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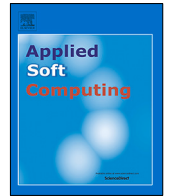
Ecotourism supply chain during the COVID-19 pandemic: A real case study

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ABSTRACT

The coronavirus (COVID-19) disease has caused serious and irreversible damage to the ecotourism industry, posing serious challenges to all parts of the ecotourism supply chain. The ecotourism supply chain is made up of various components, the most important of which are ecotourism centers. During these pandemic times, the primary concerns of these centers are to improve their deplorable economic conditions and retain customers for the post-coronavirus era. As a result, an investigation should be conducted to address these concerns and provide appropriate solutions to help them overcome the challenges that have emerged. To achieve the research goal, a bi-objective mathematical model for the ecotourism supply chain in an uncertain environment is developed, accounting for the effects of COVID-19. The first objective function minimizes the total cost of the supply chain, while the second maximizes customer satisfaction. The proposed mathematical model is solved using a fuzzy goal programming (FGP) method. A sensitivity analysis study is also carried out to examine the performance of some basic parameters. Furthermore, the model is tested in a real case study to determine its efficacy. Finally, some effective managerial insights are proposed to improve the situation of the centers during the pandemic.

1. Introduction

The tourism industry (TI) is the world's fastest and largest growing industry and is regarded as a critical tool for developing and improving economic conditions in many parts of the world [1]. To develop the TI and take advantage of its benefits, a thorough examination of all active and related elements is required. In other words, proper management of the members involved in the Tourism Supply Chain (TSC) is one of the most important key strategies for achieving these goals in any touristic destination [2]. The TSC includes travelers, travel agencies, advertisers and marketers of travel customers, hotels and their staff, airlines, airports, and people directly or indirectly involved as employees of various airports such as aircraft fuel suppliers [3]. The TSC also includes people in destination countries whose livelihoods are dependent on this industry and a few other related sub-sectors [4]. The TI is extremely vulnerable to external events such as natural disasters (floods, earthquakes, hurricanes, terrorism, and fires) and the spread of epidemic diseases such as SARS. Furthermore, the TI is an industry that is based on human-centered activities [5]. So, any disasters such as the spread of a pandemic disease or starting a war, or other natural disasters will result in stagnation and cause it to be damaged severely [6–8].

Ecotourism represents a new opportunity for developing countries to improve their TI [9]. Ecotourism has been introduced as a branch of tourism that consists of responsible trips to natural areas that preserve the environment and improve the lives of the local people [10,11]. One of the most important components of the ecotourism supply chain (ESC) is ecotourism centers (ECs). In the last few years, the spread of the coronavirus disease has greatly impacted ECs, particularly their economic situations. The spread of the coronavirus disease has had a significant impact on ECs, particularly their economic situations. As a result, studying the effects of coronavirus on the structure of these centers is critical for their survival and development in this condition [12]. Under normal circumstances (prior to the coronavirus outbreak), the centers provide some services such as food, souvenir, and accommodation centers in order to generate revenue, meet customer demands, and gain their satisfaction [13]. However,

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the ecotourism industry (EI) has been facing serious challenges as a result of the COVID-19 pandemic, as a result of which the World Health Organization (WHO) issued recommendations against traveling and crowding public places [14]. So, in such circumstances, the Owners and Managers (O&Ms) of the ECs should try to avoid further economic damage and unemployment while also attempting to retain their customers, which is their primary concern in the post-corona era. To address these critical issues, this paper presents a bi-objective mathematical model as well as useful managerial suggestions to assist the centers' O&Ms in making an appropriate decision and implementing a proper policy. The first objective function (OF) minimizes the total cost, while the second one maximizes customer satisfaction. COVID-19 outbreaks prompted the closure of foreign borders, the imposition of domestic travel restrictions, and the cancellation of the majority of flights. As a result, hotels and tourist attractions were also forced to close, causing significant damage to the TI [15]. Another critical point to remember is that during the COVID-19 pandemic, forecasting and estimating the amount of demand in the EI is incredibly. In this regard, the proposed model considers the demand parameter to be uncertain. To solve the model, first, an equivalent crisp model is presented. Then, the fuzzy goal programming (FGP) method is applied to solve the bi-objective model. Then, the fuzzy goal programming (FGP) method is applied to solve the bi-objective model. Iran is considered as one of the potential countries for ecotourism activities due to its numerous natural features and attractions. Therefore, to check the correctness and validity of the proposed model, a real case study in this country has been conducted.

Through this paper, we make significant contributions to the literature by studying the current conditions of the ECs during the pandemic and presenting some efficient and effective suggestions to improve their operational conditions, particularly their economic situations. What distinguishes our study from others is that it is the first to investigate the conditions of an active business in the EI during the COVID-19 pandemic and to make useful and effective suggestions to address these serious and pressing challenges. The goal of this study is to find answers to the following questions:

- What is the optimized value for each OF including cost and customer satisfaction?
- Which methodology should be used to solve the uncertainty problem?
- What is the final optimized quantity of the center's capacity for each type of service?
- By how much should the center increase its capacity for some of the services, if needed?
- What percentage of the customer demand of each group is met?
- Among the new services, which one is beneficial for the center to offer?

This paper has been presented as follows: Section 2 reviews and summarizes the available research on the effects of coronavirus disease on the TI. Section 3 describes the proposed model and method of solution. The case study is presented in Section 4. Section 5 discusses the input and output data, case study results, and sensitivity analyses. Section 6 makes recommendations and discusses some beneficial managerial insights. Finally, Section 7 provides a conclusion to the whole paper. Fig. 1 depicts the overall structure of the current study, including the main purpose of the research, the proposed mathematical model, solution method, and case study.

2. Literature review

Since the outbreak of the COVID-19 pandemic, a significant number of papers have been published that investigate and consider various aspects of the COVID-19's impacts on the tourism industry. In this section, we have attempted to research and summarize papers that were particularly pertinent to our current study. To accomplish this, we have reviewed articles that focus exclusively on tourism during the COVID-19 pandemic and covered topics such as the COVID-19 risk in tourism, disruption on tourism caused by the COVID-19, the TSC during the COVID-19, economic and social effects of the pandemic on tourism, tourist satisfaction and the COVID-19 pandemic, solution recovery for tourism during the COVID-19 pandemic, solutions for recovery amid the COVID-19 pandemic and other such issues.

Making proper quarantine-related decisions greatly aids governments in controlling and improving the dreadful conditions caused by COVID-19. Therefore, Altuntas and Gok [16] considered this issue in Turkey's domestic tourism (DT). In their research, they also used the DEMETL method and obtained the necessary data from TurkStat (a statistical institute in Turkey). One of the significant effects of the coronavirus disease on the TI is the serious economic damage. Pham et al. [17] investigated the economic aspect of inbound tourism during the disease. Therefore, they examined the economic aspect of inbound tourism during the disease. In order to conduct the analysis in a better way, they classified the economic effects of the disease into two categories: microeconomic effects and wide-ranging effects. Moreover, they employed specific tools and approaches for each category. Bhaskara and Filimonau [18] introduced organizational learning (OL), which is an effective way to combat the pandemic's effects on businesses in the TI. The researchers examined the effects of historical disasters on the OL in the TI and compared them with those of COVID-19. Kaushal and Srivastava [19] studied the effects of the COVID-19 pandemic on the tourism and hospitality industry (THI). First, they examined all the challenges caused by the pandemic for the THI and then offered all necessary industry-related learning from the beginning till the present. Besides, they also claimed that their research aids the development of the industry. One of the remarkable issues in the TI during the pandemic is to study its impact on the demand. Hence, Yang et al. [20] investigated this issue. Their findings revealed that some tourism sectors, such as the cultural and famous attractions, suffered more severe damages than others during this time. Furthermore, to examine tourism demand, they considered three items: economic level, foreign economic relations, and population density. Macao's economy is heavily dependent on the gambling industry (GI), and it is a major global hub for the GI. The coronavirus has severely impacted the TI, especially the GI in Macao, leading to awful economic conditions in the region. Therefore, Lim and To [21] researched this subject and presented helpful suggestions for the improvement of the GI in the region. Studying all the components of the supply chain is important in combating crises such as a pandemic. In this regard, González-Torres et al. [22] examined the TSC during the COVID-19 pandemic. They asserted that the epidemic reduced income for all elements of the TSC and claimed that the government, tour operators, and competitors of each TSC institution are crucial in managing the COVID-19 disruption. Spa tourism is one of the most important sections of the TI and is growing rapidly. Spain is one of the most popular countries for this form of travel, where the coronavirus outbreak has caused major issues. Thus, Pinos Navarrete and Shaw [23] attentively researched the current situation and provided effective remedies to resolve it and prepare for COVID-19. Marine Tourism (MT), like all other sectors of the TI, has suffered from the COVID-19 disease's consequences and obstacles. Therefore, King et al. [24] investigated the current condition
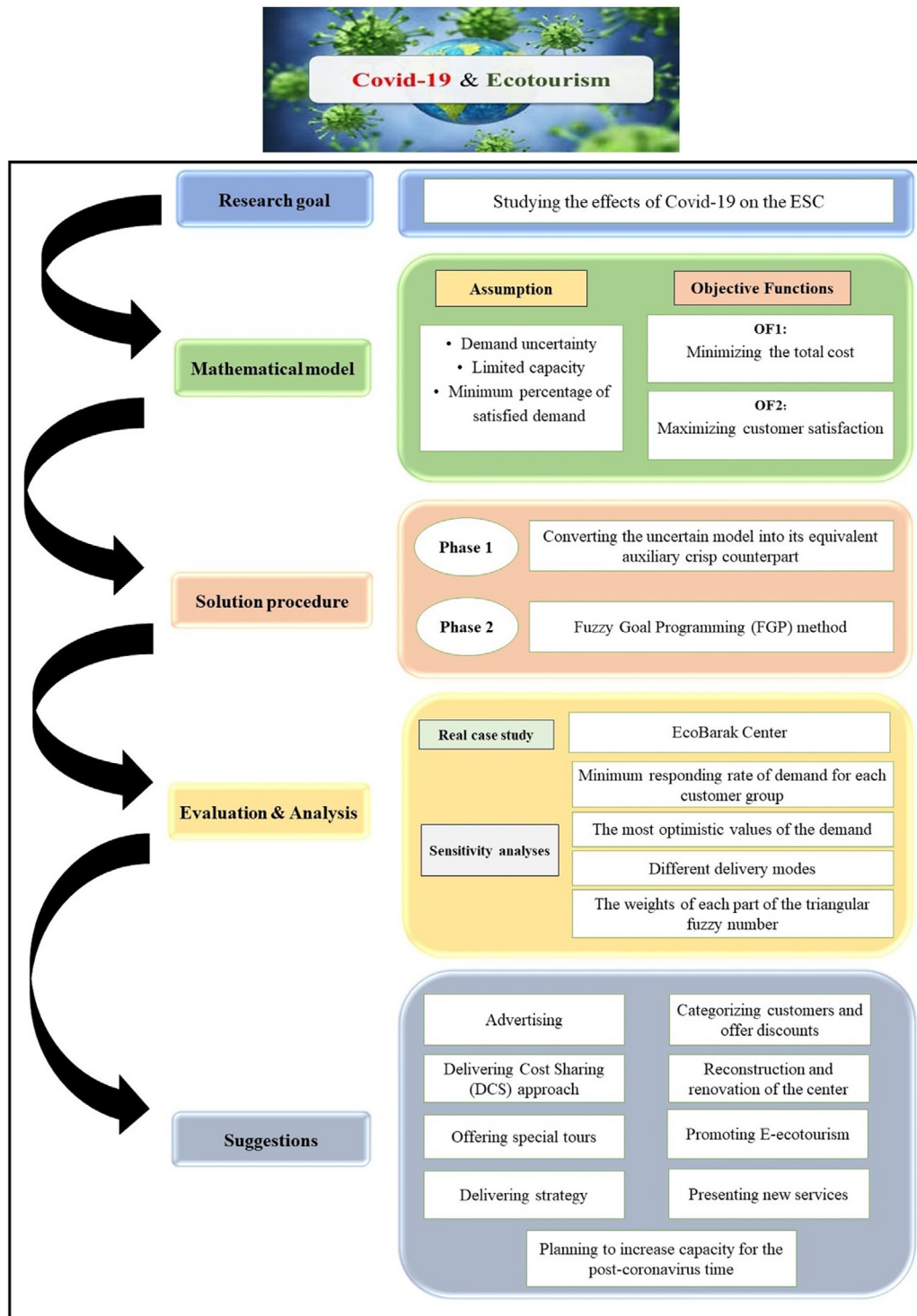
Fig. 1. The overall structure of the current research.

of the MT in Indonesia. They advised all the elements of the MT to use a resilient socio-ecological system to tackle the COVID-19 pandemic and any other similar potential crises. Haqbin et al. [25] investigated the state of small and medium-sized firms (SMEs), one of the TI's active participants, during the COVID-19 pandemic. They provided excellent recovery solutions to SMEs in order to improve their condition. The recovery strategies presented are organized into five categories: finance, marketing, operations, communication, and human resource strategies. In addition, they used the best-worst approach in their research to arrive at their conclusions. Arbulú et al. [27] investigated the condition of the DT in Spain during the COVID-19 pandemic. Their main concern was to relieve the pandemic crisis on the National Travel Industry (NTI) by improving the DT when the international tourism demand is fully or nearly lost. They also employed the value-at-risk method to evaluate the trend of demand in the NTI. Zhang et al. [26] examined the TI and its demand trend in Hong Kong during the COVID-19 pandemic. They first assessed the pandemic's impact on the TI and its demand, and then proposed recovery

Table 1
Concise information on the reviewed papers in the literature review section.

Author(s) name	Tourism fields	Main discussion	Tools, methods, or approaches	Case study
Altuntas and Gok [16]	DT	Economic situation	DEMATEL method	Turkey
Pham et al. [17]	Inbound tourism	Economic situation	The computable general equilibrium modeling technique	Australia
Bhaskara and Filimonau [18]	TI	OL	–	Bali province, Indonesia
Kaushal and Srivastava [19]	THI	Generally	–	India
Yang et al. [20]	TI	Tourism demand	–	China
Lim and To [21]	GI	Economic situation	ARIMA, correlation, and regression	Macao, China
González-Torres et al. [22]	TI	TSC and Economic disruption	–	Spain
Pinos Navarrete and Shaw [23]	Spa tourism	Economic situation	–	Spain
King et al. [24]	MT	Generally	–	Indonesia
Haqbin et al. [25]	TI	SMEs	Best-Worst method	–
Zhang et al. [26]	TI	Tourism demand	A combined approach	Hong Kong
Arbulú et al. [27]	DT	National travel demand	The value-at-risk method	Spain
Farzanegan et al. [28]	International tourism	Infected cases and death	Cross-country regression analysis	France, Italy, Spain, China, and the United States
Fong et al. [29]	TI	Generally	Online survey	Macao, China
Qiu et al. [30]	TI	Social cost	Willingness to pay model	Hong Kong, Guangzhou, and Wuhan
Carr [31]	TI	Indigenous people and tourism	–	New Zealand
Cheer [32]	TI	HF	–	–
Hong et al. [33]	The B&B industry	Tourist satisfaction	the importance-performance analysis	China
Hall et al. [34]	TI	Social and economic situation	–	–
Weed [35]	Sport and tourism	Social, economic, and health situation	–	Comparing the results in some countries

scenarios to help the TI improve its situation. They used a combination of econometric and judgmental methods in their research. Farzanegan et al. [28] studied the relationship between international tourism and the number of COVID-19-related deaths. They showed that the number of infected cases and deaths is higher in countries that are more advanced in international tourism. Fong et al. [29] examined the role of governments in controlling the spread of the coronavirus and improving the TI during the pandemic by using a conceptual model based in China. Due to the outbreak and spread of the coronavirus, activities related to tourism were significantly disrupted. Therefore, it is very important to examine the costs imposed on the TI. Thus, Qiu et al. [30], in their paper, used an evaluation method to assess the imposed costs by the coronavirus, especially the social cost in the TI. Carr [31] investigated the role of indigenous Maori citizens in the development of tourism in New Zealand during and after COVID. In this regard, he suggested that the government should provide support and resources to indigenous people in order to help them develop tourism. Cheer [32] identified three factors for developing a new concept as human flourishing (HF), tourism transformation, and coronavirus. The HF refers to the rational use of individual human potentials such as talents and abilities to achieve specific goals and objectives. Its goal is to strengthen the relationship between tourism and host communities. During coronavirus, the Bed and Breakfast (B&B) industry, like many other industries, had to encounter several challenges [33]. Therefore, Hong et al. [33] were the first to investigate the effects of coronavirus on tourist satisfaction and the B&B industry in China. Moreover, in their paper, an importance-performance analysis was used to present some useful suggestions for this industry

following the outbreak. A cross-disciplinary team comprised of tourism experts and health academics was formed to collaborate on coronavirus research. Hall et al. [34] investigated the TI during the coronavirus pandemic. In their paper, first, they explained the impacts and risks of pandemic diseases and then discussed the possibility of TI recovery. Weed [35] explored the relationship and role of the TI and sports in combating coronavirus. He advised researchers to conduct beneficial and effective investigations and research to improve the condition created as a result of the virus from an economic, social, and health perspective. Table 1 provides concise information about the papers reviewed in this section. The information listed includes the authors' names, the field of tourism, the component of tourism researched, the instruments and methodologies utilized in each study, and the case study.

2.1. Research problem and contribution

Based on the above literature review, it is clear that, despite the large number of recent publications that appear to analyze the impacts of the COVID-19 on tourism and offer ways to mitigate its consequences, there are still numerous gaps to be addressed. For example, it is evident that no study has been conducted to aid in the planning of tourist centers' operations using any of the decision-making tools. Therefore, the work in this paper will be a valuable contribution in this regard and, thus, fill this gap to support ecotourism centers and other structures with similar characteristics. Some of the major contributions of the current research are as follows:

- Studying and analyzing the effects of the COVID-19 pandemic on the ESC for the first time;
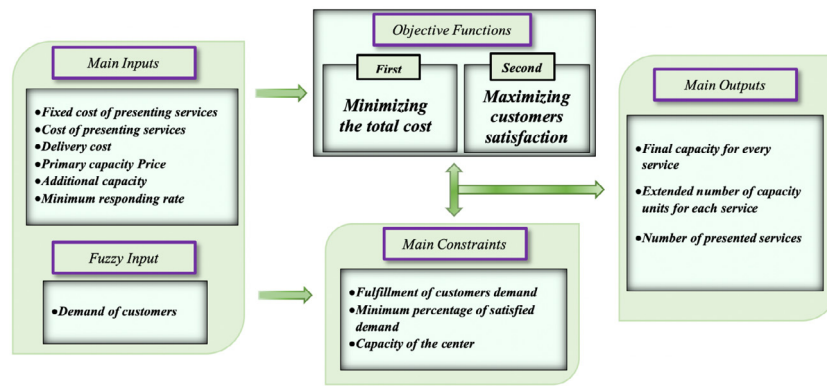
Fig. 2. Conceptual framework of the proposed mathematical model.

- Designing a mathematical model by considering demand uncertainty for the ESC during the pandemic;
- Applying a common and proper solution methodology, based on the literature review, to control for uncertainty and solve the mathematical model;
- Using a real case study to evaluate the proposed mode;
- Proposing useful and practical managerial suggestions for all activities in the ESC and discussing them.

3. The proposed mathematical model

As mentioned before, the EI and other aspects related to this industry have faced significant challenges. Hereupon, they struggle to resolve these issues, and it is clear that achieving this goal is impossible without conducting the essential research. Furthermore, the development and improvement of the EI are undeniably dependent on retaining consumers (tourists) and providing customer satisfaction, and this issue has become increasingly significant in the current times. The salient point is that proper supply chain management is one of the key factors in achieving this goal. Therefore, in this research, the ESC has been studied and a related mathematical model has been presented. The proposed supply chain is a two-level supply chain that includes ECs and customers. The centers offered a few services during the COVID-19 pandemic to generate revenue in order to avoid a huge economic burden, as well as to retain its customers for the post-pandemic period. The services are offered at different quality levels, and since it was difficult to calculate demand during the pandemic, the variable was considered to be uncertain in the model. Furthermore, the model is designed as a multi-period model to accurately and effectively plan the center's management to provide fast and on-time responses, while ensuring the satisfaction of customer demand at the highest possible level. One of the decision variables of the proposed model is the final capacity of the center. The variable considers the center's capacity limitation to help the management decide whether to increase the capacity of the existing services or to introduce a new service by investing more money. Clearly, the capacity number, which will be increased, is dependent on the current capacity of the center to customer demands. In summary, the major assumptions considered in the proposed ECS include the following variables:

- Demand uncertainty
- Different quality levels for each service
- The limited capacity of each service
- Multi-period supply chain
- The minimum response rate for the demand of each customer group.

Fig. 2 illustrates the considered assumptions and the conceptual framework of the mathematical model.

Indices

i	Index of services $(1, \ldots, I)$
j	Index of customers $(1, \ldots, J)$
q	Index of quality levels for service $(1, \ldots, Q)$
t	Index of time periods $(1, \ldots, T)$

Parameters

ec_{iq}	Cost of increasing one unit of capacity for presenting new service i with quality level q
fc_i	Fixed cost of presenting service i
tp_{iqt}	Total cost of providing each service i with quality level q during period t
dc_{ji}	Delivery cost of service i to customer group j
$\widetilde{d}_{jiqt}$	Demand of customer group j for service i with quality level q during period t
ca_{iq}	Initial capacity of service i with quality level q
ed_{iq}	Additional capacity number for service i with quality level q
mc_{iqt}	Maximum capacity number for service i with quality level q during period t that can be extended
α_j	minimum responsiveness rate of demand for customer group j
ey_{iq}	1, if the EC already offers service i with quality level q; otherwise, 0

Decision variables

M_{iqt}	Final capacity of the center for service i with quality level q during period t
N_{iqt}	Number of capacity for service i with quality level q during period t to be extended
X_{jiqt}	Number of service i with quality level q in period t presented to the customer group j
Y_{iq}	1, if service i with quality level q is offered by the center; otherwise, 0

Objective Functions (OFs)

Eq. (1) illustrates the first OF that minimizes the total cost of the chain. The costs of the chain include the cost of presenting the services, the cost of presenting the new service if required,

and the cost of providing the services to the customers.

$$\text{Min } Z_1 = \sum_j \sum_i \sum_q \sum_t tp_{iqt} \times X_{jiqt} + \sum_j \sum_i \sum_q \sum_t dc_{ji} \times X_{jiqt}$$
$$+ \sum_i \sum_q \sum_t \left(ec_{iq} N_{iqt} + fc_i Y_{iq} \right) \tag{1}$$

The second OF in Eq. (2) maximizes customer satisfaction. This equation expresses the rate of responsiveness to customer demand. The numerator and the denominator of the fraction represent the number of satisfied customer demands and the total number of demands, respectively. When the equation is equal to 1, it means that the maximum responsiveness has been accomplished. The ceiling symbol "⌈⌉" used in the denominator of the fraction in Eq. (2) ensures that the demand is discrete.

$$\text{Max } Z_2 = \frac{\sum_j \sum_i \sum_q \sum_t X_{jiqt}}{\sum_j \sum_i \sum_q \sum_t \left\lceil \widetilde{d}_{jiqt} \right\rceil} \tag{2}$$

Constraints

$$\sum_q \sum_t X_{jiqt} \geq \alpha_j \sum_q \sum_t \left\lceil \widetilde{d}_{jiqt} \right\rceil \qquad \forall j, i \tag{3}$$

$$X_{jiqt} \leq \left\lceil \widetilde{d}_{jiqt} \right\rceil \qquad \forall j, i, q, t \tag{4}$$

$$\sum_j X_{jiqt} \leq M_{iqt} \qquad \forall i, q, t \tag{5}$$

$$ed_{iq} \times Y_{iq} + ca_{iq} ey_{iq} + N_{iqt} = M_{iqt} \qquad \forall i, q, t \tag{6}$$

$$N_{iqt} \leq \left(mc_{iqt} - ca_{iq} \right) \left(ey_{iq} + Y_{iq} \right) \qquad \forall i, q, t \tag{7}$$

$$Y_{iq} + ey_{iq} \leq 1 \qquad \forall i, q \tag{8}$$

$$Y_{iq} \in \{0, 1\} \qquad \forall i, q \tag{9}$$

$$M_{iqt}, N_{iqt}, X_{jiqt} \geq 0, \text{ int} \qquad \forall j, i, q, t \tag{10}$$

Constraint (3) indicates the minimum percentage of demand that must be met. Constraint (4) specifies that the number of services offered by the center to each customer group cannot exceed the demand for that service. The center offers each service in packaged units, therefore demand must be discrete. In this regard, the ceiling symbol is utilized in Constraint (3) and Constraint (4). Constraint (5) shows that the number of services available at the center can be less than or equal to the final capacity. Constraint (6) defines the center's final capacity for each service. Constraint (7) indicates how much capacity for each service must be increased if the initial capacity is insufficient. Constraint (8) ensures that there is no need to offer any services that are already offered at the center. Finally, Constraint (9) and Constraint (10) define the decision variable domains used in the proposed model. The models (1)–(10) form a bi-objective mixed-integer linear program with deterministic parameters. In the next section, we will explicitly incorporate the random nature of the demand and introduce a fuzzy goal programming (FGP) approach for its solution.

4. Solution procedure

There are two ways to incorporate uncertainties into optimization models: (i) considering the uncertainty of some parameters and (ii) applying flexible programming [36]. The epistemic uncertainty with ambiguous coefficients in goal and constraints is one of the techniques used to consider parameter uncertainty. The Possibilistic Programming (PP) method is frequently used to integrate this type of uncertainty [37]. The PP method is based on enumerating the number of occurrences of each incorrect data. As a result, the Membership Functions (MFs) are determined by evaluating historical data [38]. Flexible programming, on the
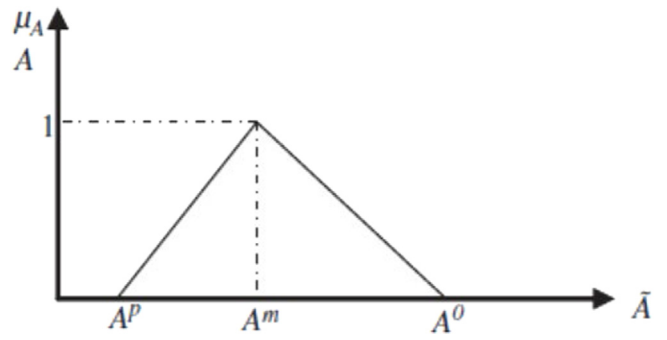

Fig. 3. The TFD of the fuzzy parameter $\widetilde{A}$.

other hand, is associated with flexibility in the target values of the OFs. In this method, The DM determines the MF of the fuzzy goals and constraints using this way [39].

The solution procedure used in this paper to solve the proposed model has two phases. In the first phase, the model is designed as an analogous auxiliary crisp one to account for demand unpredictability [40]. In the second phase, a fuzzy FGP approach is used to achieve the best possible results for both objectives [41].

4.1. Phase 1: Equivalent auxiliary crisp model

To achieve the most appropriate solutions within the PP models, several strategies have been proposed in the literature. The one by Lai and Hwang [42] is employed in this research to convert the model into its equivalent auxiliary crisp counterpart. In Eq. (3) and Constraints (3) and (4), the weighted average method is used to defuzzify the demand parameter $(\widetilde{d}_{jiqt})$. The fuzzy parameter is characterized through the triangular form of a fuzzy number. The Triangular Possibility Distribution (TPD) is a well-known technique for modeling the ambiguous character of parameters [38,43]. Fig. 3 demonstrates the TPD of a fuzzy number $\widetilde{A} = (A^p, A^m, A^o)$, with each part representing the most pessimistic, the most possible, and the most optimistic value, respectively.

Consequently, the equivalent crisp model of Eq. (2) can be expressed as follows:

$$\text{Max } Z_2 = \frac{\sum_j \sum_i \sum_q \sum_t X_{jiqt}}{\sum_j \sum_i \sum_q \sum_t \left\lceil \left(w_1 d^p_{jiqt,\beta} + w_2 d^m_{jiqt,\beta} + w_3 d^o_{jiqt,\beta} \right) \right\rceil} \tag{11}$$

Similarly, the equivalent auxiliary crisp constraints of Constraints (3) and (4) are rewritten as follows:

$$\sum_q \sum_t X_{jiqt} \geq \alpha_j \times \sum_q \sum_t \left\lceil \left(w_1 d^p_{jiqt,\beta} + w_2 d^m_{jiqt,\beta} + w_3 d^o_{jiqt,\beta} \right) \right\rceil$$
$$\forall j, i \tag{12}$$

$$X_{jiqt} \leq \left\lceil \left(w_1 d^p_{jiqt,\beta} + w_2 d^m_{jiqt,\beta} + w_3 d^o_{jiqt,\beta} \right) \right\rceil \quad \forall j, i, q, t \tag{13}$$

The DM specifies the value of β, which represents the minimum acceptable possibility. The constants w_1, w_2, and w_3 denote the weights of each part of the Triangular Fuzzy Number (TFN), respectively. In this paper, to determine the amount of all weights and β as well, we rely on the most likely values used by [42] and some other more recent papers such as Wang and Liang [44]; Torabi and Hassini [45]; Noori-Darvish et al. [46]; Paydar and Saidi-Mehrabad [40]. The numerical values of these parameters that we adopted during our experiments are $\beta = 0.5$, $w_2 = \frac{4}{6}$, $w_1 = w_3 = \frac{1}{6}$.

The solution procedure pseudo-code
Input the parameters of the model
Allocate a weight (W_j) to each part of FTN
Convert the uncertain model into its equivalent auxiliary crisp counterpart.
For $i = 1\ to\ K$
Calculate AL for OF_i
Specify the maximum deviation for each OF_i
End For
Convert the bi-objective model into a single one based on the MINMAX-GP method
Solve the MINMAX-GP model
Report the results

Fig. 4. Pseudo-code of the solution procedure.

4.2. Phase 2: The FGP method

The goal programming (GP) approach was created by Charnes et al. [47] to solve linear programming problems with different conflicting OFs (see also Paydar et al. [48]). It is a multi-criteria decision-making (MCDM) technique and is used to solve multi-objective problems. In the real world, items such as the aspiration level (AL) or the weight assigned to each OF and/or some other employed parameters are sometimes too ambiguous to consider. As a result, in such cases, fuzzy set theory is combined with GP and referred to as FGP [49]. Yaghoobi and Tamiz [50] have developed one of the many extended methods for implementing the FGP. The MINMAX-GP concept is used in this method. In this method multi-objective and bi-objective models are both converted into a single objective model. The general model of Yaghoobi and Tamiz, which introduces new variables, is presented below [51]:

$$\max = \lambda$$

$$f_i - s_i \leq b_i \qquad i = 1, \ldots, io \qquad (14)$$

$$f_i - v_i \leq b_i \qquad i = io + 1, \ldots, jo \qquad (15)$$

$$f_i + v_i - s_i = b_i \qquad i = jo + 1, \ldots, k \qquad (16)$$

$$\lambda + \frac{1}{\Delta_i^U} s_i \leq 1 \qquad i = 1, \ldots, io \qquad (17)$$

$$\lambda + \frac{1}{\Delta_i^L} v_i \leq 1 \qquad i = io + 1, \ldots, jo \qquad (18)$$

$$\lambda + \frac{1}{\Delta_i^U} s_i + \frac{1}{\Delta_i^L} v_i \leq 1 \qquad i = jo + 1, \ldots, k \qquad (19)$$

$$\lambda, s_i, v_i \geq 0 \qquad i = 1, \ldots, k \qquad (20)$$

Here, λ, s_i, and v_i are auxiliary variables, and b_i is the amount of the AL. Δ_i^U and Δ_i^L state the maximum possible value of deviation for the minimization objective and the minimum possible value of deviation for the maximization objective, respectively. Constraints (14) and (17) apply to the minimization objective, and Constraints (15) and (18) are related to the maximization objective. Furthermore, Constraints (16) and (19) are deemed meaningful when the objective value is equal to the AL.

To better illustrate the procedure of the used methodologies in this paper, we have prepared a pseudo-code shown in Fig. 4.

5. Case study

EcoBarak Center is an EC that was established in 2017 in Lafour rural district, Mazandaran province, Iran to provide services to tourists. Prior to the COVID-19 pandemic, EcoBarak provided a variety of services such as food, edible and non-edible souvenirs, transportation, tours, and lodging. Following the official announcement of the coronavirus outbreak, the transmission rate and the number of coronavirus-positive cases in Iran increased rapidly. Therefore, the Ministry of Health and Medical Education, as well as the National Headquarter for Coronavirus Disease Management, recommended that the government close some of the busiest and most crowded institutions and entities, such as touristic centers, as they pose a high risk to public health. As a result of this decision, the center remained closed from the beginning of March until the end of April 2020. When the rate of coronavirus infection decreased, tourism centers were allowed to resume operations, but only in a limited capacity and with the full implementation of strict hygiene-related guidelines. Subsequently, EcoBarak decided to reopen and offer some potential services at this time in order to earn money, maintain, and improve its economic situation, as well as retain its customers. The services offered by the center include (1) local poultry, (2) traditional sweets, (3) homemade pickles and jams, (4) local vegetable family products, (5) local rice, and (6) local handicrafts. Services 1–5 are edible souvenirs, while service 6 is a non-edible souvenir. In addition, prior to the coronavirus outbreak, the center used to provide services to local customers – in Tehran province, Iran's capital, and other provinces – as well as international customers. Obviously, due to flight cancellations, the center lost all of its international customers, as well as the majority of its visitors from other Iranian regions. As a result, the majority of the EC's remaining customers were either local or from Tehran province. The center offers services in two quality levels: ordinary and special. The distinction between the two for different services has different implications. Rice, for example, is classified into two types based on factors such as cooking quality and color, as well as flavor. In addition, for local vegetable family products, homemade pickles and jams, and traditional sweeties, the quality level is summarized in the amount and type of ingredients. A 15-day time horizon is considered for accurate planning of center activities, fast and on-time response to customer demand, and efficient cost management. To make the offered services more tangible, they are presented in Fig. 5.

Fig. 5. A picture of the provided services.

Table 2
Cost of increasing one unit of capacity for presenting new service.

Quality level	Type of services											
	1		2		3		4		5		6	
	1	2	1	2	1	2	1	2	1	2	1	2
Cost (Tomans)	0	0	4500	6300	4000	5500	3800	5000	0	0	0	0

Table 3
Initial capacity of service with the quality level.

Quality level	Type of services											
	1		2		3		4		5		6	
	1	2	1	2	1	2	1	2	1	2	1	2
Capacity	30	0	40	15	36	0	45	21	15	0	0	0

Table 4
Total cost of providing each service and the maximum number of the capacity of each service can be extended.

For all periods	Type of services											
	1		2		3		4		5		6	
Quality level	1	2	1	2	1	2	1	2	1	2	1	2
Total price (Tomans)	30000	0	18000	25000	16000	22000	15000	22000	160000	230000	20000	0
Maximum capacity (units)	65	0	70	30	75	35	80	40	30	15	70	0

Table 5
Delivery cost of each ecotourism service to each customer group (Tomans).

		Type of services					
		1	2	3	4	5	6
Type of customers	1	6800	6000	6000	4500	37500	3800
	2	9000	8000	9000	6000	50000	5000

5.1. Input data

The center sells traditional sweets as well as local vegetable family products that are available at both ordinary and special quality levels. Services such as local poultry, homemade pickles and jams, and local rice are offered only at the ordinary level. Unless specified otherwise, local handicrafts can only be offered at an ordinary quality level, and homemade pickles/jams and local rice can be offered at a special quality level upon request. All products, with the exception of local poultry, rice, and handicrafts, are delivered in one-kilogram packages and containers. In addition to local rice, which is presented in packages of 10 kg, local poultry and handicrafts are presented one by one as well. That means that if a customer requests two packages of local vegetable family products, they will be delivered two packages, 1 kg each. Similarly, if there is a demand for three packages of local rice, three packages of 10 kg, which is equivalent to 30 kg, will be sent to the customer. In a particular period, the center can present a total of 35 items of ordinary-level local handicrafts, 18 packages of homemade pickles/jams, and 5 packages of local rice at a special quality level. The center must satisfy at least 70% of the needs of customers. There is no fixed cost for services such as local poultry, rice, and handicrafts, as the center just acts as the reseller. In addition, the fixed costs for services such as traditional sweets, homemade pickles/jams, and local vegetable family products are equal to 10, 4, and 6 million Tomans, respectively. Table 2 shows the cost incurred by customers for adding one unit of capacity for each new service. Table 3 shows the center's initial capacity for each service it offers. It also displays the total cost of each service offered as well as the maximum capacity for each service in different periods. According to Table 4, the different amounts of services do not change across the periods due to the short time intervals. Table 5 presents the delivery cost of each service to each of the two customer groups. Thus, delivering the services will cost 15% of the service's selling price to local customers, whereas Tehran customers will have to pay a 20% premium on the delivery cost with respect to the selling price. Finally, Table 6 shows the most likely values of demand for each service by each customer group in each period. The most pessimistic and optimistic values of the fuzzy demand are calculated by multiplying the most possible value by 0.8 and 1.2, respectively.

5.2. Results

The FGP method developed by Yaghoobi and Tamiz was used to solve the proposed model. In this method, first, the AL and maximum available deviation for each OF should be specified. As a result, each OF will be solved separately, and the results will represent the AL of each OF. We implemented the Lingo software to solve each of the mono-objective models and yielded the following ALs: 50,855,800 for OF1 and 1 for OF2. The maximum deviation depends on the opinion and experience of the managers at the center. A tolerance for spending up to 20% more on total costs in exchange for greater responsiveness to customer demands is considered. So, we assumed here a value of $\Delta_i^U = 10{,}171{,}160$ for OF1 and $\Delta_i^L = 0.2$ for OF2. Fig. 6 shows the results of each OF in different statuses. According to Fig. 6, the
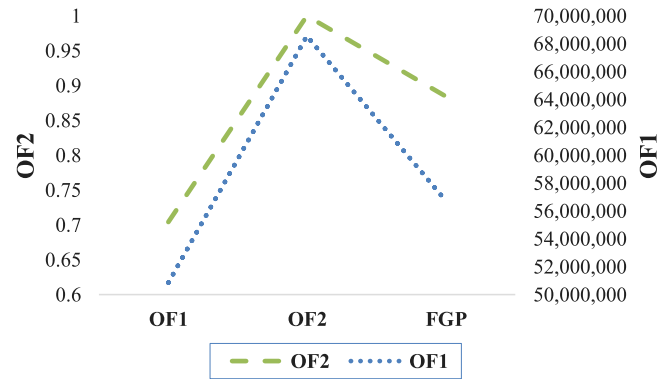

Fig. 6. The results of each objective function in different statuses.

optimal solutions for each OF, when solved separately, are as obtained above (50,855,800 and 1). Based on Fig. 6, when the first OF is kept at its AL, the second one equals 0.7042. Similarly, when the second OF is kept at its optimal level, the first one increases to become equal to 68,554,100. However, when the bi-objective model is solved using the FGP method, the values of each OF are equal to 56,710,200 and 0.8847, respectively. Tables 7–9 report the detailed results of solving our bi-objective mathematical model by FGP. According to these results, the center must offer local vegetable family products at a special quality level and local handicrafts at an ordinary quality level. Table 7 illustrates the additional capacity units of each service that must be made available at each period. More specifically, the reported results show that the number of capacity extensions for local poultry (Service 1) is zero in each period, which means that the initial capacity for this service is adequate and sufficient. Table 8 expresses the final capacity of the center for each service, at each quality level, and during each period. Finally, Table 9 shows the number of units of each service that the center offers to each customer during each period.

While the above results appear to be very meaningful and to be a useful tool for EcoBarak managers in planning their activities, it would be very useful to analyze the effects of some of the key parameters on the obtained results. This will provide additional information to center management on how to select the best combination of all DM-based input values, which will be covered in the following section.

5.3. Sensitivity analyses

To scrutinize the effects of some basic parameters of the proposed model, a sensitivity analysis is carried out, and the related results are presented in the sequel. These parameters include the minimum response rate to demand, the most optimistic values of the demand, and the weights settings of each part of the TFN. Moreover, different modes of delivering services are considered and their impacts on the delivery cost are studied and analyzed.

5.3.1. The minimum response rate to demand for each customer group (α_j)

One of the most important reasons for the center to provide services during the pandemic is to retain its customers. To accomplish this, the center must increase the rate of satisfied customer demands. Thus, determining the proper value of the minimum response rate is critical and beneficial for DMs. Several values for this parameter were tested and analyzed, and the results are shown in Fig. 7. Based on these findings, it is clear that when the value of α_i increases, so do the values of both objective functions and at almost the same rate. This means that if the

Table 6
The most likely values of the demand (units).

		Quality level	Periods				
			1	2	3	4	5
Local customer							
	1	1	10	14	11	8	13
		2	0	0	0	0	0
	2	1	18	14	19	10	13
		2	9	6	7	5	5
Type of services	3	1	15	19	17	22	15
		2	6	8	10	9	6
	4	1	25	30	26	22	31
		2	10	13	11	10	12
	5	1	0	0	0	0	0
		2	0	0	0	0	0
	6	1	2	3	1	2	3
		2	0	0	0	0	0
Tehran customers							
	1	1	16	13	15	14	17
		2	0	0	0	0	0
	2	1	18	17	23	21	19
		2	6	8	9	7	10
Type of services	3	1	31	26	21	27	29
		2	8	10	11	9	13
	4	1	30	24	27	34	28
		2	10	12	8	10	9
	5	1	13	10	8	7	12
		2	6	4	5	3	6
	6	1	7	9	10	8	9
		2	0	0	0	0	0

Table 7
The additional capacity number of each service must be extended.

		Quality level	Periods				
			1	2	3	4	5
	1	1	0	0	0	0	0
		2	0	0	0	0	0
	2	1	0	0	2	0	0
		2	0	0	0	0	0
	3	1	10	9	2	13	8
Type of services		2	0	0	0	0	0
	4	1	10	9	8	11	14
		2	0	0	0	0	0
	5	1	0	0	0	0	0
		2	15	15	15	15	15
	6	1	70	70	70	70	70
		2	0	0	0	0	0

Table 8
Final capacity of the ecotourism center for each service.

		Quality level	Periods				
			1	2	3	4	5
	1	1	30	30	30	30	30
		2	0	0	0	0	0
	2	1	40	40	42	40	40
		2	15	15	15	15	15
	3	1	46	45	38	49	44
Type of services		2	18	18	18	18	18
	4	1	55	54	53	56	59
		2	21	21	21	21	21
	5	1	15	15	15	15	15
		2	20	20	20	20	20
	6	1	105	105	105	105	105
		2	0	0	0	0	0

center wants to meet all of its customers' demands (100 percent responsiveness), it must incur a cost increase of approximately 18%. Similarly, the center can save approximately 41% of its total cost if it achieves an 8% decrease in customer satisfaction.

5.3.2. The most optimistic values of the demand

The center can try to increase the most optimistic values of the demand if its managers decide to perform some advertising and/or discounting campaigns. In this case, it is assumed that depending on the intensity of the advertising and discounting

Table 9
Number of each service are presented to each customer group during each period.

		Quality level	Periods				
			1	2	3	4	5
Local customers							
Type of services	1	1	10	14	11	1	5
		2	0	0	0	0	0
	2	1	18	14	19	10	13
		2	9	6	3	5	5
	3	1	15	19	17	22	15
		2	3	8	10	9	6
	4	1	25	30	26	22	31
		2	10	13	11	10	12
	5	1	0	0	0	0	0
		2	0	0	0	0	0
	6	1	2	3	1	2	3
		2	0	0	0	0	0
Tehran customers							
Type of services	1	1	16	13	15	0	9
		2	0	0	0	0	0
	2	1	18	17	23	21	19
		2	0	1	2	0	0
	3	1	31	26	21	27	29
		2	0	0	8	0	12
	4	1	30	24	27	34	28
		2	10	8	8	10	9
	5	1	13	10	8	7	12
		2	2	0	0	0	0
	6	1	7	9	10	8	9
		2	0	0	0	0	0
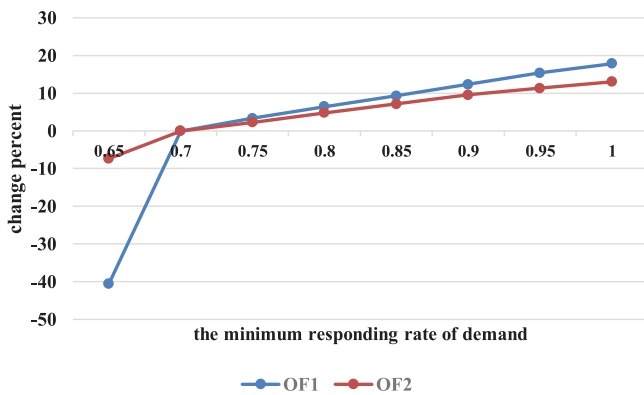
Fig. 7. Results of the sensitivity analysis related to the minimum response rate to demand (α_i).

Fig. 8. Results of the sensitivity analysis of the most optimistic values of the demand.

promotion, the most optimistic value of the center's demand can achieve an increase of 15%, 20%, 25%, 30%, 35%, and 40%. Fig. 8 reports the results of such an experiment, showing that, unsurprisingly, as the amount of the most optimistic values of the demand increases, the amount of satisfied demand will increase too. However, as demand grows, the rate of demand responsiveness does not change significantly, despite the fact that the cost rises. The reason for this behavior is that, due to the center's limited capacity, it cannot respond to customer demand beyond a certain threshold amount.

5.3.3. Different delivery modes

In this subsection, four modes of delivery are considered for each group of customers. The effects of these modes on the total cost of the supply chain and the delivery cost are also investigated. The four modes under consideration are as follows:

Mode 1: The center directly delivers the orders to the customers in a face-to-face mode. In this case, the center needs to
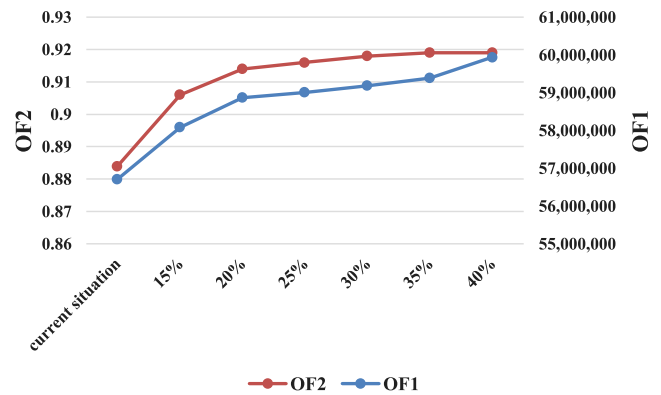
hire some home delivery staff to deliver the orders to the customers (direct interaction).

Mode 2: The center delivers the orders to the customers by using other delivery methods such as freight carriers and postal services (indirect interaction mode).

Mode 3: The center delivers the orders of local customers in person and those of Tehran customers using delivery intermediaries (hybrid interaction mode).

Mode 4: Local customers can directly visit the center to collect their orders, and the orders of Tehran customers are also handled face to face.

According to the results summarized in Table 10, mode 4 clearly outperforms the other modes in terms of delivery cost and total cost. This mode, however, has some drawbacks. Indeed, the center should test the feasibility of local customers coming to the center to pick up their orders. Due to the special conditions imposed by coronavirus disease and the strict health instructions,

Table 10
Results of sensitivity analysis for the four defined delivery modes.

Modes	Delivery cost	OF1	OF2
1	9,145,600	56,710,200	0.8847
2	9,439,500	56,973,600	0.8838
3	9,588,300	57,035,400	0.8838
4	7,930,100	55,325,600	0.8905

Table 11
Results of sensitivity analysis related to the weight settings for each part of the TFN.

	Weights			OF1	OF2
	W1	W2	W3		
1	1/7	5/7	1/7	56644700	0.8832
Current mode	1/6	4/6	1/6	56710200	0.8847
3	1/5	3/5	1/5	56737520	0.8855
4	1/4	2/4	1/4	56830700	0.8878
5	1/3	1/3	1/3	57140700	0.8955

local customers may have a low desire to travel to receive their orders in person. As a result, the center should verify the suitability of this mode in real-world scenarios and implement a different mode if mode 4 is not well received by local customers. Among the other modes, mode 1 appears to be the most cost-effective in terms of delivery, OF1 and OF2. Therefore, if the center managers notice that local customers are reluctant toward mode 4, mode 1 may act as an alternative.

5.3.4. Weight settings of each part of the TFN

As stated previously, the demand parameter in the proposed mathematical model is uncertain and has been represented as a TFN. To solve the proposed model, first, we converted the uncertain demand into its crisp form by assigning weights W1, W2, and W3. To investigate the effect of the weights on the amount of each OF, various values for each weight are tried. Table 11 displays the results of setting various weights. From these findings, it can be seen that the closer the value of each weight is, the better the values for each OF are obtained. However, given the conceptual meaning of the greatest possible value, its weight (W2) should be more than the other weights [52]. As a result, W1 = 1/6, W2 = 4/6, and W3 = 1/6 have been considered in this study.

6. Discussions and managerial insights

As indicated earlier, to achieve the research goal and questions, based on some existing assumptions and limitations in the real world, a bi-objective mathematical model has been designed. The model is then solved using Lingo software (a powerful tool for solving operations research problems), and the results are presented in Section 5.2. These findings comprehensively provide answers to the research questions. Moreover, for a more detailed study of the effects of some key parameters on the amount of each OF, a section on sensitivity analyses has been provided. With regard to the outputs and findings of the present investigation, some practical managerial suggestions are presented and discussed in this section. We should also emphasize that each of the provided managerial insights can significantly contribute to the development and prosperity of ECs and other similar institutions active in the EI.

Advertising is a regular and purposeful form of communication that can be a creative and innovative way to persuade customers to make the final decision to purchase a specific product or service. It is used in various businesses and industries, including EI. Managers of ECs can increase demand and, consequently, their profit by better presenting their business and products to customers through effective advertising approaches. The results

of the sensitivity analyses (Section 5.3.2) show that when advertising is used, the demand for the center increases. The main goal of the O&Ms of the ECs is to retain their customers during the pandemic. For this, the center can categorize its customers and identify its loyal customers to offer them special discounts. Furthermore, the center may consider offering discounts on some of the products in order to target new customers based on the number of orders they place. Due to the conditions developed as a result of the pandemic, including the travel ban and lack of physical presence of passengers, ECs can currently offer only a limited number of services. According to the case study and its results, the centers can present some additional services that were not offered pre-COVID due to the capacity of the center. For example, the center had never sold local handicrafts in the past, but given the acceptable number of demands for this service, offering this service may allow the center to not only increase its profits but also improve customer satisfaction. Since the ECs are not crowded with customers during the pandemic, the O&Ms of the centers reconstruct and renovate the centers, as well as disinfect the accommodation centers and clear the relevant ecotourism areas such as forests of trash, debris, and pollution as preparatory actions for the post-coronavirus period. Moreover, the ECs can offer a new service called special one-day family tours. This type of tour is only provided to the member of a family with the limited and specific capacity and under strict observance and implementation of health protocols. The purpose of offering this service is to elevate the spirits of the customers and promote the center's prosperity and development [53]. The concept of virtual tourism (VT) is formed by developing new-age information technology tools. Nowadays, the VT is recognized as a major approach to tourism development. Therefore, this approach can be used in the ecotourism field. With the spread of coronavirus, the O&Ms of the centers can rely on this approach to prevent some possible damages and help improve and develop the EI during this disease and post that [54]. The ECs can introduce themselves and their services to their existing customers, as well as attract new ones for the post-corona era by utilizing virtual ecotourism or e-ecotourism [55]. Certainly, when social conditions return to normal (after the end of COVID-19), with the lifting of flying and travel restrictions, the number of customers visiting ECs will increase drastically [56]. Therefore, the centers' O&Ms should be prepared with proper and efficient planning and allocation of sufficient resources for the post-COVID period. Different ways can be used by ECs to deliver orders to their clients. Four potential approaches are discussed in Section 5.3.3. According to the findings, the first strategy is the most suited among the others under the existing circumstances. According to this strategy, the EC is responsible for the direct delivery of items to all clients. This model is based on a face-to-face relationship with customers, which reconnects the center with its customers and strengthens their relationship. In addition to the four approaches, another option is the delivery cost-sharing (DCS) method. In the current situation, as indicated in Table 10, the total cost of the supply chain is equal to 56,710,200 Tomans and the delivery cost is 9,145,600 Tomans. This means that approximately 16.2% of the total cost of the supply chain is the cost of delivering services. In this paper, we suggested an alternative approach called DCS, which investigates and analyzes delivery costs as well as examines many possible scenarios for dividing service delivery costs between customers and the ecotourism center. The DCS approach entails three scenarios, which are described below:

1. **All delivery cost is charged to the customers:** If all delivery costs are to be borne by the customers, the costs of the center will be reduced; however, this will lead to decreased customer satisfaction, which will lead to the reduction of the demand rate and total profits for the center in the future.

2. **All delivery cost is charged to the center:** This mode is the exact opposite of the previous scenario. If the center bears the entire delivery cost, the total expenditure of the center will increase, but on the other hand, customer satisfaction will increase, which can cause a growth of the demand rate and, thus, of the total profits of the center.

3. **Delivery cost is divided into different proportions between the customers and the center:** The third scenario is probably the most appropriate and efficient as compared to the others. In this mode, both the customers and the ecotourism center bear the delivery cost. This cost can be divided equally or in different proportions between them based on the level of loyalty of each customer.

As a result, choosing the most appropriate scenario depends on various factors such as the politicization of the center and the economic conditions of the customers. The ECs can also test these scenarios for a limited amount of time and then select the most appropriate scenario by analyzing the outcomes. This work has the potential to be expanded in a variety of ways. For example, rather than focusing on the ecotourism center level, we can generalize our focus to consider a touristic services provider that can combine several sectors and services (such as sea, mountain, and land activities). The contribution would consist of creating an integrated decision support tool that can efficiently coordinate the services offered by various centers and entities. Inevitably, the total supply chain to be designed will be large-scale and have a high level of complexity. Another direction for the expansion of this research could be to find a new way for product delivery based on the concept of crowd shipping, which was recently established by a few researchers [57,58].

7. Conclusions

Ecotourism is part of the TI that has been gaining more and more attention recently. It can contribute to the economic, social, and cultural development of local societies. Recently, the EI has faced various challenges, one of which is the prevalence of coronavirus. With the outbreak of the COVID-19 pandemic, the O&Ms of the ECs try to keep the center safe from severe economic and social damages, as well as to retain and satisfy customers. As a result, they offer some services that are suitable for the current restrictive conditions. Given the above-mentioned parameters, a bi-objective mathematical model for the ECS that takes into account the effects of the pandemic is proposed. The first OF minimizes the total cost of the chain, and the second one maximizes customers satisfaction. Due to the uncertainty in the demand parameter, the FGP method is used to solve the model, and the optimal values of each OF are 56,710,200 Tomans and 0.8847, respectively. According to the obtained findings, the center should feature local vegetable family products of special quality and local handicrafts of ordinary quality. The goal of this research is to assist the O&Ms of the ECs in making better decisions and implementing the most appropriate policies during and after the pandemic.

CRediT authorship contribution statement

Seyyed Mehdi Hosseini: Conceptualization, Data curation, Formal analysis, Investigation, Methodology development, Validation, Visualization, Writing of the manuscript. **Mohammad Mahdi Paydar:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology development, Validation, Visualization, Writing of the manuscript. **Mehdi Alizadeh:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology development, Validation, Visualization, Writing of the manuscript. **Chefi Triki:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology development, Validation, Visualization, Writing of the manuscript.

Declaration of competing 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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