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Fight against COVID-19: what can be done in the case of Iran?

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A B S T R A C T

In recent decades, several outbreaks have threatened societies and claimed many lives. Outbreak response management plays a crucial role in reducing the fatality rate and the total healthcare system cost. Among all the parameters affecting the performance of the outbreak response system, the available resources are one of the most important. This becomes critical when the number of infected people who need such resources is substantial. In such circumstances, the system cost and the death rate may significantly rise. Therefore, in this paper, we present an analysis of the impact of the contact frequency among people during an outbreak considering the capacity of the healthcare system expressed as the total number of hospital beds following a systems dynamics approach. We investigate the case of the novel Coronavirus, known as COVID-19, in Iran for which the results indicate the circumstances under which the healthcare system may become exhausted, and a catastrophe may occur. Finally, some suggestions are made based on the analysis of the results to avoid such circumstances.

1. Introduction

Human societies have been struggling with many outbreaks throughout the history, from the plague in 541 [1] to the recent novel Coronavirus Disease emerged in 2019 [2], known as COVID-19, which has identified to belong to the previously known Coronavirus family. Some of the most well-known Coronavirus variants are responsible for Severe Acute Respiratory Syndrome (SARS) and its Middle East counterpart (MERS). Table 1 presents a brief comparison of these three.

Table 1. *A brief comparison of the three most well-known coronavirus variants.*

Virus	Disease	Number Infected	Number Dead	Year	Fatality Rate	Reference
SARS-CoV	*SARS*	*8,096*	*774*	*2002*	*9.6%*	*Wong, et al. [3]*
MERS-CoV	*MERS*	*2,442*	*842*	*2012*	*34.5%*	*Donnelly, et al. [4]*
2019-nCoV	*COVID-19*	*148,052*	*5,544*	*2019*	*3.7%*	*World Health Organization [5]*

As shown in Table 1, although the COVID-19 fatality rate is considerably lower than that of the other two variants, the number of infections world-wide is extremely larger than that of others. The 2019-

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nCoV has a large reproduction number [6] which makes it the cause of the current dangerous global pandemic disease. For some countries, the impact has been more severe. More specifically, China, as the first country hit by the virus, Italy, Iran, and South Korea are the countries with the most number of confirmed infected cases on 14 Mar 2020. Iran, as one of the most hardly hit by COVID-19, had a critical situation on 20 Feb 2020 to 3 Mar 2020 [7] and has a confirmed Case Fatality Rate of 0.048 based on the data available on 15 Mar 2020.

One of the most important factors that affects the fatality rate, is the healthcare system capacity. In case of an outbreak, the epidemic disease can be controlled as long as the number of infected people remains below the total capacity. If not, the number of people who die increases significantly both due to the epidemic infection, and the lack of the service to other patients with emergency conditions. Therefore, analyzing the impact of the parameters that affect the total number of infected people at each time is crucial.

In this paper, the impact of the contact frequency among people and the total susceptible population are focused on to present the analysis of their impact on the behavior of the COVID-19 outbreak in Iran considering the total capacity of Iran's healthcare system, defined in the total number of beds available following a systems dynamics approach. The exposition of this paper is organized as follows. In Section 2, the material and methods are discussed. The results are presented in Section 3, and Section 4 concludes the paper.

2. Material and Method

In this section, a brief description of the data, the nomenclature, the equations and the model of the problem are discussed.

2.1. The Data

The data for the number of confirmed cases, the death cases, and the recovered cases are provided by the Iran Ministry of Health and Medical Education. The data are collected for the period between 18 Feb 2020 and 15 Mar 2020.

2.2. The Model

In this section, a systems dynamics model of the COVID-19 outbreak is presented. Fig. 1 depicts the model and its elements implemented in Vensim Software. In the proposed model, there are four level variables to represent the "population susceptible to COVID-19", the "population infected with COVID-19", the "population dead due to COVID-19", and the "population recovered from COVID-19". It is assumed that the "population susceptible to COVID-19" is the total number of people who will eventually be infected, will develop clinical symptoms of the disease, and need hospitalization.

There are three flows transferring the inventories (levels), namely, the "infection rate", the "death rate", and the "recovery rate". The "infection rate" is assumed to be a function of "the contact between the infected and uninfected people" and the "infectivity" of the disease, while the "death rate" is a function of the "population infected with COVID-19", "mortality", and the "sickness period". The "recovery rate" depends on the "population infected with COVID-19" and the "sickness period".

The parameters of the model are either obtained or estimated using the available data and information, or tuned to fit the number of observed cases. Some of the parameters including the "contact frequency" and the "proportion of total population infected" are then used to analyze the outcomes of the outbreak under different scenarios.

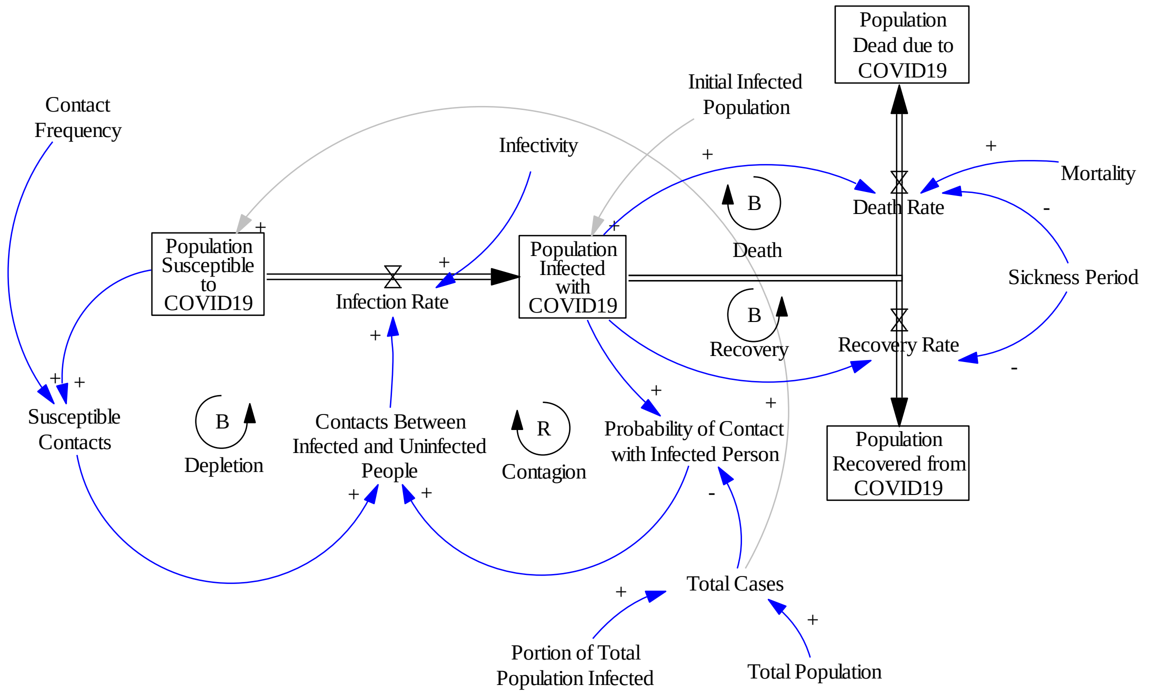

Fig. 1. COVID-19 outbreak dynamics model.

3. Results

In this section, the model is validated by providing a comparison between the real number of confirmed death cases and the simulated number of death cases. Then, the simulation of the model assuming the parameters that fit the current real number of confirmed death cases is presented and discussed. Finally, nine scenarios are analyzed considering three levels for each of the parameters "portion of the total population infected" and "contact frequency".

3.1. The Validation of the Model

The number of confirmed death cases is chosen as a criterion for validation because among the confirmed cases, confirmed recovered cases, and confirmed death cases, the latter is the most reliable as this is most seriously tracked by the authorities and public. Fig. 2 depicts a comparison between the real number of confirmed death cases and the simulated number of death cases. The graph shows the reasonable accuracy of the model. Numerically, the average relative error of the model for the first fortnight of March 2020 is 3.86% showing the validity of the model.

According to Fig. 3, the real number of confirmed cases may be far less than the simulated values. A justifiable reason is that there may exist several undetected cases due to several reasons, including lack of test kits, early death before testing, other diagnoses, etc. In fact, this graph expresses a potentially significant fact: there may be far more cases than the real number of confirmed cases. A similar argument is true for the real number of confirmed recovered cases as depicted in Fig. 4.

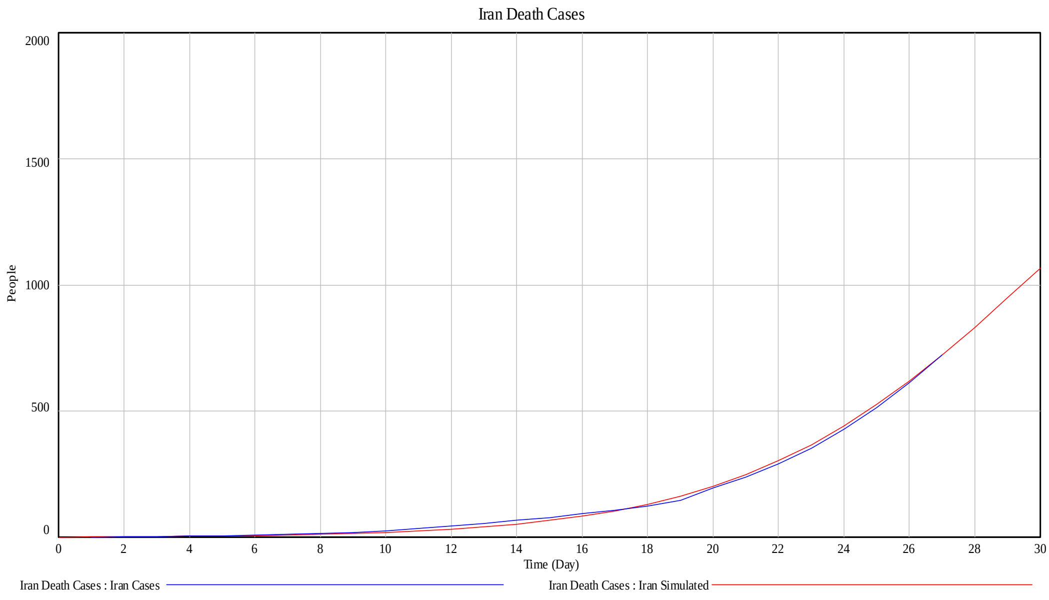

Fig. 2. *A comparison of the real number of confirmed death cases and the simulated death cases (30 days).*

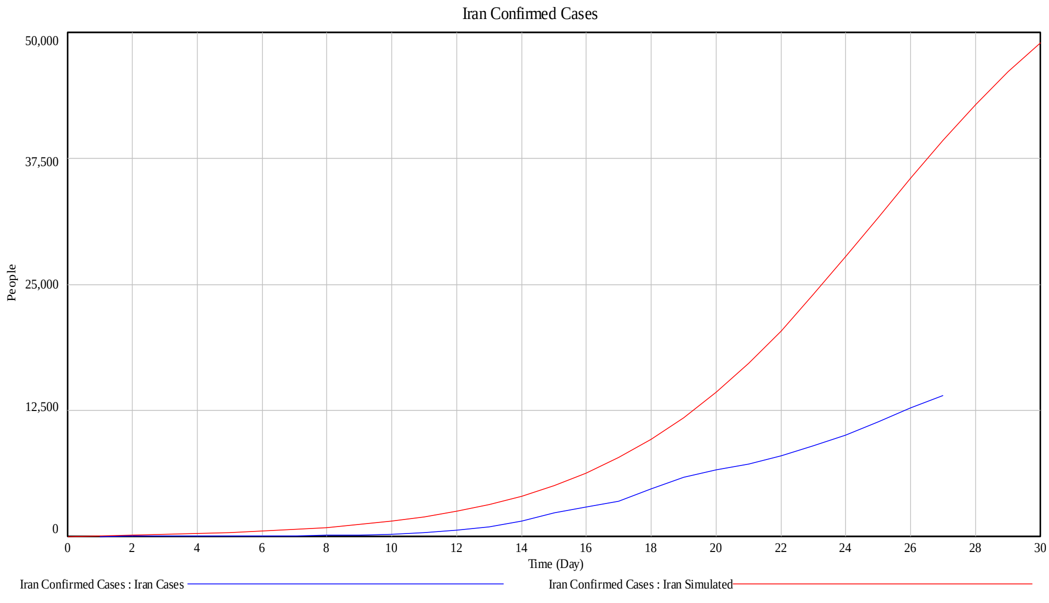

Fig. 3. *A comparison of the real number of confirmed cases and the simulated number of cases (30 days).*

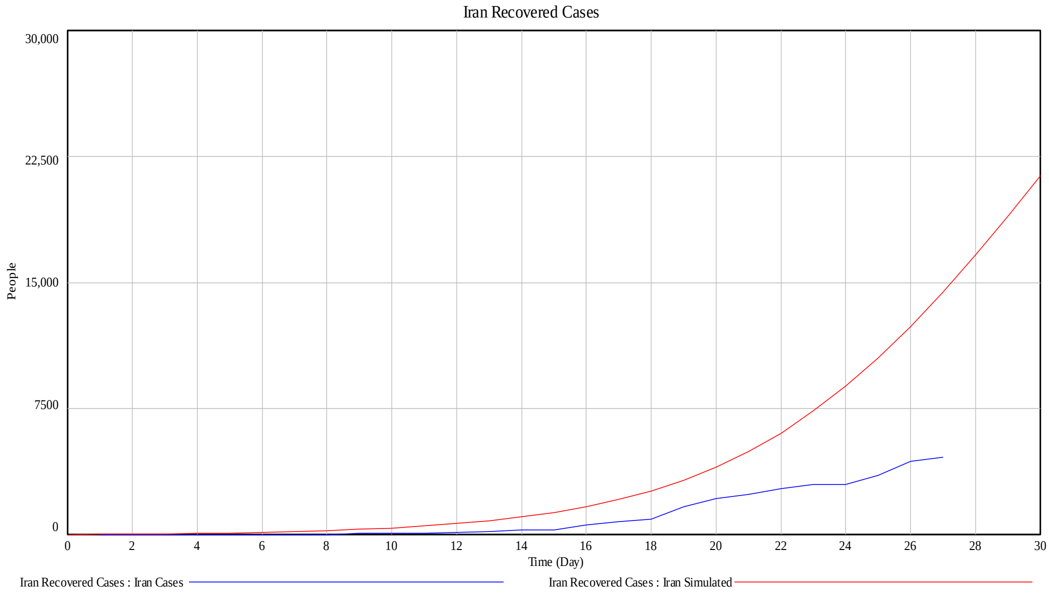

Fig. 4. *A comparison of the number of confirmed recovered cases and the simulated recovered cases (30 days).*

3.2. The Simulation of Current Situation

Assuming the parameters that fit the current real number of confirmed death cases, the simulation was run for 90 days from 18 Feb 2020. According to Fig. 5, the total number of death cases may reach more than 3000 in 90 days.

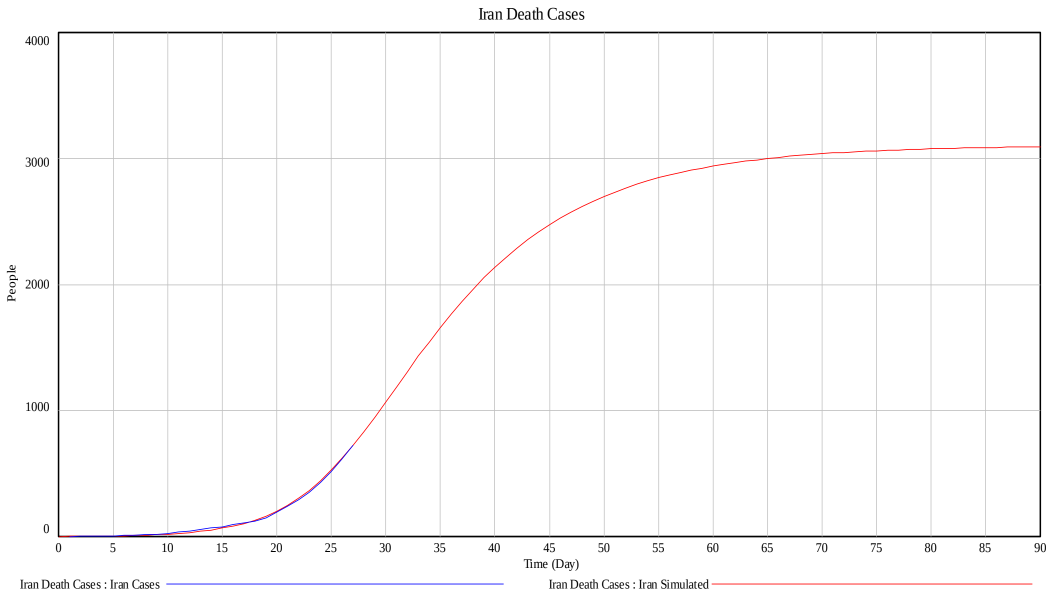

Fig. 5. *Simulated number of death cases (90 days).*

Fig. 6 depicts the number of infected population through time. It is critically important to compare this number to the total available beds in Iran. The total number of hospital beds and intensive care unit (ICU) beds in Iran are 150,000 and 15,000, respectively. From the former about 50,000, and from the latter about 10,000 are often occupied, leaving 100,000 hospital beds and 5,000 ICU beds available. From Fig. 6, it can be seen that in the third week of the outbreak, this number exceeds 5,000 and rises to over 24,000 in the fourth week which is far beyond the number of ICU beds. However, since a portion of the confirmed cases (around 25%) may need an ICU bed, the only period during which there may be a shortage of ICU beds will be the fourth week and fifth week, i.e., from around 9 Mar 2020 to around 23 Mar 2020. Fortunately, assuming the parameters under which the simulation is run, there will be no shortage for hospital beds.

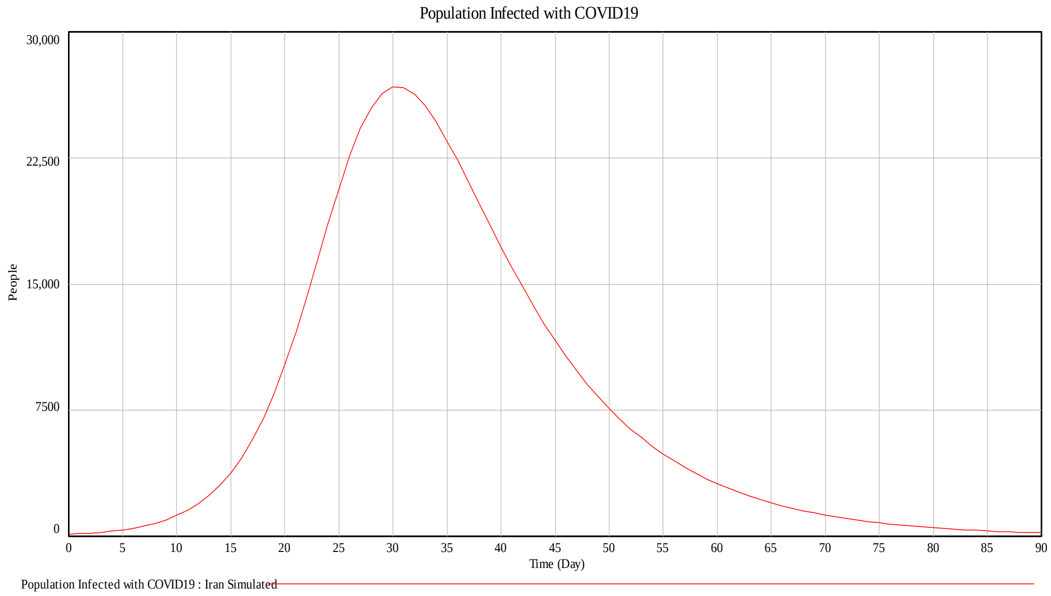

Fig. 6. *Simulated number of population infected (90 days).*

To obtain the above results, the parameters of the models are determined as presented in Table 2. The "contact frequency" is determined to fit the actual data, and the value is also against the common sense. The infectivity is tuned to fit the actual data. In addition, the value is verified through seeking the experts' opinions, and comparison with similar outbreaks, e.g., SARS where the number is about 0.047. To obtain the "initial infected population", the initial number of death cases is used. More specifically, knowing that the initial number of death cases is 2, and the fact that the global death rate is about 3%, the "initial infected population" is initially set to 67. Then the parameter is tuned to fit the actual data. For the "portion of total population infected", the number of different countries vary from 0.00005 to 0.0002; therefore, the initial value for this parameter is set to lie in this interval. Then, the parameter is tuned so that the model is fit to the real data. The "sickness period" is considered to be the average for the observed sickness periods reported by health authorities. Finally, the "mortality" is initially set to the global value for COVID-19, i.e., 3%, and then, the parameter is tuned so that the model fits the actual data. This is in agreement with the findings of Jung, et al. [8] who found a 95% confidence interval for the confirmed case death rate to be in $(3.5\%, 7.5\%)$ in one scenario, and $(5.3\%, 12.3\%)$ in another.

Table 2. *Parameters values.*

Parameter	**Value (Unit)**
Contact Frequency	*6 (People per Person per Day)*
Infectivity	*0.06 (Dimensionless)*
Initial Infected Population	*120 (People)*
Portion of Total Population Infected	*0.0008 (Dimensionless)*
Total Population	*83,992,949 (People)*
Sickness Period	*11 (Days)*
Mortality	*0.05 (Dimensionless)*

3.3. The Scenarios

In this section, nine scenarios are analyzed considering three different values for each of the two variables of “portion of the total population infected” and “contact frequency”. The scenarios are depicted and encoded in Table 3.

Table 3. *Scenario codes and changes in the corresponding parameters.*

Contact Frequency (People per Person per Day) ➔ Portion of the Total Population Infected (People) 🡻	**-1**	**0**	**+1**
–10%	*LL*	*LC*	*LH*
0	*CL*	*CC*	*CH*
+10%	*HL*	*HC*	*HH*

Assuming a 10% decrease in the portion of the total population infected in comparison to its current situation, the three scenarios of people contacting the current number of persons, one person less and one person more are analyzed, and the results are illustrated in Fig. 7 and Fig. 8.

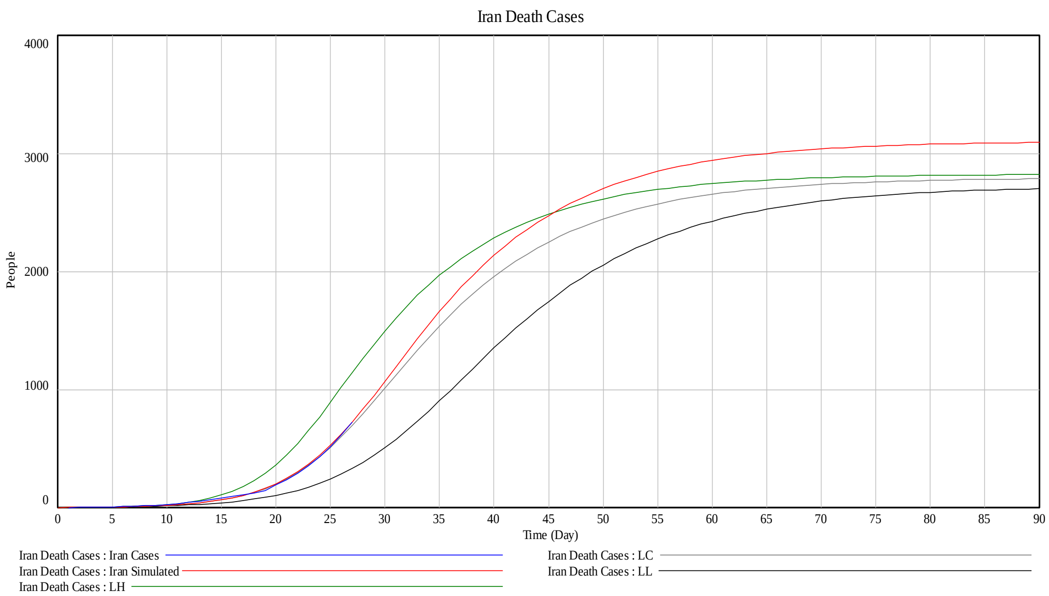

Fig. 7. *The illustration of the death cases in the current situation and the real data, LL, LC, and LH scenarios.*

Similarly, considering the current portion of the total population infected, the corresponding scenarios are CL, CC, and CH, which are depicted in Fig. 9 and Fig. 10. Finally, assuming a 10% increase in the current portion of the total population infected, three scenarios of HL, HC, and HH are simulated for which the graphs are shown in Fig. 11 and Fig. 12. The data summarized in Table 3 show that in current situation, if people decrease their contact frequency by one person per day, they can prevent more than 90 deaths. The social distancing becomes more significant if the portion of the total population infected is 10% higher than its current value. In this case, decreasing the contact frequency by one unit can save more than 100 lives. In general, such decrease may prevent more than 740 deaths under different scenarios.

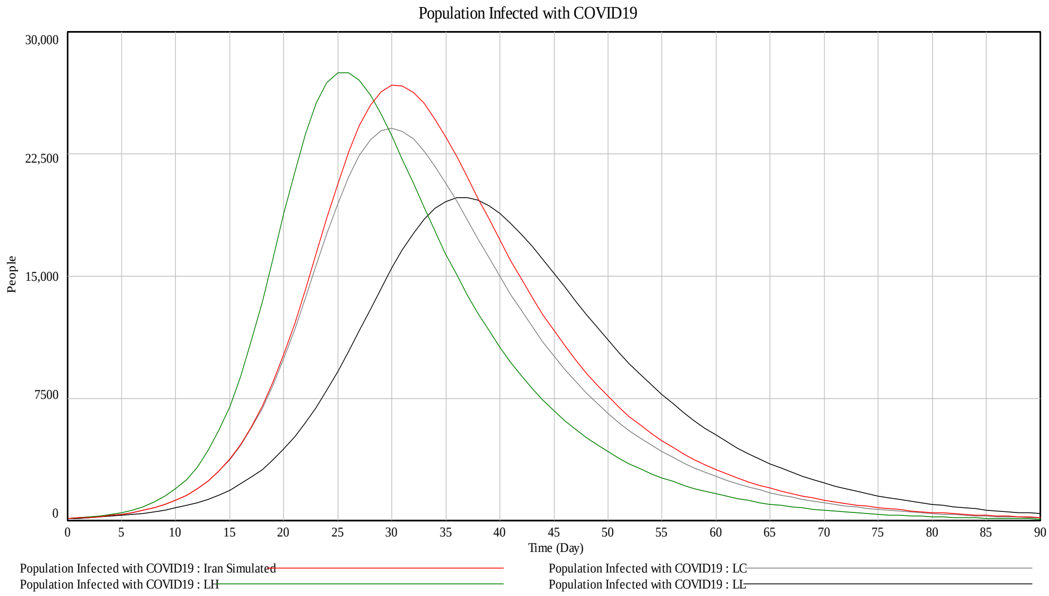

Fig. 8. *The illustration of the infected cases in the current situation and the real data, LL, LC, and LH scenarios.*

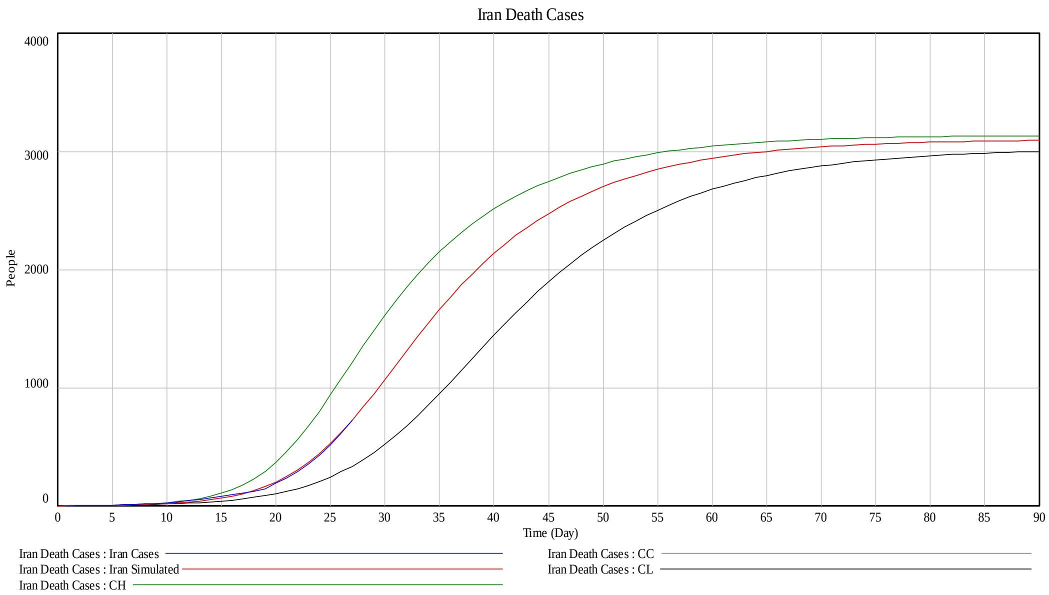

Fig. 9. *The illustration of the death cases in the current situation and real data, CL, and CH scenarios.*

These are the estimated deaths cases due to COVID-19. More importantly, as shown in Table 4, the total number of people infected may vary from 19,930 to 33,640, a 13,810 difference. This is more than the available number of the ICU beds in Iran! Considering the current situation, the maximum number of infected people through time is 26,710 while if the contact frequency is decreased by one unit, it can be lowered to 22,040. Assuming that 25% of the people with the clinical symptoms of COVID-19 will need ICU, in the current situation, 6,678 ICU beds are needed while if people decrease their contact frequency by on person per day, 5,510 ICU beds will be needed. The former is far beyond the number of ICU beds available while the latter is approximately equal that number. In the former case, the number of deaths will increase significantly not only due to the COVID-19 itself, but also because pushing the healthcare system to the edge of its capacity and beyond can exhaust the service providers leading to more deaths caused by those who need ICU and cannot get the service they need. This indicates the crucial role of social distancing, especially in case of Iran.

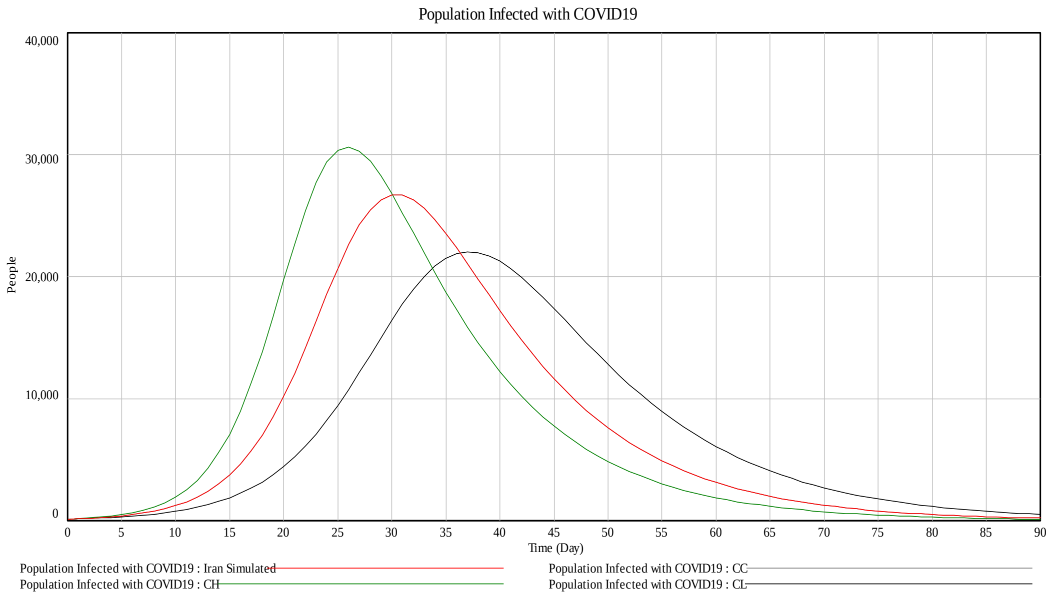

Fig. 10. *The illustration of the infected cases for the current situation and the real data, CL, and CH scenarios.*

Finally, the total number of infected people may vary from 57,030 to 72,350. A more than 15,000 difference between the numbers of cases under different scenarios emphasizes the significance of social distancing. This number of cases may have huge social and economic impact on Iran, and must be considered very carefully.

Another critical impact of decreasing the contact frequency is the subtle fact that it postpones the time at which the outbreak reaches its maximum number of cases, allowing preparation of healthcare resources that leads to a better outbreak response management. In other words, while under the current situation the maximum number of cases is expected to be observed on the fourth and fifth week, if the contact frequency is decreased, it is postponed to the fifth or sixth week.

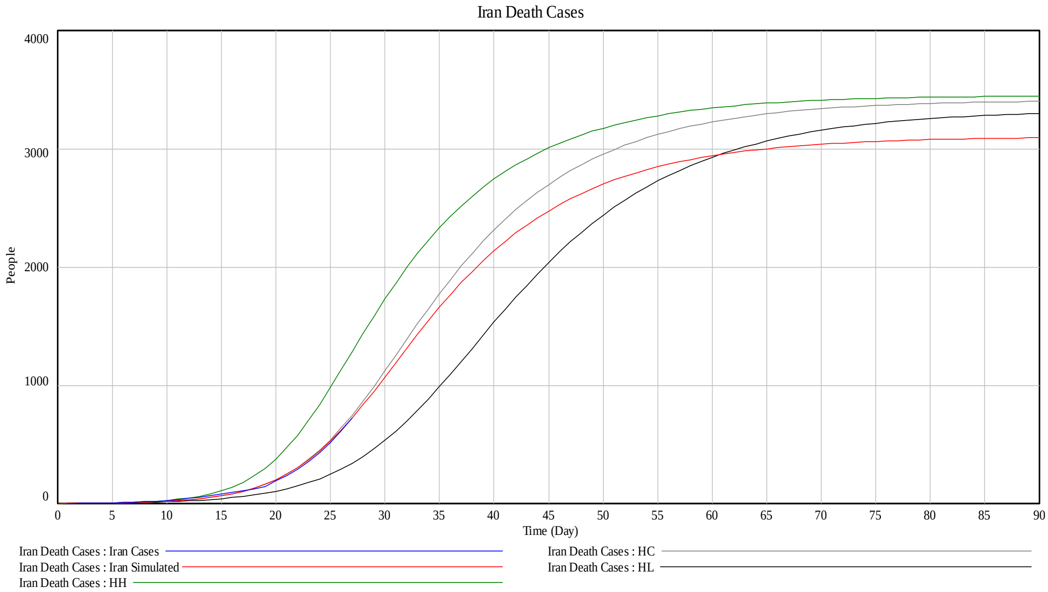

Fig. 11. *The illustration of the death cases in the current situation and the real data, HL, HC, and HH scenario.*

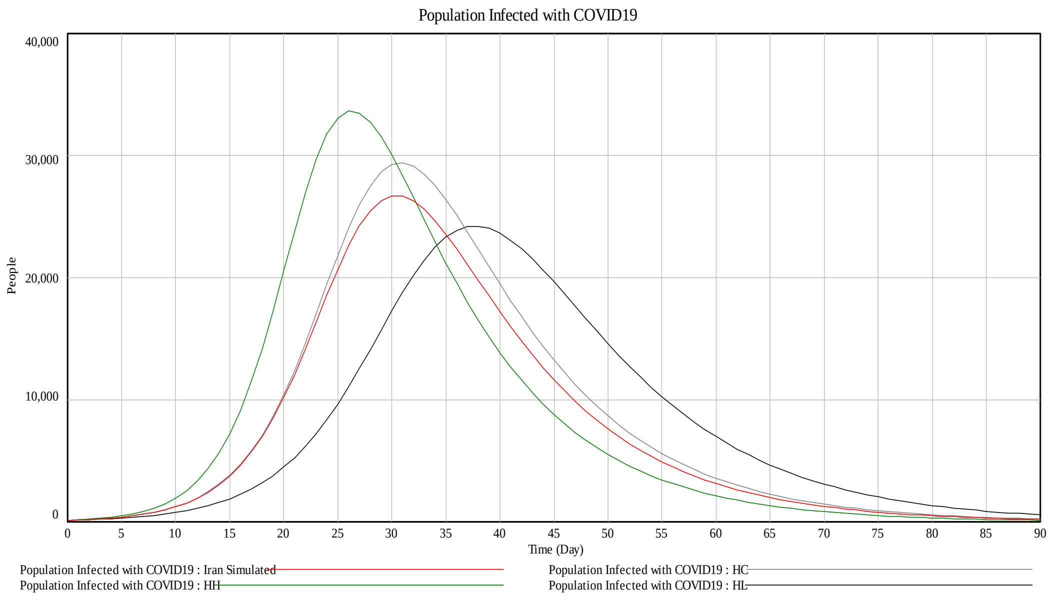

Fig. 12. *The illustration of the infected cases for the current situation and the real data, HL, HC, and HH scenarios.*

Table 4. *The number of deaths cases under different scenarios.*

Contact Frequency (People per Person per Day) ➔	**Death Cases**			**Total Infected**			**Maximum Infected**		
Portion of the Total Population Infected (People) 🡇	**-1**	**0**	**+1**	**-1**	**0**	**+1**	**-1**	**0**	**+1**
–10%	*2,701*	*2,784*	*2,820*	*57,030*	*58,520*	*59,190*	*19,830*	*24,080*	*27,510*
0	*2,999*	*3,092*	*3,133*	*63,360*	*65,020*	*65,770*	*22,040*	*26,710*	*30,620*
+10%	*3,297*	*3,401*	*3,445*	*69,690*	*71,520*	*72,350*	*24,220*	*29,400*	*33,640*

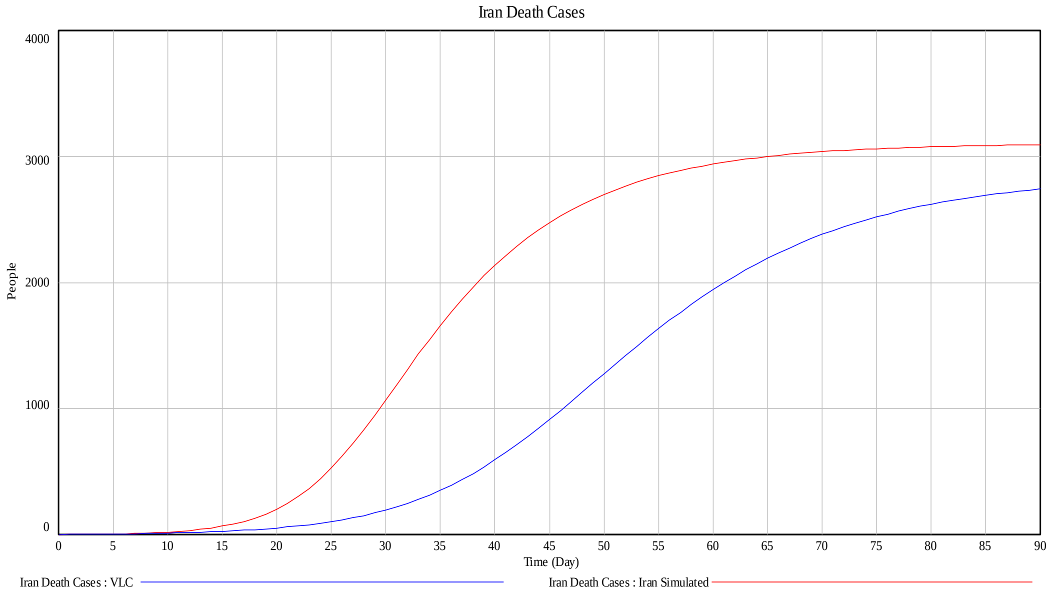

Fig. 13. *The impact of decreasing the contact frequency by 2 units on the number of death cases.*

As the final analysis, considering a decrease of 2 person per day in contact frequency, the maximum number of infected people will be 16,250 occurring on the tenth and eleventh week. Assuming that 25% of these infected people will need ICU bed, 4063 beds will be required which is within the Iran healthcare system capacity. Under such conditions, the number of deaths is also decreased to 2,742 resulting in saving 350 lives. This is depicted in Fig. 13 and Fig. 14.

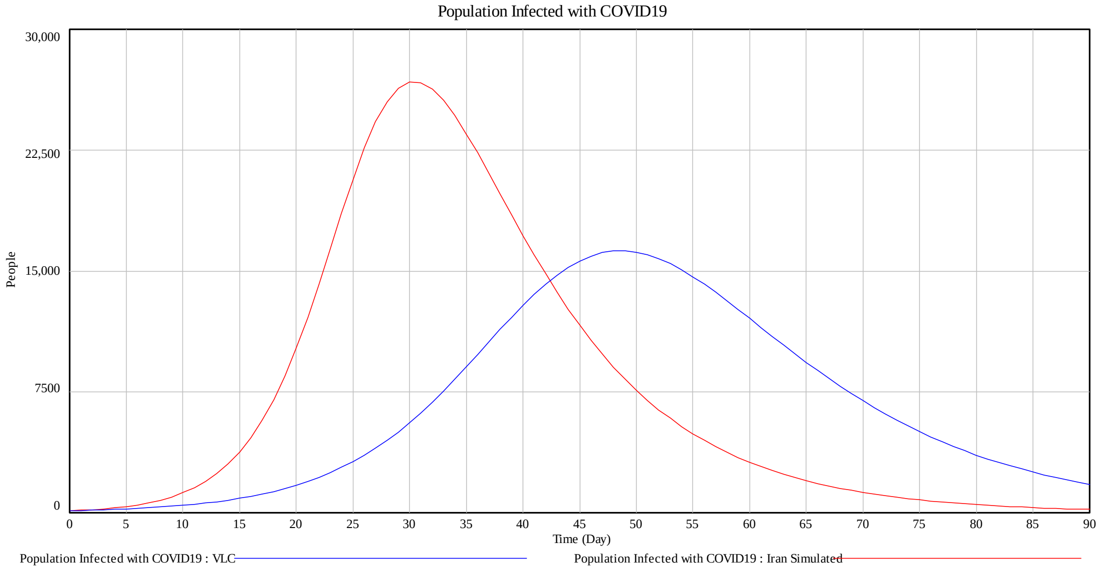

Fig. 14. *Comparison of the infected cases if the contact frequency is decreased by 2 units with the current situation.*

4. Conclusion

In this paper, an analysis of the impact of significant parameters on the COVID-19 outbreak in Iran was investigated. The model for the dynamics of the epidemic disease is developed and validated against the real data. Various analyses are conducted and several scenarios are studied to shed light on the influence of the parameters on the possible outcomes. The results showed the significance of the social distancing and self-isolation, especially under the scenarios where the portion of the total population infected is assumed to be high.

For the case of Iran there is a great opportunity to decrease the contact frequency by even more than one unity, and that is the national holidays of for the New Year, i.e., Norouz. The decision-makers must take advantage of this opportunity to encourage people to stay at their home by convincing them to do so by describing the underlying reasons through various media. If not, there is threat that Iranian people who have the tradition of visiting families and friends during these days, actually increase the number of people they visit every day by even more than one person per day which may result in a national and even global disaster.

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