouse gas emissions, respectively. The proposed dental tourism supply chain model is presented in Figure (3).

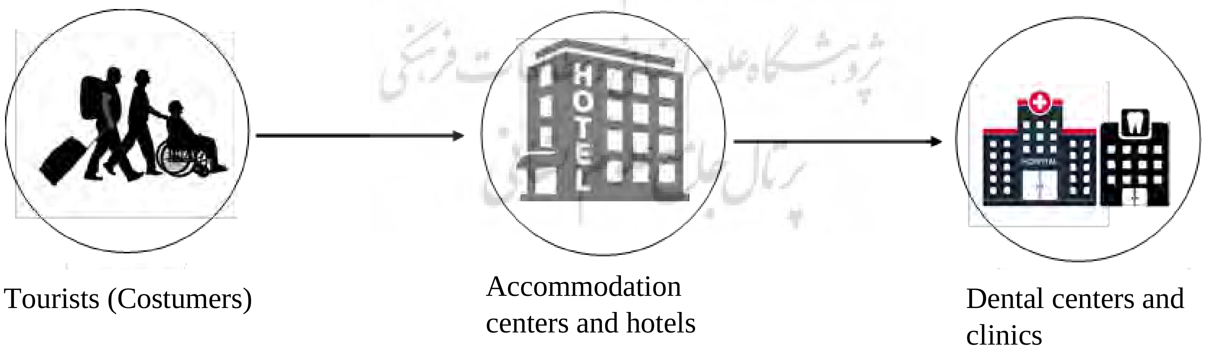

Figure 3. Proposed green supply chain network

In this section, the mathematical modeling of the problem under investigation, which includes symbols (Table 3), parameters (Table 4), variables (Table 5), objective functions, and constraints of the problem (Table 6), will be presented.

Table 3. Problem sets

Set of customers	$\boldsymbol{i = 1.2..3. \ldots}$
Set of Dental services	$k = 1.2..3. \ldots$
Set of potential locations for residential centers	$j = 1.2..3. \ldots$
Set of potential locations for medical centers	$m = 1.2..3. \ldots$
Set of quality levels of potential residential center locations	$z = 1.2..3. \ldots$
Set of dental services	$f = 1.2..3. \ldots$
Set of potential options for transportation between centers	$h = 1.2..3. \ldots$

Table 4. Problem parameters

Fixed cost of constructing a residential center j	$\boldsymbol{FC_j}$
Fixed cost of constructing a residential center m	FCC_m
Cost of expanding the capacity of dental services k in a medical center m	TO_{km}
Cost of launching a new capacity of dental services k in a medical center m	TC_{km}
Number of days required to receive a dental service set f	NE_f
Attendance coefficients of customer set i	CK_i
If dental services k are initially provided by medical center m, it is equal to 1, if this service is provided by capacity expansion it is equal to 0 and otherwise it is equal to -1	TP_{km}
Demand rate of customer set i for dental services f	DE_{if}
Initial capacity of medical centers m for dental services k	CA_{mk}
Additional capacity of dental services k in medical center m	CB_{km}
Capacity of residential center j	CA_{sj}
Maximum allowed number of potential medical centers m for dental services k	MAX_{mk}
Minimum demand rate of customer set i that must be met	MN_i
Carbon dioxide emissions when constructing potential medical centers m	CO_m
Carbon dioxide emissions when constructing potential residential centers j	CD_j
Maximum number of residential centers to be constructed	AB
Cost of moving patients from residential center j To medical center m	TCK_{jm}
If residential center j has quality level z, it is equal to 1	QU_{Jz}

Table 5. Problem variables

The final capacity of medical center m for dental service k	$\boldsymbol{QA_{mk}}$
The additional capacity developed for dental service k in medical center m	QD_{km}
The satisfied demand of patients with dental service set f among customers i	QF_{fi}
The number of patients with dental service f among customers i who are assigned to residential centers j.	QC_{fij}
The number of patients with dental service k who are transferred from residential centers j to medical centers m by means of transportation h and assigned.	QB_{kjmh}
If medical center m is built, it is 1, otherwise it is 0.	QE_m
If residential center j is built, it is 1, otherwise it is 0.	QG_j
If dental service k is newly provided by medical center m, it is 1, otherwise it is 0.	IK_{km}
If transportation h is selected to transfer patients from residential centers j to medical centers m, it is 1, otherwise it is 0.	XY_{hjm}

$$Min\, z_1 = \sum_j (FC_j * QG_j) + \sum_m (FCC_m * QE_m) + \sum_k \sum_m (TO_{km} * QD_{km}) + \sum_k \sum_m (IK_{km} * TC_{km}) + \sum_h \sum_k \sum_j \sum_m (QB_{kjmh} * TCK_{jm}) \quad (1)$$

$$\text{Min}\, z_2 = \sum_m (QE_m * CO_m) + \sum_j (QG_j * CD_j) \quad (2)$$

Table 6. Problem constraints

$\sum_{j} \boldsymbol{QG_j} \leq \boldsymbol{AB}$		(3)
$\sum_{h} XY_{hjm} \leq 1$	$\forall\, j.m$	(4)
$XY_{hjm} \leq \sum_{k} QB_{kjmh}$	$\forall\, h.j.m$	(5)
$\sum_{k} QB_{kjmh} \leq M * XY_{hjm}$	$\forall\, j.m.h$	(6)
$IK_{km} \leq QE_m$	$\forall\, k.m$	(7)
$IK_{km} + \lvert TP_{km} \rvert \leq 1$	$\forall\, k.m$	(8)
$\sum_{j}\sum_{h} QB_{kjmh} \leq M * \left[\frac{IK_m + TP_{km+1}}{2}\right]$	$\forall\, k.m$	(9)
$\sum_{k}\sum_{j}\sum_{h} QB_{kjmh} \leq M * QE_m$	$\forall\, m$	(10)
$QF_{fi} \leq DE_{if}$	$\forall\, i.f$	(11)
$\sum_{k}\sum_{j}\sum_{m}\sum_{h} (QB_{kjmh} = NE_f * QF_{fi})$	$\forall\, i$	(12)
$QF_{fi} \geq MN_i * DE_{if}$	$\forall\, i.f$	(13)
$CB_{km} * Ik_{km} + CA_{mk} * TP_{km} + QD_{km} = QA_{mk}$	$\forall\, k.m$	(14)
$\sum_{j}\sum_{h} QB_{kjmh} \leq QA_{mk}$	$\forall\, k.m$	(15)
$QD_{km} \leq MAX_{mk} * \left[\frac{IK_{km} + Tp_{km+1}}{2}\right]$	$\forall\, k.m$	(16)
$\sum_{f}\sum_{i} QC_{fis} \leq M * QG_J$	$\forall\, j$	(17)
$\sum_{j}\sum_{z} QU_{jz} * QC_{fis} = CK_i * QF_{fi}$	$\forall\, i\,.f$	(18)
$QE_m\,.QG_j\,.IK_{km}\,.XY_{hjm} \in \{0.1\}$		(19)
$QC_{fis}\,.QD_{km}\,.QF_{fi} \geq 0$. عدد صحیح		(20)
$QB_{kjmh}\,.QA_{mk} \geq 0$		(21)

Relations (1) and (2) show the objective functions to minimize the total supply chain costs and minimize the amount of carbon emissions, respectively. Constraint (3) limits the maximum number of accommodation centers that have the potential to be established. Constraint (4) indicates that there is a maximum of one type of facility for transferring flow between facilities. Constraint (5) indicates that a product flow must be established between different facility centers for a means of transport to be selected. Constraint (6) ensures that there will be no transportation between locations that are not connected. It also states that flow is only allowed through active transportation options in the network. Constraint (7) states that selected treatment centers can increase the capacity of new medical services. Constraint (8) shows the relationship between current service provision and the ability to increase capacity for each treatment center. Constraint (9) indicates that the allocation of patients to treatment centers is possible only if that center can currently provide medical services or can provide medical services by increasing capacity. Constraint (10) ensures that patients are only assigned to selected medical centers. Constraint (11) specifies the maximum responsibility for the demand of each customer group for each set of dental services. Constraint (12) ensures that the allocation of patients is equal to the demand met for each medical service. Constraint (13) shows that a certain minimum rate of customer demand is met. Constraint (14) determines the capacity of each medical center for each medical service. Constraint (15) ensures that the allocation of patients to each medical center is proportional to the center's capacity. Constraint (16) determines how much each service can be increased if there is a need to increase the capacity of existing medical services. Constraint (17) ensures the allocation of tourists to selected accommodation centers. Constraint (18) indicates that the allocation of tourists is proportional to their demand and according to the requested quality level. Constraints (19) to (21) define the decision variables of the model.

Findings

Based on the studies conducted within the scope of this research, three types of dental services, seven clinics, and six hotels have been considered. With the approach of prioritizing each objective, the Pareto front outputs for 8 cuts and a maximum of 100 points in the solution space are shown in Table (7).

Table 7. Pareto point output based on the preference of the objective functions

Objective number	First objective value	Second objective value	Best value
First objective preference	18785698	1196	18785698
Second objective preference	19741855	988	988

In this research, the trial-and-error method and recommendations derived from related metaheuristic algorithm studies were employed to calibrate the algorithm parameters. In real-world optimization scenarios, most problems exhibit inherent complexities—such as non-convexity, non-linearity, and multi-modality—that significantly reduce the effectiveness of classical optimization approaches. Consequently, metaheuristic algorithms are adopted to address such challenges. Although these algorithms may not be grounded in rigorous mathematical proof, they are highly effective in achieving near-optimal solutions within a reasonable computational time. Among the various metaheuristic techniques applied to multi-objective optimization, two key algorithms have been utilized in this study: the Non-dominated Sorting Genetic Algorithm II (NSGA-II) and the Non-dominated Ranked Genetic Algorithm (NRGA). Given the Pareto-based, conflicting, and non-linear nature of the objectives in this research, these multi-objective metaheuristic algorithms were implemented to determine optimal weights for the model's objective functions.

The NSGA-II algorithm, recognized as one of the most fundamental and widely used methods for multi-objective optimization, operates through the following stages:

1. Initial population generation,
2. Fitness evaluation,
3. Non-dominated sorting according to Pareto dominance rules,
4. Crowding distance calculation to preserve diversity,
5. Selection,
6. Crossover and mutation operations,
7. Merging of parent and offspring populations, and
8. Population replacement to form the next generation.

The resulting parameter values for both algorithms are presented in Table 8, where mutation rate and crossover rate represent the percentage of the initial population chosen for their respective evolutionary operations.

Table 8. Algorithm parameters

Parameter	Value
Number of rounds (repetitions)	120
Initial population size	100
Crossover probability (rate)	0.8
Mutation probability (rate)	0.2

Given the absence of prior studies in this specific domain to benchmark the proposed model, the performance results of the NSGA-II algorithm were compared with those of the NRGA algorithm, as referenced in Daneshvar et al. (2019). To facilitate this comparison, several performance indicators were defined: Mean Ideal Distance (MID), Solution Diversity, Number of Pareto Solutions (NPS), and Computation Time (TIME). According to standard evaluation criteria and the Pareto-optimal solutions obtained from both algorithms, the comparative results are presented in Table 9. In this table, lower MID and TIME values reflect greater efficiency, whereas higher Diversity and NPS values indicate superior performance in generating well-distributed and numerous optimal solutions. As reported in the final row of Table 9, the NSGA-II algorithm demonstrates higher desirability with respect to solution Diversity, indicating stronger exploration capability across the Pareto front, while the NRGA algorithm exhibits better performance in computation time, achieving faster convergence. Overall, when assessing the relative effectiveness of the two algorithms, the Diversity criterion emerges as the most significant measure for evaluating comparative efficiency in multi-objective optimization.

Table 9. Calculation results of the two algorithms NRGA and NSGAII

Problem number	NRGA algorithms				NSGAII algorithms			
	TIME	Diversity	MID	NPS	TIME	Diversity	MID	NPS
	6.58	334226	564876	52	7.11	321776	52863	47
1	7.23	667545	239118	64	10.05	322765	389716	56
2	14.65	118902	560344	62	9.36	678910	409692	74
3	22.75	544799	321766	76	18.98	521109	254611	80
4	24.07	324655	566902	65	21.46	278995	176542	45
5	29.16	675386	432176	81	26.99	798002	514776	62
6	39.07	721164	308566	65	33.64	766392	389242	36
7	52.31	654887	766892	75	48.76	4566650	688901	42
8	82.61	6542761	656705	90	74.65	6548871	277601	71
9	87.16	4326657	487981	70	82.38	8079533	456189	66
total	365.59	14910982	4905326	700	333.38	22883003	3610133	579

Also, Figures (4), (5), and (6) show the comparison between the algorithms based on the aforementioned three criteria.

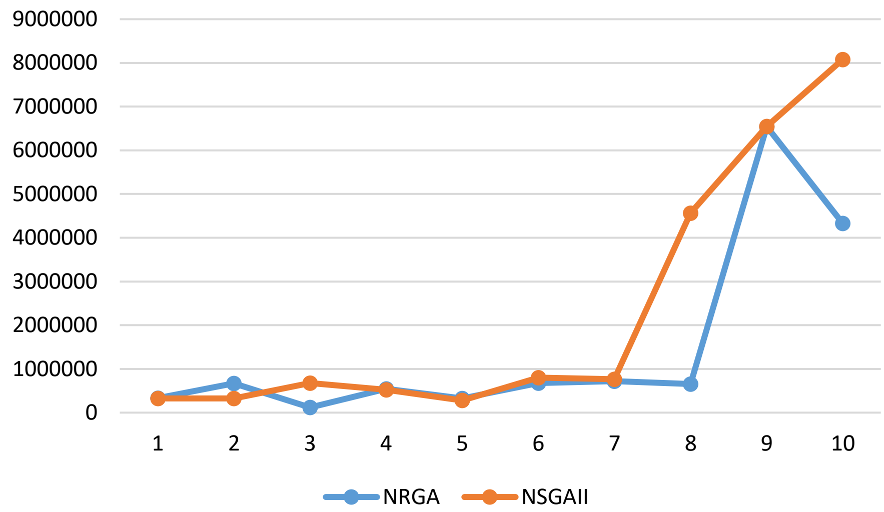

Figure 4. Comparison of NRGA and NSGAII algorithms in the Diversity criterion

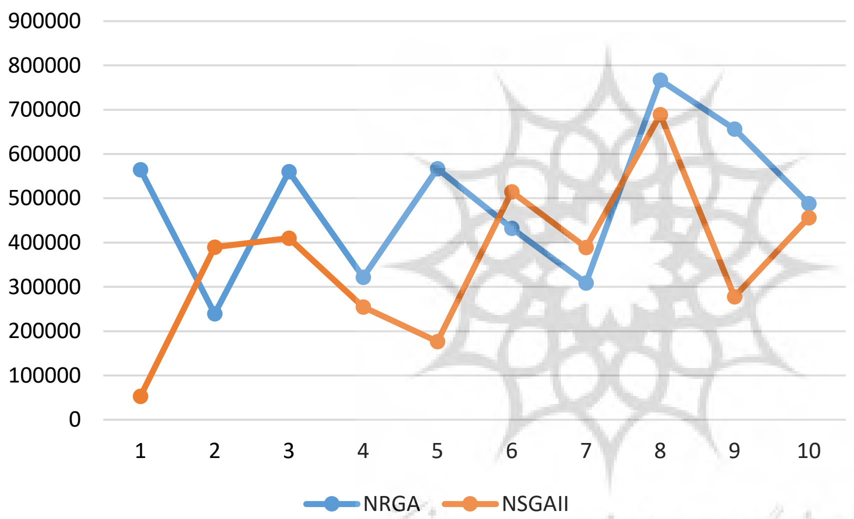

Figure 5. Comparison of NRGA and NSGAII algorithms in the MID criterion

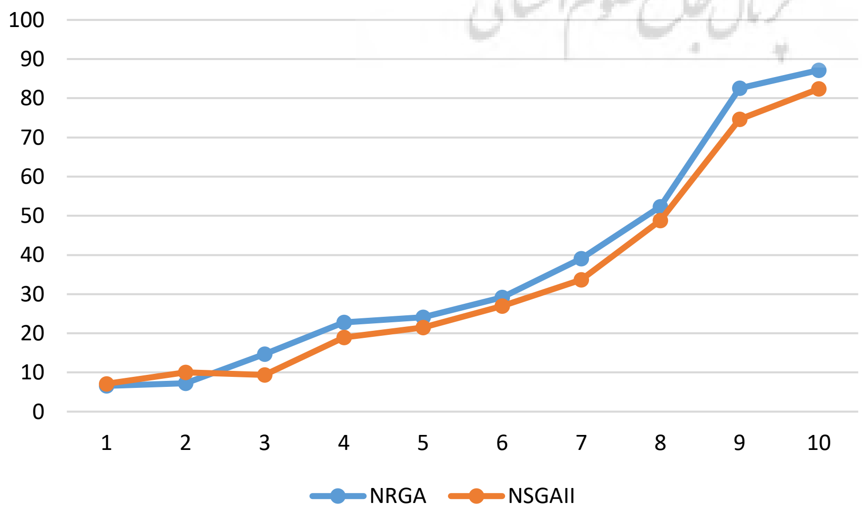

Figure 6. Graphical comparison of NRGA and NSGAII algorithms in TIME criterion

As shown in the figures, with more tests, the Diversity criterion increases after a while and reaches a significant level. Although the MID criterion has converged for both algorithms, the NSGA-II algorithm shows overall lower and more optimal values.

Discussion and Conclusion

In this research, the solution of a multi-objective model for a green dental tourism supply chain using evolutionary algorithms has been investigated. The tourism industry is recognized as a multi-dimensional industry that, unlike other economic sectors, consists of a range of service providers including travel and tour operators, air, rail, road, and sea transport agents, hotels, guesthouses and hostels, tourism attraction operators, restaurants, handicraft product stores, and other items of interest to tourists, most of whom operate in the private sector and compete in a free economic market. The supply chain of tourism services and products includes a wide range of service providers such as restaurants, handicrafts, tourism industry infrastructure, and other related services. By examining the strengths and weaknesses of a destination, evaluating issues related to sustainable tourism, and considering various aspects including contributing to environmental issues, economic development and the well-being of local communities, preserving cultural identity, respecting the rights of local communities and indigenous people, as well as environmental aspects including the development of sustainable transport, reducing, minimizing, and preventing pollution and waste generation, the tourism supply chain seeks practical solutions for the tourism industry and consumers. Supply chain network design encompasses crucial decisions that significantly impact the operational structure of the supply chain. Therefore, the aim of this research is to design a green dental tourism supply chain network and solve it using metaheuristic algorithms. The modeling of this chain is based on environmental considerations and the minimization of the total cost of the dental tourism supply chain. Due to the lack of similar research observed in the field of green dental tourism, metaheuristic algorithms have been used to evaluate the model. The model was solved using NRGA and NSGA-II metaheuristic algorithms, and the obtained results were compared. The research results show that the NSGA-II algorithm has higher efficiency and provides more accurate results. This research is the first to integrate the concepts of health tourism supply chain, dental tourism, and green tourism. Also, unlike a significant number of studies in this field, a quantitative and mathematical modeling approach has been chosen as the basis of the work. Specifically, compared to the research of Ahmadimanesh et al. (2019), environmental considerations have been taken into account, and a metaheuristic algorithm has been used. Given the vast scope of supply chain issues and considering the conditions and nature of real-world problems, some areas of these issues that can be considered by researchers in continuation of this research include:

- *Considering uncertainty for some supply chain parameters, for example, uncertainty in demand and cost.*
- *Minimizing the distance between clinics and accommodation centers.*
- *Using other metaheuristic algorithms to solve the problem.*
- *Providing an objective function entitled maximizing the social responsiveness of the dental tourism supply chain.*

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