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Applied Soft Computing Journal 104 (2021) 107217

Contents lists available at ScienceDirect

Applied Soft Computing Journal

journal homepage: www.elsevier.com/locate/asoc

Supply chain design to tackle coronavirus pandemic crisis by tourism management

Faezeh Motevalli-Taher, Mohammad Mahdi Paydar *

Department of Industrial Engineering, Babol Noshirvani University of Technology, Babol, Iran

ARTICLE INFO

Article history:
Received 16 December 2020
Received in revised form 20 January 2021
Accepted 15 February 2021
Available online 20 February 2021

Keywords:
Pandemic control
COVID-19
Multi-objective supply chain optimization
IMCGP
Tourism management

ABSTRACT

The rapid growth of the COVID-19 pandemic in the world and the importance of controlling it in all regions have made managing this crisis a great challenge for all countries. In addition to imposing various monetary costs on countries, this pandemic has left many serious damages and casualties. Proper control of this crisis will provide better medical services. Controlling travel and tourists in this crisis is also an effective factor. Hence, the proposed model wants to control the crisis by controlling the volume of incoming tourists to each city and region by closing the entry points of that region, which reduces the inpatients. The proposed multi-objective model is designed to aim at minimizing total costs, minimizing the tourist patients, and maximizing the number of city patients. The Improved Multi-choice Goal programming (IMCGP) method has been used to solve the multi-objective problem. The model examines the results by considering a case study. Sensitivity analyses and managerial insight are also provided. According to the results obtained from the model and case study, two medical centers with the capacity of 300 and 700 should be opened if the entry points are not closed.

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1. Introduction

Among natural disasters, infectious diseases are one of the leading causes of death in humans. There have been many pandemics and events in human history such as polio, smallpox, cholera, and HIV, which have caused injury or death to many people [1]. The influenza pandemic in Spain 1918–1919, is estimated at 20 to 50 million people worldwide [2,3]. Also, the influenza A(H1N1) virus in 2009, spread over most of the countries causing a lot of deaths [4]. Also, many acute illnesses include respiratory infections, malaria, measles, and diarrhea. Common infectious diseases after natural disasters are closely related to unsanitary health conditions and malnutrition that affect the population [5].

The expansion of communication between communities has increased the speed of transmission of infectious diseases time [6]. A pandemic is a condition in which prevalence is beyond imagination and a pandemic can be controlled with proper management over a period of time [7]. A recent pandemic, COVID-19 (Corona Virus Disease 2019), affected the entire world, causing extensive human and financial damage. The prevalence of coronavirus has increased the number of visits to medical centers (MC) and has often caused problems for these centers [8].

One of the most important factors in the increasing expansion of the COVID-19 is the lack of compliance with the relevant health and safety tips. Unnecessary transit and travel are some of the factors in maintaining and expanding COVID-19. By controlling travel, we can help reduce the spread of this pandemic and prevent contamination of clean areas [9]. Also, by closing the entry points of some areas, it is possible to prevent congestion in MCs and reduce medical services. By reducing the number of tourists entering the city, it is possible to prevent the spread of this virus and further infection in that area. It also threatens the place when tourists return to their origin.

Therefore, by enforcing the laws prohibiting inter-regional traffic at appropriate times in times of crisis and pandemic outbreak, this chain of disease transmission can be terminated sooner and the level of response of MCs can be increased to reduce the workload and fatigue of medical staff. Also, if needed, mobile MCs that could be set up quickly can be built to cover more patients.

Due to a large number of patients and their rapid growth in pandemics, the problem of cost management and crisis control is essential. Therefore, given the importance of human health concerning financial issues, we must look for a way to properly and accurately manage this chain. Mathematical modeling is one of the management methods that leads to a logical and accurate answer by considering various conditions and parameters, leading to the achievement of the correct result in a logical time [10]. In such a situation, decisions cannot be made, based on the single objective models [11].

In this study, a supply chain is designed for MCs and patients during a pandemic, based on the case study of COVID-19.

* Corresponding author.
E-mail address: paydar@nit.ac.ir (M.M. Paydar).

https://doi.org/10.1016/j.asoc.2021.107217
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This multi-objective model includes city patients, tourist patients, existing and potential MCs, and aims to minimize total costs, minimize tourist patients, and maximize city patients to provide better services. Considering the objectives of the problem and the COVID-19 pandemic that poses a threat to health and environmental pollution, sustainability's economic, social, and environmental aspects have been considered in this study. This leads to more and better medical services that increase patient satisfaction, and better management of the chain helps to reduce the accumulation of environmental pollution.

2. Literature review

This section reviews some previous studies on COVID-19 and some other similar pandemics disease. Following the revelation of the existing research gaps, these articles have been expressed and compared. Then, the research gap is explained to clarify and to reveal the importance of the proposed problem.

2.1. COVID-19 pandemic and tourist management

As mentioned in the introduction, there have been pandemics so far that research like Dowdy et al. [12] that have used decision tree models to manage the cost of infectious disease testing in India, Dasaklis et al. [1] that analyzed some researches in the context of Epidemic control and their effects, and Winskill et al. [13] that investigated factors related to malaria transmission were considered in terms of cost in Africa. Among the factors they studied were internal spraying residues, insecticide-treated nets, and seasonal malaria prevention chemotherapy has been done. In the recent pandemic, COVID-19, studies have been conducted in various fields, and most of these studies include statistical analysis.

The Impact of the COVID-19 on the treatment of diseases and health has been presented in some articles. Zareie et al. [14] examined the impact of the COVID-19 on people's health and the rate of casualties. Govindan et al. [15] that proposed a decision support system for managing the demand for health systems in COVID-19, Ren et al. [16] investigated the choice of medication for COVID-19 heart disease patients, Cusinato et al. [17] studied the impacts of COVID-19 in repurposing drugs, Aggarwal et al. [18] predicted disease using decision support systems, and Ngoc Su et al. [19] investigated the human resource in the hospital in Vietnam using statistical analyses.

This pandemic has also caused significant changes and impacts in the environment, with articles such as Amankwah-Amoah [20] that have examined the environmental aspects of COVID-19 sustainability by analyzing the influential factors in the aviation industry. Also, Saadat et al. [21] examined the extent to which environmental pollution was reduced during the COVID-19. Moreover, Kargar et al. [22] investigated the waste management of medical centers, Vaka et al. [23] that compared the factors affecting renewable energy in Malaysia in the COVID-19 pandemic in Asian countries, and Zou et al. [24] developed a distribution system for supermarkets in pandemic situation.

The recent pandemic has had a direct and significant impact on the tourism industry. With the reduction of travel and travel bans, tourism faced many changes and challenges. Karim et al. [25] used the reports of Malaysia in COVID-19 to find out the changes in the tourist and hospitalization process. They investigate the problem with the conceptual methodology technique. Their study aimed to predict future Malaysian tourism management using statistical analyses. Qiu et al. [26] estimated the urban desire to pay for reducing dangers of the pandemic among tourism process by the method of triple bounded dichotomous choice contingent valuation. They want to forecast the costs with determined scenarios by informing people. Kock et al. [27] studied the future of tourism and the effects of COVID-19 in travels. They investigate the mental impacts of this pandemic on tourism industry changes to find a pattern for planning based on empirical findings. Gössling et al. [28] studied the impacts of the recent pandemic, COVID-19, on tourism and traveling in the first days of spreading it. They used the statistics of this disease to find the procedure and reduction of tourism in that period. They report their observations from all of their investigations. Higgins-Desbiolles [29] described the impacts of email on the tourism industry among COVID-19 which weaken this industry and the jobs that are related to it. They argued about the future of the students and education in tourism. Of course, there is not much explanation for this, so the tourism pattern is changing due to the spread of the COVID-19.

Studies that have been done in the field of COVID-19 control, to the best of our knowledge are often statistical and do not have a mathematical model. Aydin and Yurdakul [30] used machine learning to analyze the performance of the countries in COVID-19. They analyzed the data via clustering and decision tree method. Chinazzi et al. [31] examined the impact of traffic restrictions in Wuhan, China, from January to February 2020. They found that the prevalence was reduced by about 50 percent with 90 percent restrictions. Kraemer et al. [32] examined the impact of import restrictions in Wuhan, China. With official data from China, they found that the incidence had decreased as imports from the city declined.

2.2. Research gap

With the spread of the COVID-19 pandemic around the world and the spread of its unforeseen events, the importance of managing this crisis and the need for a regular network to control the disease is essential. Mathematical modeling is one of the most accurate and good management methods by which the most reliable and closest results to reality can be achieved and a better prediction of the crisis in the future can be provided.

Previous researches, shown in Table 1, are presented in Section 2.1. to reveal existing research gaps. Most of these articles have used statistical analysis to assess the prevalence or estimate of potential casualties. In this study, a mathematical model for the prevalence of infectious diseases in each region is designed based on the COVID-19 case study. This problem simultaneously considers the multi-objective of cost minimization, minimizing the tourist patients, and maximizing the number of city patients, which have not been yet proposed any multi-objective mathematical model in this context. Also, so far, no model has been considered for controlling tourists and travelers entering the city, taking into account medical centers, patients, and tourists. However, there is almost no mathematical model for tourist management in other non-medical fields. The proposed model helps to improve the COVID-19 pandemic control condition by mathematically optimizing a multi-objective problem.

3. Problem statement

The presented multi-objective and multi-period model is designed to manage the COVID-19 crisis and provide better medical services to patients. The model includes the city that tourists enter the area from different entry points. City patients and tourist patients go to medical centers (MC) for medical services. They receive services depending on the type of their disease, which is acute and requires hospitalization or non-acute. Due to the hospitalization of some patients, the time of hospitalization is considered in the model.

Table 1
Review of some papers related to COVID-19.

Authors	Year	Method	Research area related to pandemic	Case study
Zareie et al.	2020	Statistical analyses	Rate of casualties	China
Govindan et al.	2020	Decision support system	Demand for health systems	–
Kargar et al.	2020	Mathematical modeling	Waste management	Iran
Kock et al.	2020	Find a pattern based on empirical findings	Future of tourism industry	–
Qiu et al.	2020	Conceptual methodology technique	Urban desire to pay for reducing dangers of tourism	–
Kraemer et al.	2020	Statistical analyses	Impact of import restrictions	China
Aggarwal et al.	2021	Decision support system	Prediction of disease	India
Zou et al.	2021	Mathematical modeling	Distribution system	–
Ngoc Su et al.	2021	Statistical analyses	Health human resources	Vietnam
Cusinato et al.	2021	Statistical analyses	Drug repurposing	–
This study	**2021**	**Mathematical modeling**	**Tourism management and pandemic control**	**Iran**

There are different types of MCs according to their capacity. MCs always need to have at least a certain amount of medical services available. Therefore, if necessary, new potential MCs are established, which can be field or temporary. If there is no city patient, tourist patients can be admitted and there is no shortage of services; otherwise, by restricting entry points, more tourists should be prevented from entering the area. Prohibition policies should be introduced to control the crisis, and that entry point should be banned. Minimizing total cost, minimizing the tourist patients, and maximizing the number of city patients, are the objective functions of the presented model.

Indices:

p	Patient type
s	Entry point of tourist
h	Medical Center (MC)
b	MC type
t	Time period

Parameters:

AI_p	Infection rate coefficient of the city with patient type p
γ_{sp}	Infection rate coefficient of patient from point s with type p
PH_{pt}	If there are not patient p in time t in city that need services in MCs 1, otherwise 0
β_{pt}	Coefficient of patient discharge with type p in time t
IP_{hp}	Patients in the MC h with type p
CI	The population of the city
CW_{st}	Maximum tourist of point s in time t
CAP_{hb}	Capacity of MC h with type b
CT_{ph}	Treatment cost of patient p in MC h
f_{hb}	Opening cost of MC h with type b
LB_{spt}	The cost of lack of services for the patient of point s with type p in time t
SB_{pt}	Minimum available medical services for the patient with type p in time t
MS_{pht}	City inpatients with patient type p in MC h in time t
MW_{spht}	Tourist inpatients from point s with patient type p in MC h in time t
θ	Hospitalization period
N	A big positive number

Decision variables:

WS_{spht}	The tourist patient from point s with patient type p to MC h in time t
XS_{pht}	The patient of city with patient type p to MC h in time t
ZS_{pt}	The number of patients with type p in time t
ZW_{spt}	The number of tourist patients with type p from point s in time t
YS_{pht}	Patient with type p discharged from MC h in time t
IN_{pht}	Patients in the MC h with type b in time t
LBW_{spt}	Lack of services for the patient of point s with type p in time t
VB_{hb}	1 If MC h with type b is opened; 0 otherwise

Objective functions:

$$\text{Min } Z_1 =$$

$$\sum_p \sum_h \sum_t CT_{ph} \times XS_{pht} \tag{1a}$$

$$+ \sum_s \sum_p \sum_h \sum_t CT_{ph} \times WS_{spht} \tag{1b}$$

$$+ \sum_h \sum_b f_{hb} \times VB_{hb} \tag{1c}$$

$$+ \sum_s \sum_p \sum_t LB_{spt} \times LBW_{spt} \tag{1d}$$

$$\text{Min } Z_2 = \sum_s \sum_p \sum_h \sum_t MW_{spht} \times WS_{spht} \tag{2}$$

$$\text{Max } Z_3 = \sum_p \sum_h \sum_t MS_{pht} \times XS_{pht} \tag{3}$$

In the proposed model, the first objective function is minimizing total costs. Four terms of this objective function are described in (1a)–(1d). Term (1a) calculates the treatment cost of city patients in MCs, term (1b) is the treatment cost of tourist patients in MCs. Term (1c) shows the opening cost of new MCs; and the fourth term, (1d), is the cost of lack of services for the tourist patient. The second objective function, Eq. (2), minimizes the tourist patients whom inpatients in MCs to avoid travel more. This function helps to control the management of the tourist in entry points to find the right time to impose a traffic ban. And the third one, in Eq. (3), maximizes the number of city patients whom inpatients in MCs; to prioritize the city patients and reduce the number of tourist patients to impose traffic restrictions and to increase the capacity of more treatment and service capacity.

Constraints:

$$\sum_s \sum_p WS_{spht} + \sum_p XS_{pht} \le \sum_b CAP_{hb} \times VB_{hb} \quad \forall h, t \tag{4}$$

$$\sum_s \sum_p WS_{spht} + \sum_p XS_{pht} + IP_{hp} = IN_{pht} + YS_{pht'}$$
$$\forall p, h, t = 1, t' \ge t + \theta \tag{5}$$

$$\sum_{s}\sum_{p} WS_{spht} + \sum_{p} XS_{pht} + IN_{pht-1} = IN_{pht} + YS_{pht'} \quad \forall p, h, t > 1, t' \geq t + \theta \tag{6}$$

$$\sum_{p}\sum_{h} YS_{pht} = \sum_{p} (ZS_{pt} + ZW_{pt}) \times \beta_{pt} \quad \forall t \tag{7}$$

$$\sum_{s}\sum_{p}\sum_{h} MW_{spht} + \sum_{s}\sum_{p} LBW_{spt} = \sum_{p} ZW_{pt} \quad \forall t \tag{8}$$

$$\sum_{p}\sum_{t} YS_{pht} \leq N \times \sum_{b} VB_{hb} \quad \forall h \tag{9}$$

$$\sum_{p}\sum_{t} XS_{pht} \leq N \times \sum_{b} VB_{hb} \quad \forall h \tag{10}$$

$$\sum_{s}\sum_{p}\sum_{t} WS_{spht} \leq N \times \sum_{b} VB_{hb} \quad \forall h \tag{11}$$

$$\sum_{p}\sum_{t} IN_{pht} \leq N \times \sum_{b} VB_{hb} \quad \forall h \tag{12}$$

$$\sum_{p}\sum_{h}\sum_{t} MS_{pht} + \sum_{s}\sum_{p}\sum_{h}\sum_{t} MW_{spht} \leq N \times \sum_{b} VB_{hb} \quad \forall h \tag{13}$$

$$\sum_{b} VB_{hb} \leq 1 \quad \forall h \tag{14}$$

$$\sum_{s}\sum_{p} WS_{spht} \leq CW_{st} \quad \forall s, t \tag{15}$$

$$\sum_{h}\sum_{b} CAP_{hb} - \sum_{p}\sum_{h} IN_{pht} \geq \sum_{p} SB_{pt} \quad \forall t \tag{16}$$

$$\sum_{s}\sum_{p}\sum_{h} MW_{spht} \leq N \times \sum_{p} PH_{pt} \quad \forall t \tag{17}$$

$$\sum_{p} ZS_{pt} \leq \sum_{p} AI_{p} \times CI \quad \forall t \tag{18}$$

$$\sum_{p} ZW_{spt} \leq \sum_{p} \gamma_{sp} \times CW_{st} \quad \forall s, t \tag{19}$$

$$VB_{hb} \in \{0, 1\} \quad \forall h, b \tag{20}$$

$$WS_{spht}, XS_{pht}, ZS_{pt}, ZW_{spt}, YS_{pht}, IN_{pht}, LBW_{spt} \geq 0 \text{ and integer} \quad \forall p, s, h, t \tag{21}$$

Constraint (4) shows the capacity of MCs. Inequalities (5) and (6) are the balance between the inpatients in MCs by considering the hospitalization period. Constraint (7) is the balance between the discharged patient and the existing patients. Constraint (8) indicates the balance of hospitalization of tourist patients in the MC. Constraints (9)–(14) indicate the decisions related to opening new MCs. Constraint (15) guarantees that tourist patients must not exceed the maximum tourist of that point. Constraint (16) specifies the minimum available medical services in MCs. Constraint (17) ensures that If no city patient needs MC services, tourist patients could use the services. Constraints (18) and (19) are calculating the number of patients of the city and tourist patients according to their infection rate coefficient. Constraints (20) and (21) express types of decision variables.

4. Solution approach

Considering different criteria for decision-makers in disaster situations to avoid and control the troubles is inevitable. Though, multi-objective problems will appear. In such a problem which there is required to consider several goals at the same time, it is very important how to analyze and solve these problems. Therefore, due to the nature of the problem, we should look for a way to find a single-objective function that provides the best answer compared to other methods. There are many methods to transform the multi-objective problem into a single-objective one; in this research, to solve the multi-objective problem, the improved multi-choice goal-programming (IMCGP) method has been used.

4.1. Goal programming (GP)

The goal programming (GP) method is one of the most important models of multi-objective planning. This method was proposed by Charns and Cooper in 1961 [33]. This approach was proposed for systems that have conflicting and multiple goals. All GP proposed methods have a common texture and all of them aim to minimize unfavorable deviations from the aspirations. Goal-programming is able to consider different goals compared to linear programming. It also allows deviations from goals and thus creates flexibility in the decision-making process. In other words, GP shows the way to move simultaneously towards several goals. Unlike linear programming, which maximizes or minimizes the goal, GP minimizes the deviations between the intended goals and the actual results.

4.2. Revised multi-choice goal programming (RMCGP)

The GP sets an aspiration level for each objective function and solves the problem accordingly. Due to insufficient and accurate information, it may be difficult to determine aspiration levels. To solve this, the multi-choice goal programming (MCGP) was presented by Chang in 2007, where decision-makers can have multiple goals (Chang, 2007). Chang extended the MCGP model and proposed revised multi-choice goal programming (RMCGP), where instead of a number for objective functions, decision-makers could have a range for each objective [34].

4.3. Improved multi-choice goal programming (IMCGP)

Jadidi et al. [35] have presented a model that combines the RMCGP method and the GP with the priority function by considering a goal interval instead of a single goal. They believe that in some cases the value of the objective function may exceed the expected level, which will result in a penalty for the model; that is not considered in previous models [35]. Accordingly, because the probability of unforeseen and sudden events occurring in crisis is high, the IMCGP method has been used to solve the proposed problem. The proposed model includes three objectives, minimizing total costs, minimizing the tourist patients, maximizing the number of city patients. The model obtained from the IMCGP method is as follows, shown in Eqs. (22) to (29). Eq. (22) is the

new single-objective function. Equations (23)–(29) are the new constraints that will be added to the model.

$$Max \sum_{k=1}^{3} (W_k^{\alpha} \alpha_k - W_k^{\beta} \beta_k) \quad (22)$$

Subject to:

$$f_k(x) = \alpha_k g_{k,\min} + (1-\alpha_k) g_{k,\max} + \beta_k (g_k^- - g_{k,\max}) \quad k = 1, 2 \quad (23)$$

$$f_k(x) = \alpha_k g_k^+ + (1-\alpha_k) g_{k,\min} + \beta_k (g_k^- - g_{k,\min}) \quad k = 3 \quad (24)$$

$$h_i(x) = (\leq or \geq) 0 \quad i = 1, 2, \ldots, n \quad (25)$$

$$\alpha_k \leq y_k \leq 1 + \alpha_k \quad k = 1, 2, 3 \quad (26)$$

$$\beta_k + y_k \leq 1 \quad k = 1, 2, 3 \quad (27)$$

$$0 \leq \alpha_k, \beta_k \leq 1 \quad k = 1, 2, 3 \quad (28)$$

$$y_k \in \{0, 1\} \quad k = 1, 2, 3 \quad (29)$$

Thus α_k is a zero–one continuous coefficient, and the normalized distance shows the obtained objective function from g_k^+. g_k^- indicates the kth value of the objective function in the undesirable state. $[g_{k,\min}, g_{k,\max}]$ indicates the level of aspiration to be determined by the decision-maker. In this proposed model, it is assumed that the upper bound of the aspiration level $g_{k,\max}$ is equal to the value of g_k^+, which represents the value of the kth objective function in the desired state, while the lower bound of the aspiration level $g_{k,\min}$ can be greater than or equal to the value of g_k^-. The range $[g_k^-, g_k^+]$ is divided into more desirable $[g_{k,\min}, g_{k,\max}]$ and less desirable $[g_k^-, g_{k,\min}]$. β_k represents the normalized distance of the kth objective function from $g_{k,\min}$. If the value of the obtained objective function kth is greater than $g_{k,\min}$, a penalty will be added to the model which takes a value between zero and one. y_k is a zero–one variable, W_k^{α} and W_k^{β} are the weights of each objective, and $h_i(x)$ is the ith model's primary constraints.

5. Case study

The presented model is designed based on a real case study of the COVID-19 crisis in Mazandaran, one of the most populous provinces of Iran, located in the north of Iran. Mazandaran is one of the areas in the country that has a high range of patients; and because of its specific region and climate, has a large number of tourists and important entry points to the province and a lot of traffic. The population of Mazandaran is about 3 million people and tourists enter this province from 3 main entry points.

This model includes the city that tourists enter the area from 3 different entry points (s_1), (s_2), and (s_3). City patients and tourist patients go to MCs. They receive services depending on the type of their disease, which is acute (p_1) or non-acute (p_2). Due to the hospitalization of some patients, the time of hospitalization is considered in the model.

There are 5 MCs and 2 types according to their capacity. MCs always need to have at least a certain amount of medical services available. If it is necessary, 3 new potential MCs could be established in field or temporary. If there is no city patient, tourist patients could be admitted and there is no shortage of services; Otherwise, by restricting entry points, more tourists should be prevented from entering the area. Each patient leaves the MC after undergoing a certain time of treatment. The considered time horizon in this study is 15 days. Some important parameters are mentioned in Section 5.1, and the results, sensitivity analyses and managerial insights in Section 5.2, Section 5.3 and Section 5.4, respectively.

Table 2
The infection rate coefficient of the city.

γ_{sp}	Patient type	
Entry point	p_1	p_2
s_1	0.0002	0.0003
s_2	0.0001	0.0002
s_3	0.0001	0.0003

Table 3
The patients in the MC.

IP_{hp}	Patient type	
MC	p_1	p_2
h_1	167	104
h_2	350	248
h_3	283	196
h_4	345	270
h_5	290	225

Table 4
The maximum tourist of entry points in the first time period.

CW_{st}	Entry point		
	s_1	s_2	s_3
	5000	2800	3500

Table 5
The capacity of MC.

CAP_{hb}	MC type	
MC	b_1	b_2
h_1	300	0
h_2	0	700
h_3	300	0
h_4	0	700
h_5	0	700
h_6	300	0
h_7	0	700
h_8	300	0

5.1. Input parameters

According to the Iran Ministry of Health and Medical Education's statistics, the infection rate coefficient of the city with patient type p, are considered 0.0001 and 0.0004 for acute and non-acute, respectively [36]. The infection rate coefficient of tourist patients from each entry point is shown in Table 2, patients in each MC in each type in Table 3, and the maximum tourist of each entry point in the first time period in Table 4. Table 5 is shown the capacity of each MC with its type. Hospitalization period is 7 days for acute patients. The minimum available medical services for the patients in the first time period is shown in Table 6. The city inpatients and the tourist inpatients in each MC are presented in Tables 7 and 8 in the first time period, respectively.

5.2. Results

The presented model is solved in a computer with CPU Core i5 and 8GB RAM in 27 min by Lingo17 software with Branch

Table 6
The minimum available medical services in the first time period.

SB_{pt}	Patient type	
	p_1	p_2
	300	200

Table 7
The city inpatients in the first time period.

MS_{pht}	Patient type	
MC	p_1	p_2
h_1	94	72
h_2	228	190
h_3	186	97
h_4	270	236
h_5	215	150

Table 8
The tourist inpatients in the first time period.

MW_{spht}		MC				
Entry point	Patient type	h_1	h_2	h_3	h_4	h_5
s_1	p_1	40	73	55	38	62
	p_2	19	26	38	12	42
s_2	p_1	15	18	30	16	5
	p_2	6	13	21	9	15
s_3	p_1	18	31	12	21	8
	p_2	7	19	40	13	18

Table 9
The obtained values of objective functions.

	Z1	Z2	Z3	IMCGP
Z1	**50,834,203**	1539	360,344	82,427,603
Z2	62,565,063	**702**	903,133	1,050
Z3	38,697,201	627	**484,612**	594,168
IMCGP	–	–	–	**0.8812**
New MCs	0	0	3	2
TLS	45	12	63	52

Table 10
The tourist patient from points in the first time period.

WS_{spht}		MC							
Entry point	Patient type	h_1	h_2	h_3	h_4	h_5	h_6	h_7	h_8
s_1	p_1	57	237	63	203	197	0	169	103
	p_2	50	130	44	113	164	0	80	51
s_2	p_1	40	95	57	94	70	0	75	32
	p_2	24	62	31	76	58	0	21	12
s_3	p_1	46	94	58	135	107	0	104	63
	p_2	30	82	37	79	99	0	74	30

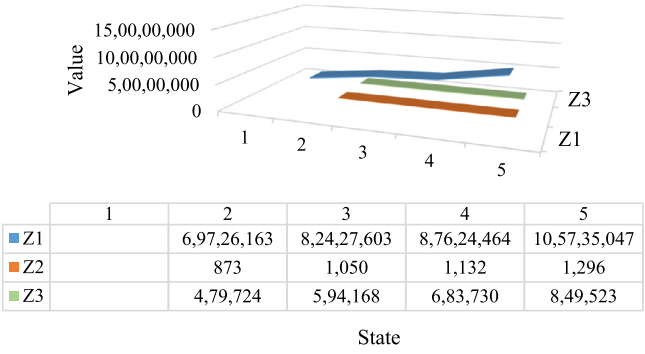
and Bound (B&B) method. The IMCGP is used to transform the presented multi-objective model to its single-objective one. The weight of each objective function is considered 0.3, 0.3, and 0.4, according to experts and decision-makers. The obtained values of each objective function and the value of IMCGP are given in Table 9. The total lack of services for tourist patients (TLS) is given to decide better about the prohibition policies to ban the entry points. The number of opened MCs are also reported as a New MCs in the tables. The goals are 50,000,000, 800 and 500,000, respectively for first to third objective functions. Some other key results are presented in Tables 10 to 12, the tourist patient from points in the first time period, the number of tourist patients in the first time period, and the opened MCs respectively.

Table 11
The number of tourist patients in the first time period.

ZW_{spt}	Patient type	
Entry point	p_1	p_2
s_1	1,029	632
s_2	1,661	284
s_3	607	891

Table 12
The opened MCs.

VB_{hb}	MC type	
MC	b_1	b_2
h_1	1	0
h_2	0	1
h_3	1	0
h_4	0	1
h_5	0	1
$\boldsymbol{h_6}$	**0**	**0**
$\boldsymbol{h_7}$	**0**	**1**
$\boldsymbol{h_8}$	**1**	**0**



	1	2	3	4	5
Z1		6,97,26,163	8,24,27,603	8,76,24,464	10,57,35,047
Z2		873	1,050	1,132	1,296
Z3		4,79,724	5,94,168	6,83,730	8,49,523

State

Fig. 1. The comparison of the value of objective functions.

5.3. Sensitivity analyses

The sensitivity analyses of some parameters, which would affect more to decision making are done. sensitivity analyses of the infection rate coefficient of the city and weights of the objective functions in the solution method are presented in Tables 13 and 14.

5.3.1. Sensitivity analysis of infection rate coefficient of the city

The infection rate coefficient of the city is one of the most influential factors to make decisions for the COVID-19 crisis. Hence, changing this coefficient can affect the results of the model impressively. This coefficient can be controlled in the city by applying entry ban rules at the entry points. This means that by reducing tourists and closing points, the infection rate can be controlled. The comparison of the value of objective functions is illustrated in Fig. 1 and the total lack of services for tourists (TLS) is shown in Fig. 2. The results of the sensitivity analysis of this parameter are reported in Table 13. As shown in Table 13 and Figs. 1 and 2, by decreasing the non-acute patients' infection rate, the TLS and new MCs will decrease; and the IMCGP reduced. Though, the whole chain got better. Therefore, it is necessary to control entry points to reduce the infection rate.

5.3.2. Sensitivity analysis on weights of objective functions

The weight of the objective functions in the solution method indicates the importance of that objective to the decision-maker. Therefore, changing the weight of the goals leads to significant changes in the results. Therefore, analyzing the sensitivity of

Table 13
Sensitivity analysis of minimum available medical services.

State	Infection rate coefficient of the city		Z1	Z2	Z3	IMCGP	New MCs	TLS
	p_1	p_2						
1	0.00001	0.0003	69,726,163	873	479,724	0.8636	1	48
2	**0.0001**	**0.0004**	**82,427,603**	**1,050**	**594,168**	**0.8812**	**2**	**52**
3	0.0002	0.0003	87,624,464	1,132	683,730	0.8649	1	59
4	0.0002	0.0004	105,735,047	1,296	849,523	0.9013	3	61

Table 14
Sensitivity analyses of weights of each objective function.

State	W1	W2	W3	Z1	Z2	Z3	IMCGP	New MCs	TLS
1	0.2	0.4	0.4	94,504,744	1,084	568,624	0.8216	1	57
2	0.3	0.3	0.3	84,548,146	1,109	374,720	0.8527	1	60
3	**0.3**	**0.3**	**0.4**	**82,427,603**	**1,050**	**594,168**	**0.8812**	**2**	**52**
4	0.2	0.3	0.2	91,406,664	1,067	416,684	0.8392	0	55
5	0.4	0.3	0.4	83,263,703	1,215	283,703	0.8103	3	62

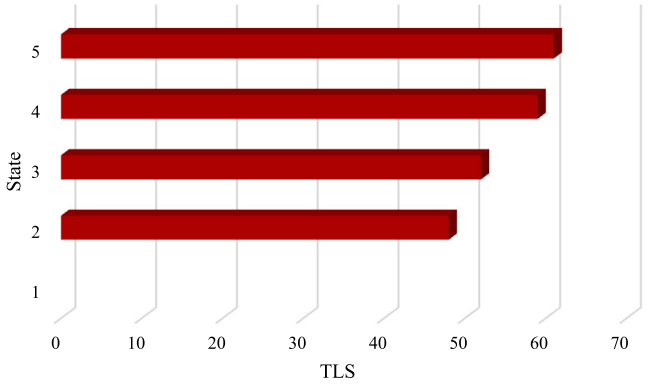


Fig. 2. The total lack of services (TLS).

this parameter and examining the changes in the results can help make better decisions. Table 14 demonstrate the different weights for objective functions and the key results. In state 5, by increasing the importance of the first objective function, the TLS and new MCs increased. In state 2, by decreasing the importance of the third objective function, the new MCs decreased but the TLS increased.

5.4. Managerial insights

Given the prevalence of the COVID-19 pandemic and the importance of controlling this crisis for communities, and considering the results of model solving and sensitivity analysis, the following management suggestions are provided for the regions affected by this crisis. Depending on the goals (minimizing the total cost, minimizing the tourist patients, maximizing the number of city patients), the following suggestions can help decision-makers make better decisions and reduce potential losses.

In all decisions and planning, cost is an important and influential factor that always increases in costs affects on other factors of the network. Therefore, in the proposed model, considering the cost, we can help the correct management of this crisis with mathematical planning. According to the aforementioned data and results, two medical centers with capacities of 300 and 700, potential MC 2 and 3, should be built to prevent the lack of medical services and to reduce injuries and casualties. Also, due to the minimum service available, these medical centers should be built.

Due to the importance of controlling the entry points to the cities and regions, to prevent and reduce the prevalence of COVID-19, the importance of the second and third objective functions becomes apparent. When the number of tourist patients in the city increases and there is no ability to care for and provide medical services to all patients in the city and tourist patients, this crisis should be managed by closing the entry points, which also helps the reduction of the infection rate in the city.

6. Conclusion

According to the impact of proper management on reducing losses and casualties in crises and the importance of COVID-19 pandemic control in the world, it is important to provide a comprehensive and regular program to control and improve the situation of this crisis. Iran and Mazandaran were one of the main regions involved in this crisis, which have been studied as a case study for the proposed model in this research.

The multi-objective and multi-period proposed model includes the city that tourists enter the area from entry points. Minimizing total cost, minimizing the tourist patients, and maximizing the number of city patients, are the objective functions of the presented model. City patients and tourist patients go to MCs to get medical services. Depending on the type of their disease, they receive services. There are two types of disease, acute and non-acute. the time of hospitalization is considered in the model. There are types of MCs according to their capacity. There are considered a minimum available medical services in MCs. So, the new potential MCs will be opened. If there is no city patient, tourist patients can be admitted and there is no shortage of services. By restricting entry points and route's ban policies, tourists should be prevented from entering the city.

The multi-objective model has been solved by the IMCGP method and to convert to a single-objective model. To evaluate the proposed model, a case study is considered and the data and results are described. Sensitivity analyses were then performed for more effective and sensitive parameters. Managerial suggestions are also provided to improve the COVID-19 crisis management process.

To expand the problem in the future, the uncertainty of some parameters can be considered in future research. For longer periods of time and larger areas and dimensions of the problem, meta-heuristic methods and some exact algorithms can be used. Other objectives can also be added to this problem and other variables such as transportation can be considered.

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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