JIDC | THE JOURNAL OF INFECTION IN DEVELOPING COUNTRIES

Coronavirus Pandemic

Time Series Modelling and Simulating the Lockdown Scenarios of COVID-19 in Kurdistan Region of Iraq

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Abstract

Introduction: Since the first published cases of the Coronavirus disease known as COVID-19 in the city of Wuhan Hubei Province in China, up to the time of preparation of this report in mid-September 2020 more than 30 million people have been infected all over the world. In March 2020, more than 300,000 cases have been reported all over Iraq. This study aims to represent data analysis, modelling and forecasting approaches to the presented data in the Kurdistan Region of Iraq.
Methodology: The project involves mathematical models for forecasting and artificial simulations using particles. In the study, time series models including Simple Exponential Model, Holt's Method and Brown's Models have been used for the forecasting of the future potential rates in the area. A series of simulations have been conducted to observe the possibilities of virus spread rates in a virtual world, which represents a quarter of Erbil.
Results: The outcome of the study shows how the disease have spread in Kurdistan, and what are the current rates in comparison with the neighbouring regions. The modelling clearly shows that with cases still sporadically appearing, the risk of second and third waves of infections is high.
Conclusions: Therefore, the regional government must reduce unnecessary gatherings to the lowest possible level. A scientific registry system of disease statistics must be put in place and rigorously updated all the times. We recommend that the officials use a nationwide database provided to the public to monitor movement of every infected individual, to prevent further spread.

Key words: AI Simulations; Time Series Modelling; Forecasting; COVID-19; Iraq; Kurdistan Region.

J Infect Dev Ctries 2021; 15(3):370-381. doi:10.3855/jidc.13993

(Received 24 September 2020 – Accepted 25 January 2021)

Introduction

The rapid spread of coronavirus, aka COVID-19, has threatened humanity all over the world. Scientists in various disciplines have tried to find solutions to prevent further damage of the virus. Nevertheless, since December 2019, when the first cases of the virus appeared in Wuhan city of China, up until September 2020, it has affected almost 30 million people and killed around 1 million, while 20 million have recovered. Every single country in the world has reported its numbers of cases to WHO, and it has been officially declared the crisis of the century. Iraq has not been an exception, and stands in a similar situation compared to its neighbours, shown in Table 1. According to our data, the total case per one thousand residents in Iraq is approximately 7.51. The infection rates are higher than Iran and Turkey, but lower than what Saudi Arabia and Kuwait have reported. The data shows that Kuwait has suffered from the virus with the highest rate in the area and Syria registered the lowest cases. However, the virus proves deadlier in Iran and Syria than the rest of countries in the area. The dataset has been updated upto 16 September 2020. The matter of quarantine was taken seriously in the Kurdistan Regional Government, compared to the central government of Iraq. Between 5 march 2020 and June 2020, the regional government had ordered people to stay at their homes and not go out except for emergencies. Most community centres had been closed, educational sections running their sessions online and traveling to other cities had been banned, while the air and ground port functions had been limited or closed. These quick measures proved to be effective in comparison to the neighbouring countries. The quarantine did not last for long and in the beginning of June 2020, people demanded that the government must loosen the situation. The unfortunate results of such actions could be seen in Figure 1 A and Figure 1 B, Kurdistan region registered more than 38,000 total cases of COVID-19 and about 1400 deaths. The rate per 1,000 people stays around 7.7, which is higher than Iraq itself.

Table 1. Iraq and its neighbors situation on COVID-19 between March 1 and Sep 16 2020.

Country	Population	Total Cases	Total Death	Case Per 1000 Residents	Death Per Case
Iraq	40,345,531	303,059	8,248	7.5116	0.0272
Iran	84,137,590	410,334	23,632	4.8769	0.0576
Turkey	84,460,833	296,391	7,249	3.5092	0.0245
Saudi Arabia	34,887,091	327,551	4,369	9.3889	0.0133
Jordan	10,216,709	3,852	26	0.3770	0.0067
Kuwait	4,279,091	96,999	571	22.6681	0.0059
Syria	17,558,760	3,654	163	0.2081	0.0446

Aims and Scope

This study focuses on the present and future of the situation in the region. We have targeted several questions to be answered throughout this research.

First: What would the situation be, had the region stayed without the isolation (lockdown)?

Second: What type of places should remain closed in a community?

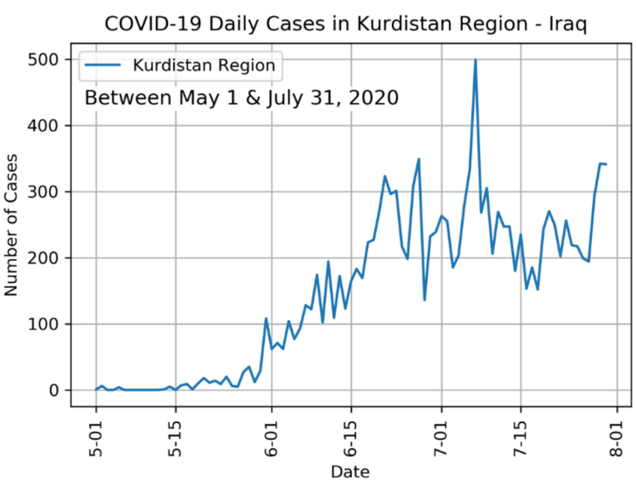
Third: What are the next steps the government must take to decrease or eliminate new infections?

Fourth: How have the health and government authorities performed in comparison with regions with similar properties such as population, age intervals and health system?

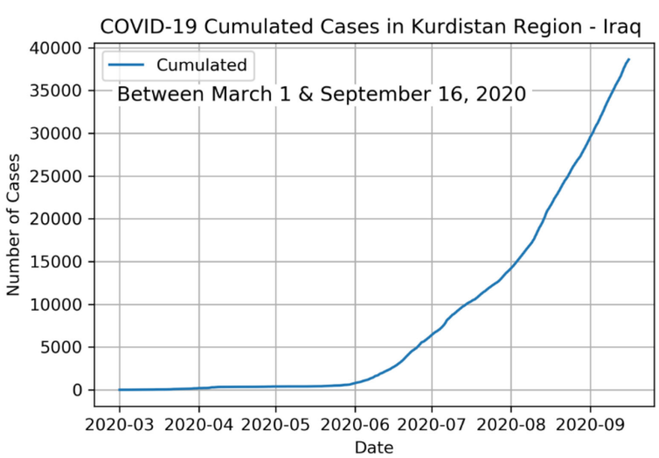
Fifth: How should the regional or central government react to the new economic perspectives?

The main aim of this project is to statistically analyse all available data, use simulations and mathematical modelling to give scientific evidence that a strict isolation system will prevent further spread of the disease in the future. The analysis also provides an in-depth statistical data analysis of the COVID-19 spreading dynamics in Kurdistan. We later demonstrated through a series of animations how the population could be entirely infected with COVID-19 if isolation rules are not fully and strictly enforced, or even under-loosening those rules. Mass gatherings have proven to be the easiest way to spread out the virus. Religeous ceremonies, classrooms, cafes, restaurants, and community gatherings were all banned. However, a few places acted out and caused a number of infections in April 2020. One of the places that was affected with this interdiction, is Karezan neighbourhood, in the city of Erbil. The location map shown in Figure 2 has been selected as a model for the

Figure 1. Daily and Cumulated Cases of COVID-19 in Provinces of Kurdistan Region, Iraq (May – July 2020).

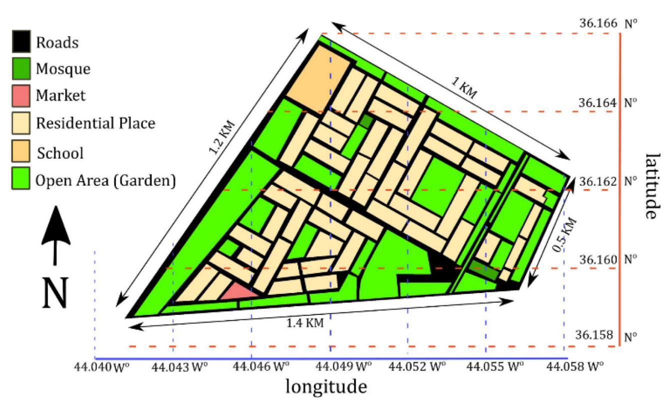


(A) Daily Cases



(B) Cumulative

Figure 2. Map of Karezan Neighborhood in Erbil, The Capital of Kurdistan Region, Iraq, for Simulation.



simulation and scenarios throughout this research. The model is an open system that can be adapted to any location, city, and population numbers.

Literature Review

The rapid spread of COVID-19 has motivated scientists all over the world to base their research on the task. Researchers of computational and mathematical sciences have approached the problem with data modelling and time series models. Most of the works that formed the basis of this study were published during March and April of 2020. Researchers of [1] have used *Exponential Smoothing* for prediction of the new cases for the incoming week. On the same area, the authors of a similar study [2] have used *Susceptible-Infectious-Recovered-Dead* (SIDR) model for predicting per day infection and recovery rates. In the research [3], the *Box-Jenkins* models and *Curve Estimation Models* are used for predictions for eight countries, including Turkey. Several show cases present the future of our societies in the case of mass spreading. The majority of studies suggest that the social distancing and "*Stay at Home*" has a significant role in the elimination of the virus. The study [4] claims that another massive wave of infection from the virus is on the way. They predicted that the situation will obtain the ordinary form no earlier than 2024. Some of the researchers have focused on specific zones. The authors of [5] have focused on the *Diamond Princess* cruise ship cases and formed a model that applies specifically to that ship. Few studies focused on the steps and mechanisms that a government must take for further prevention. The travel bans and restrictions are mentioned in [6], which uses the present data to form a model on how the travel ban delayed the spread of diseases in China and its effects on the international scale.

Methodology

Simulation

The map of Karezan neighbourhood has been geographically redrawn in the form of a single picture, with normalized colours, rotated, and presented as one single Numpy array [7]. Where each colour represents a type of building or an area, it is shown as animations on the dimension of time for each scenario. The virtual world has a semi-randomized population that represents a single community in the region. The reason we call it semi-randomized is because we have intentionally selected few virtual citizens to have some pre-existing conditions that are vulnerable to COVID-19. The ages of virtual citizens are randomly determined up to 75 years, which are the average ages in the region according to the data we have from Ministry of Health. The population distribution over residences is entirely random, because there is no data to suggest an area to be populated differently than another. The artificial citizens live their lives from a time window that begins at 9 am and ends at midnight. It is assumed that there will be no movement after that time, or simply we monitor the life of the AI particles within that range of time per day. Their behaviour relies on the scenario they

Table 2. COVID-19 cases in Iraq provinces between March 1 and Sep 16 2020.

Province	Population	Total Cases	Total Death	Infection Rate	Death Rate	Death Per Case
Al Anbar	1,661,000	3,740	67	2.2517	0.0403	0.0179
Babil	1,931,700	12,346	446	6.3913	0.2309	0.0361
Baghdad	7,665,000	86,311	2,206	11.2604	0.2878	0.0256
Basra	2,796,000	26,810	697	9.5887	0.2493	0.0260
Dhi Qar	1,979,000	15,783	635	7.9752	0.3209	0.0402
Diwanyiah	1,320,000	11,945	328	9.0492	0.2485	0.0275
Diyala	1,548,000	8,169	196	5.2771	0.1266	0.0240
*Duhok	1,218,700	8,223	142	6.7474	0.1165	0.0173
*Erbil	1,712,700	14,941	498	8.7237	0.2908	0.0333
*Halabja	186,000	1,282	23	6.8925	0.1237	0.0179
Karbala	1220300	18,283	391	14.9824	0.3204	0.0214
Kirkuk	1,515,600	11,646	473	7.6841	0.3121	0.0406
Misan	1,059,644	11,811	301	11.1462	0.2841	0.0255
Muthanna	775,900	9,366	191	12.0711	0.2462	0.0204
Najaf	1,389,000	15,761	204	11.3470	0.1469	0.0129
Nineveh	3,500,000	8,186	244	2.3389	0.0697	0.0298
Salahadin	1,509,000	6,393	136	4.2366	0.0901	0.0213
*Sulaymaniyah	1,937,000	14,166	749	7.3134	0.3867	0.0529
Wasit	1,360,000	17,897	321	13.1596	0.2360	0.0179

* Province under control of Kurdistan Regional Government.

inhabit. We have created several scenarios, which are sets of policies that apply to a community. For instance, in a scenario where all citizens remain at home, *AI* particles do not exit out of their homes. The simulation world code is available at https://github.com/MiladAbdullah/covid19-kurdistan.

Tools and Data

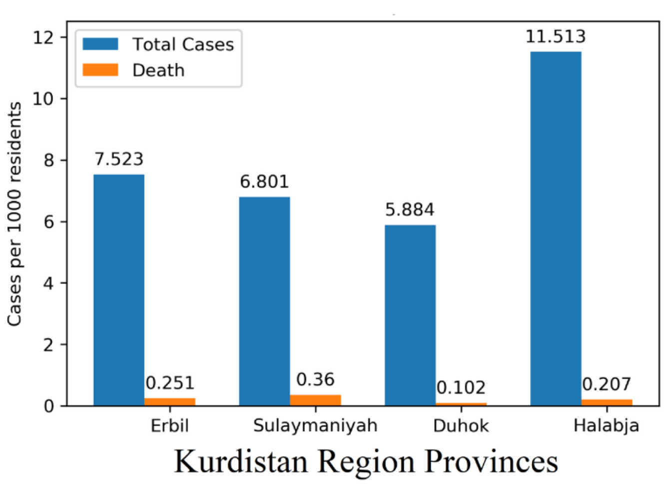
Two types of data were available: First, the data originating from government statements on *Corona* statistics in the region including news and records of new cases, recoveries, and deaths Second, the data from simulation which could be known as virtual data, including records of events each habitant of the artificial world formed. The implantation uses *Python 3.7* for the *backend* and most of *front-end* development. The statistical models were imported from StatsModels [8]. In order to produce plots and figures, we have used Matplotlib: A 2D Graphics Environment [9]. For mathematical approaches and matrix designs, we have used The NumPy Arrays [10]. Creating animations and maps were done with PIL: Python Imaging Library Aka Pillow Images. For illustrating a view to the masses and government, videos are created using OpenCV in Python [11].

Statistics

Iraq Situation in General

According to our data, Iraq has registered more than 300,000 cases of COVID-19 in all provinces. Table 2 shows the number of total cases recorded in each province of Iraq up until 16 September 2020. Although Baghdad suffered most of the cases. The city has the highest population of more than 7 million people. To tackle the issue precisely, we considered comparing four Kurdistan Region provinces (Erbil, Sulaymaniyah, Duhok, and Halabja) with the rest of Iraq, taking in consideration per-capita infection and death. As it is mentioned in the data, both cities of Erbil and Sulaymaniyah are similar and are within average of the rest of Iraq, while Dohuk had higher rate of infection amongst them. The previous table shows that Karbala had the highest rate of COVID-19 cases relative to its population. Here,we could argue that the reason behind the vast spread of the virus in Karbala, could be caused by the city being a central religious place for Shia muslims pilgrims where they gather in large groups and perform religious rituals that require mass gathering. Also, it could be argued that covid-19 testing is taken more seriously in the travel destinations, uncovering thus higher number of cases in such places. However, the virus shows less deadly in that area, and it has killed more people in the province of Sulaymaniyah as stated in the dataset.

Figure 3. COVID-19 Cases and Deaths per 1000 resident in Provinces of Kurdistan Region, Iraq.



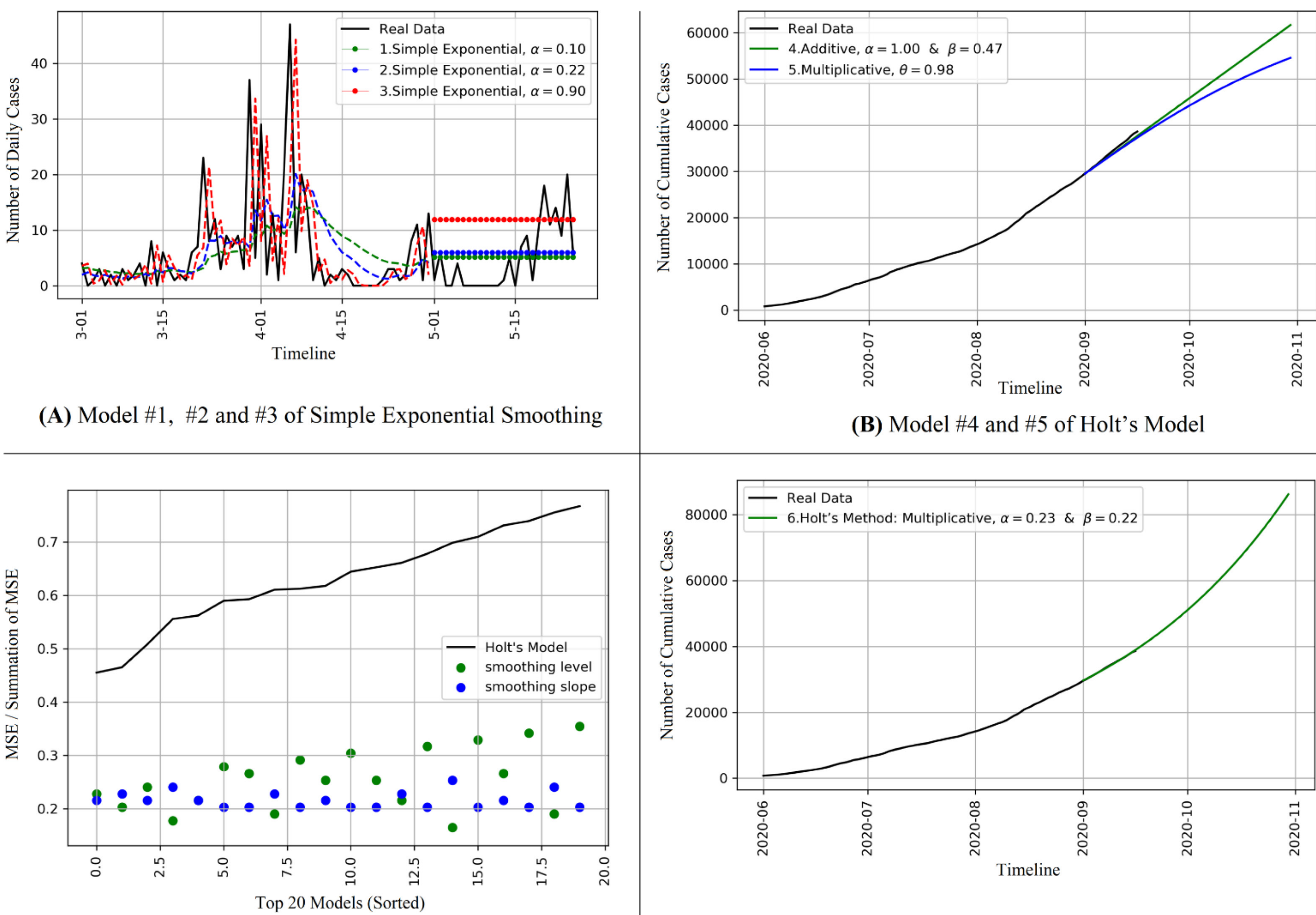
Kurdistan Region Status

Kurdistan Region, located in the northern Iraq, has been recording the COVID-19 cases since the beginning of March 2020. The regional government enacted strict mechanisms to avoid mass gatherings, and determined that people must stay at their homes. This did not go well for people whose income relies on going out and finally it deteriorated the internal economy. People denied following these kinds of harsh rules and in June 2020 they broke most of lockdown rules. Such acts raised the virus spread, obvious and clear in what is shown in Figure 1A. The situation regarding the disease in the Kurdistan region, up until September 16, 2020, is stated in Table 3. Each of four provinces in the region has applied similar lockdown rules with slight difference in performing them. It is shown that most of cases are registered in Erbil and Sulaymaniyah. However, we cannot omit the population factor. The Figure 3 illustrates that despite Halabja has the lowest cases, it actually suffers from higher rates. Halabja with a population no more than 200,000 has registered more than twice of Duhok records. Data regarding the age and gender of each registered patient has not been easy to obtain from the Government. However, what is known from their data that has been updated to a certain point, most COVID-19 patients are male between 20-40 years old. We could argue that this is the working generation. The available data suggests that males have been more effected by the virus than females. In addition, Dohuk youth suffered more than its elder age to compare with other cities in the region.

Table 3. COVID-19 cases in Kurdistan Region of Iraq between March 1 and Sep 16 2020.

Attribute	Erbil	Sulaymaniyah	Duhok	Halabja	Total
Total Cases	14,941	14,166	8,223	1,282	38,612
Recovered	11,203	9,172	2,942	1,205	24,522
Death	498	749	142	23	1,412
Active	3,240	4,245	5,139	54	12,678
Male (percentage)	61.10%	62.30%	56.60%	54.10%	61.60%
Female (percentage)	38.90%	37.70%	43.40%	45.90%	38.40%
Above 70	3.24%	4.03%	2.56%	6.45%	3.90%
60-69	5.67%	8.54%	1.28%	10.32%	7.79%
50-59	12.15%	14.24%	5.77%	20.00%	13.73%
40-49	16.65%	20.06%	19.23%	25.16%	19.48%
30-39	22.41%	26.01%	24.36%	13.55%	24.86%
20-29	20.79%	18.42%	17.31%	13.55%	18.74%
Under 20	19.08%	8.69%	29.49%	10.97%	11.50%

Figure 4. Forecasting of COVID-19 cases in Kurdistan Region – Iraq with Simple Exponential and Holt's Models.



(A) Model #1, #2 and #3 of Simple Exponential Smoothing

(B) Model #4 and #5 of Holt's Model

(C) Adjusting Smoothing Levels & Slopes of Holt's Models

(D) Forecasting the COVID-19 Cases in Model #6, Holt's Best

Forecasting Models

The real data is used to create a simple but strong forecasting model for the future of the rate of expansion of the virus in the region. We attempt to produce models for two sets of data. The first set is the cumulative number of positive cases in Kurdistan from the first positive cases between 1 March 2020 and 27 May 2020. The second set is the number of active positive cases during the same time. The number of active cases has been obtained by subtracting the cumulative positive cases and recovered cases.

Exponential Smoothing

A. Simple Exponential Smoothing
B. Holt's Method
C. Configuring Holt's Method

We used *Simple Exponential Smoothing* to predict the number of daily reports. *Exponential Smoothing* is a method for smoothing time series data employing the exponential window function [12]. .The method has only one attribute alpha, explained simply in the equation (1):

$$s_t = \alpha x_t + (1-\alpha)s_{t-1} \quad (1)$$

Alpha (α) indicates a number between 0 and 1. Setting the number high will make the model depend on the past observations. Setting it lower, will force the model to take more recent history. For our data, we have created a data range from 1st March, till 1st May 2020. This experiment, shown in Figure 4A, has been done with data of March, April and May. We predicted that even in case that number of infected is going to zero, we might expect new cases in the coming week. Three models (#1, #2 and #3) of Simple Exponential Smoothing are suggesting that new cases might appear anytime.

Holt's Method, protracted simple exponential smoothing, which allows the forecasting of data with a trend. This method involves a forecast equation and two smoothing equations for the level and slope (trend). The model consists of alpha (α) and beta (β), where alpha indicates the level of smoothing, and beta stands for the smooth slope. Both level and trend equations are part of the forecasting equations in (2), (3) and (4), extracted from [13].

Forecast: $s_{t+h|t} = \lambda_t + h\delta_t$ (2)

Level $\lambda_t = \alpha x_t + (1-\alpha)(\lambda_{t-1} + \delta_{t+1})$ (3)

Trend: $\delta_t = \beta(\lambda_t - \lambda_{t-1}) + (1-\beta)\delta_{t-1}$ (4)

Where the λ_t stands for an estimate of the level of the series at time *t,* δ_t marks an approximate of the slope of the time series at time *t*. The α describes the smoothing parameter for level $0 \leq \alpha \leq 1$, where for the trend β is used $0 \leq \beta \leq 1$. As with the simple exponential smoothing, the equation (3) represents that λ_t is a weighted average of observation x_t and one step ahead the training forecast for time *t* given by $\lambda_{t-1} + \delta_{t+1}$. The equation (4) shows that δ_t is a weighted average of the estimated trend at time base on $\lambda_t - \lambda_{t-1}$ and δ_{t-1}, the previous estimate of the trend. The forecast function is no longer flat but trending. The *h*-step-ahead forecast is equal to the last estimated level plus *h* times the last estimated trend value. Hence the forecasts are a linear function of *h.* The models (#4 and #5) are examples of Holt's method fitted on our data of June, July and August, while predicting the total cases in September and October. The results are shown in Figure 4B. Models #4 predicts the increase in the number of total cases, while model #5 suggests there will be a steadier outcome in the coming months. Naturally, adjusting the parameters of the Holt's method, significantly changes the behaviour of the model and its predictions. For this purpose, we used a large number of Holt's Methods with different values for Alpha and Beta. Figure 4C shows the top 20 models created and tested on the data of September. The best model (model #6) was later chosen to predict the total number of cases in October, illustrated in Figure 4D. Model #6 uses the data of June, July and August to predict the cases in September and October. Since we

Table 4. Comparing Exponential Time Series Models on Kurdistan Region COVID-19 data.

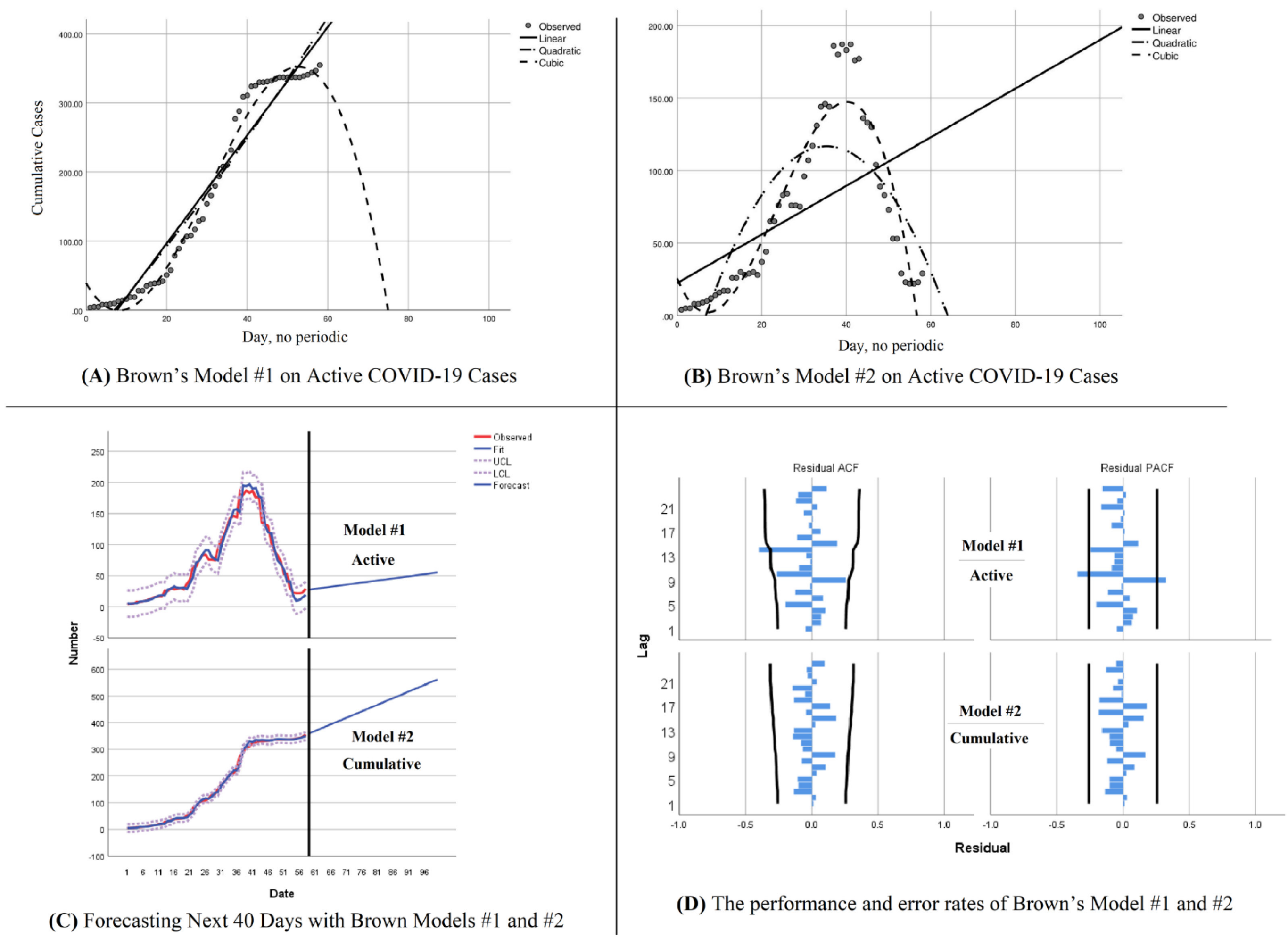
Models	**# 1**	**# 2**	**# 3**	**# 4**	**# 5**	**# 6**
Method	Simple	Simple	Simple	Holt	Holt	Holt
Trend	None	None	None	Additive	Multiplicative	Multiplicative
Train Data	March to April	March to April	March to April	June to August	June to August	June to August
Test Data	May	May	May	Sept	Sept & Oct	Sept & Oct
Observations	61	61	61	61	61	61
SSE	4,740.57	4,521.89	7,252.98	491,126.38	505,709.71	7,674,831
Smoothing Level (α)	0.1	0.22	0.9	1	1	0.22
Initial Level (λ_0)	3.13	1.96	3.61	703.11	712.66	682.5
Smoothing Slope (β)	None	None	None	0.472019	0.44	0.21
Initial Slope (δ_0)	None	None	None	78.20	1.10	1.09
Damping Slope (θ)	None	None	None	None	0.97	None

had data from September, we were able to evaluate the accuracy of the model. The prediction allowed us to estimate around 80,000 cumulative cases over the region. Table 4 shows a comparison between models #1 and #6. The observations for each model were equal, but the train and testing sets were different. The SSE stands for summation of squared errors. In fact, it is interesting that the SSE of the chosen model is highest when compared with other instances. This tells us that the predictions in COVID-19 could easily be manipulated by other variables. For example, the lockdown was loosened in the beginning of June, and the models that are trained with that data show completely different behaviour. The damping attribute in the Table 4, which is used for the model 5 only, is a degree level of how the trend could be decreased over the period of time.

Brown's exponential smoothing

To forecast the number of positive COVID-19 cases in Kurdistan, first the data has been modelled by Curve regression to estimate the number of positive cases. Then, Brown's exponential smoothing [12] was used to forecast the number of positive cases in the next thirty days. Brown's model is a suitable model for a series data that has a line trend and no seasonality. Brown's model is a Double Exponential Smoothing method and it is a special case of the Holt smoothing model. The curve regression model and Browns model are done by IBM SPSS (IBM Corp., Armonk, USA). Among the curve regression model, the model with the highest R squared has been selected and the results are shown in Table 4. Moreover, the curve estimation graph is shown in Figure 5A and Figure 5B to determine the model of best fit. To test the stationarity of the residuals, the ACF and PACF graphics of the time series for both data sets are shown in Figure 5C. The goodness of fit criteria

Figure 5. Forecasting and Timeseries Modelling COVID-19 cases in Kurdistan Region, Iraq using Brown's Method.



(A) Brown's Model #1 on Active COVID-19 Cases

(B) Brown's Model #2 on Active COVID-19 Cases

(C) Forecasting Next 40 Days with Brown Models #1 and #2

(D) The performance and error rates of Brown's Model #1 and #2

Table 5. Cubic Regression Model Performance on Kurdistan Region COVID-19 data.

Cubic Method	Model Summary					Parameter Estimates				
	R^2	F	df1	df2	P	Constant	b1	b2	b3	Equation
Cumulative positive cases	0.987	1393.8	3	54	0	39.239	-10.26	.728	-.008	$y = 39.239 - 10.26x + 0.728x^2 - 0.008x^3$
Active cases	0.872	122.22	3	54	0	25.664	-6.981	0.575	-0.008	$y = 25.664 - 6.981x + 0.575x^2 - 0.008x^3$

Table 6. The goodness of fit criteria for Brown's Model Kurdistan Region COVID-19 data.

Brown's Model	Model Fit statistics			Ljung-Box Q(18)		
	Stationary R^2	R^2	Normalized BIC	Statistics	DF	P
Cumulative positive cases	0.328	0.997	4.008	15.983	17	0.525
Active cases	0.484	0.967	4.795	33.073	17	0.11

values of the Brown's models are given in Table 5 and Table 6. The models show a high R2 value and the MAPE less than 10% for cumulative cases and near 10% for active cases data. The fitting of the models and the forecast values for the cumulative number of the COVID-19 cases and active COVID-19 cases can be seen in Figure 5D.

Infection Networks

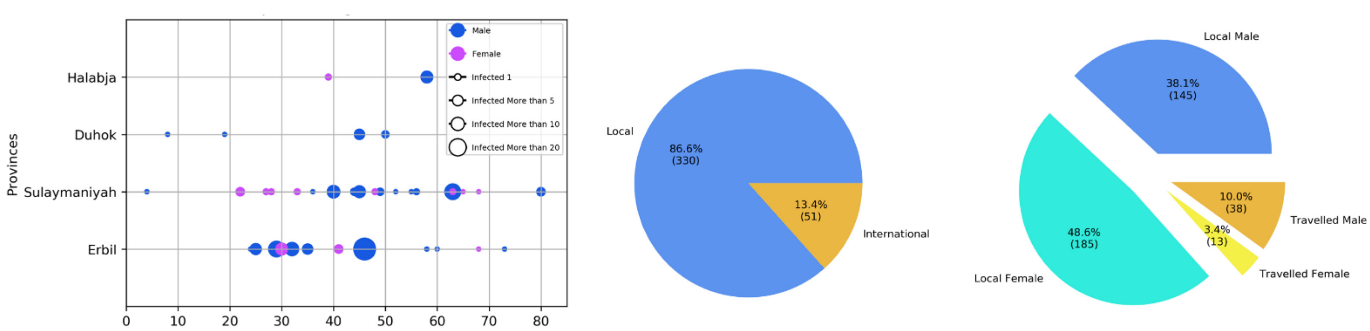
The network of infections of COVID-19 demonstrates an overview of the spread of the disease across the country. Since the beginning of the pandemic, the regional government of Kurdistan has applied a robust transportation restriction system. Moving between provinces has been limited and controlled. This has narrowed our network of infection within the province itself. The data that has been used is provided by Ministry of Health, Kurdistan Regional government. The data consists of the information on virus patients and how they have been affected. First, we provide a summary on the location of infection for all patients listed. Later, a local infection network will be presented for each province. The network graphs are produced by Gephi [14]. For further improvement we suggest that officials provide more detailed datasets. The age and location of transmitters are shown in Figure 6A.

The complete map for the Kurdistan Region is shown in Figure 7. The problems with the data set including missing data, unregistered dates and time of infections, and few other data elements. This has limited our capability to produce more detailed illustrations. The Figure 7 shows that the events of gathering could cause a catastrophic infection problem in the region. The methods of movement prevention from province to province has minimized the spread of the virus. Figure 6B tells us whether the virus was imported internationally or spread locally. Shown in Figure 6C Most international carriers were men, this implies that in our community men travel more than women.

Simulation and Scenarios

There are four scenarios that we have focused on in the simulations. To our model the level of freedom of people is an attribute that indicate each scenario. In each scenario the level of freedom is set to an integer value 1-4:

Figure 6. The Scales of Spreading COVID-19 Virus in Kurdistan Region, Iraq (March – May 2020).



(A) The Scales of Spreading COVID-19 in Different Ages of Males and Female **(B)** The Source of Infection **(C)** The Sources of Infectious Genders

1. In a world where there is complete lockdown.
2. Only one person per family can go out.
3. The hours of going out is set to 9 AM to 17 PM.
4. No restriction at all.

Each scenario provides us with an animation of days in that world, the event and daily records of infection, recovery and deaths. The recovery or death factor is set on several arguments such as age and health conditions. The disease has shown itself to be more devastating for victims with weak immune systems. That has been set to a random indicator. The recovery days in real life has been set to be between 5 to 15 days, where we added some random effect that some people will take less time and some will take longer to recover.

The simulated world has a population of 100 people where only one of them is infected previously or to be called in Day 1. The age limits are between 1-75 years. The younger an individual, the less effective the virus spread.

The disease factor is selected among most vulnerable ones, listed to the respect of their fatality rates:

- Cardiovascular Diseases
- Diabetes

Figure 7. Complete Map of Spreading of Initial cases of COVID-19 in Kurdistan Region, Iraq.

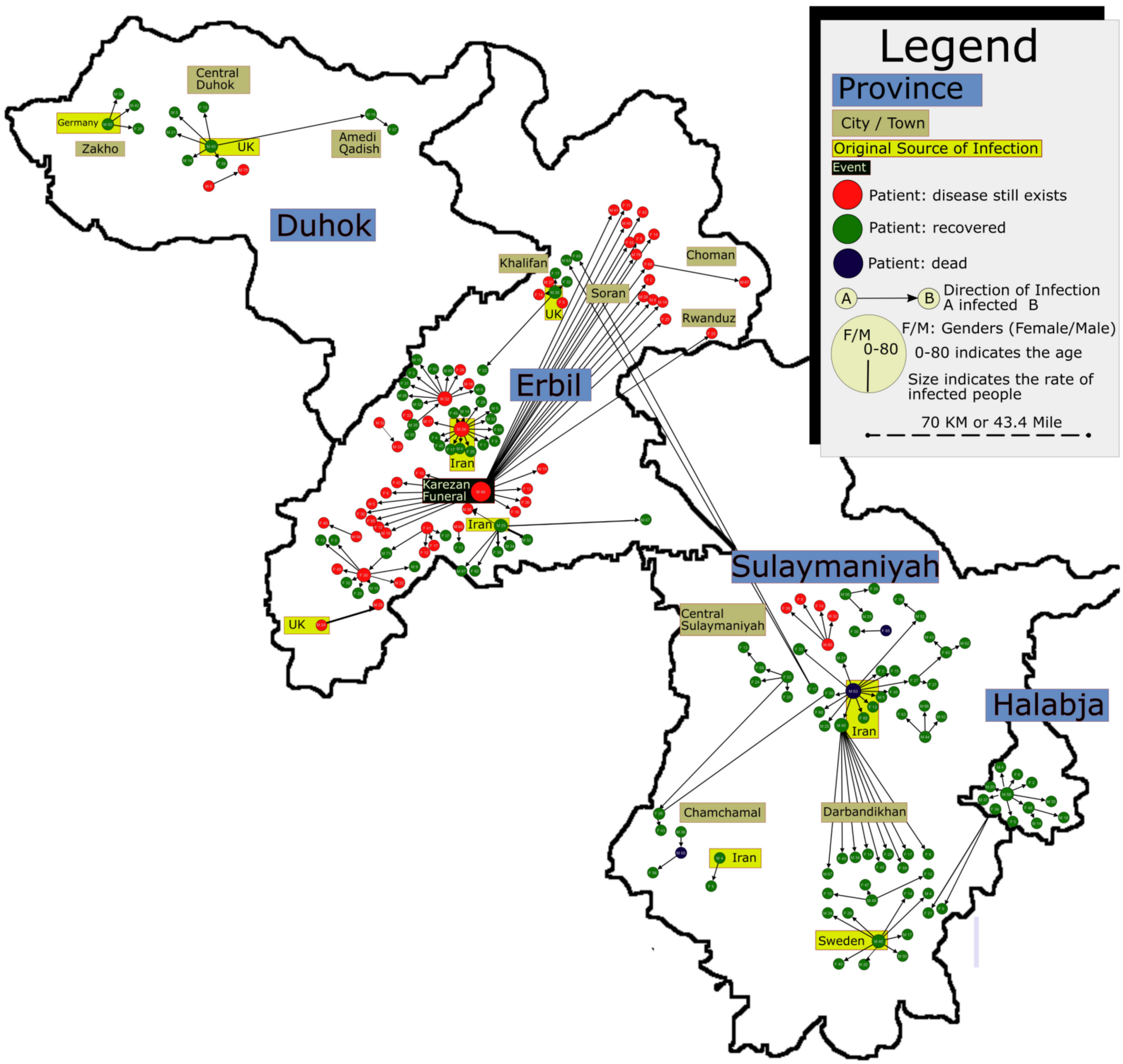


Table 7. Estimation of Daily COVID-19 Cases of Simulated worlds on Karezan Map.

Scenario / Level of Freedom	Total Infected	Peak Day	Daily Cases per Day
1	3	2	0.142857
2	91	16	4.333333
3	100	20	4.761905
4	100	7	4.761905

- Chronic respiratory diseases
- Hypertension
- Cancer

Each world is simulated for 20 days of virtual life. In the Figure 8 we can see all four scenarios at one glance after one week of simulated life when the time of their virtual world has been stopped at 15:30. Each home has number of inhabitants and they form a family. The simulation did not take in account that the recovered citizens could be once more infected with the virus, as no available report support or refutes that possibility. The world is re-paused at day 11, on 9:30 shown in Figure 9. Should we compare both observations on the level of freedom at 2 and 3, we could see that at beginning, there is not a significant change in the number of infected, and mostly it relies on the random effects. However, on day 11, it is shown that when the level of freedom is set to 3, it provides a more dangerous situation to the area. In all cases, the best option of such community is to stay at home in the case that unknown virus carriers are in the region. It is also clear that with no applied movement restriction, the entire population of a small zone can be 100% affected in less than a week.

Results

Simulation Results

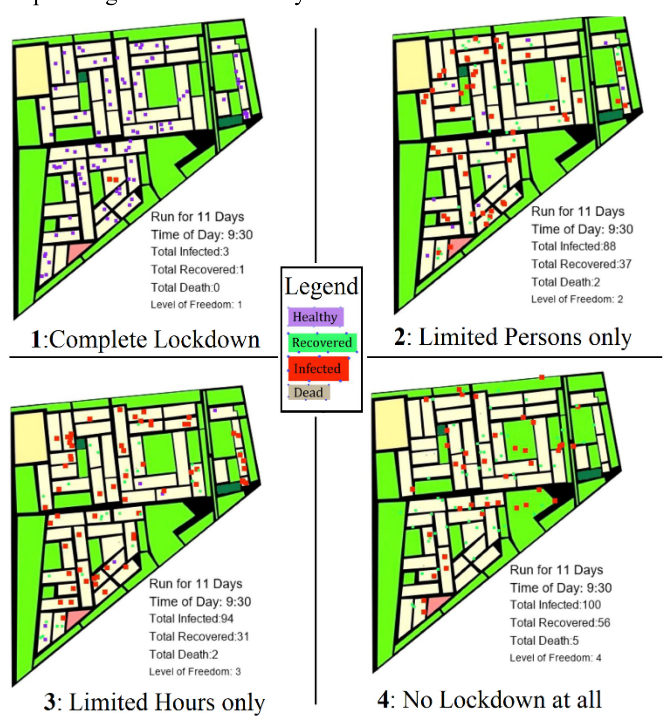
According to our study, it is illustrated in Figure 8 that a community could be 100% infected in just one week if there was no restriction. Table 7, informs us of a strong relationship between level of freedom for public and rate of infections in a community. The number of infected in scenario 3 and 4 are 100% of the population, however their peak day is different. This means it takes 20 days for the entire population to be affected in scenario 3. The same rate of effect can happen in a week when level of freedom is set to 4. Due to some random effects, rerunning the simulations might give us slightly different numbers, but the same statistical outcome.

Network of Symptoms

The disease has known symptoms that some patients show at times. These are as such: difficult breathing, fever, and cough. To illustrate the symptoms of our patients across the country, the is shown Figure

Figure 8. Simulating Karezan for Monitoring the COVID-19 Spreading For 7 Virtual Days in 4 Different Scenarios.

Figure 9. Simulating Karezan for Monitoring the COVID-19 Spreading For 11 Virtual Days in 4 Different Scenarios.



10. Most of patients are known to have shown no symptoms at all.

Our network of infection in the city of Erbil indicates that most patients that have recovered, belong to one group. In other words, in most of the cases, if the patient did not recover after the average period, the people who were infected by the same source also did not recover. These are our assumptions regarding the results:

1- Patients who are infected from same source, share similar genes, and have identical immune system.

2- The type of virus varies from source to another source, and some of the types recover faster than others.

Discussion

Data Analysis and Statistics

The data from the ministry of health statements was collected and analysed, shows that on April 6, 2020 there was a massive rise of new cases due to one event in the Karezan neighbourhood where people gathered for a ceremony. The origin of new cases was only one patient; which made the province of Erbil stride in the number infected after that event, compared with Sulaymaniyah.

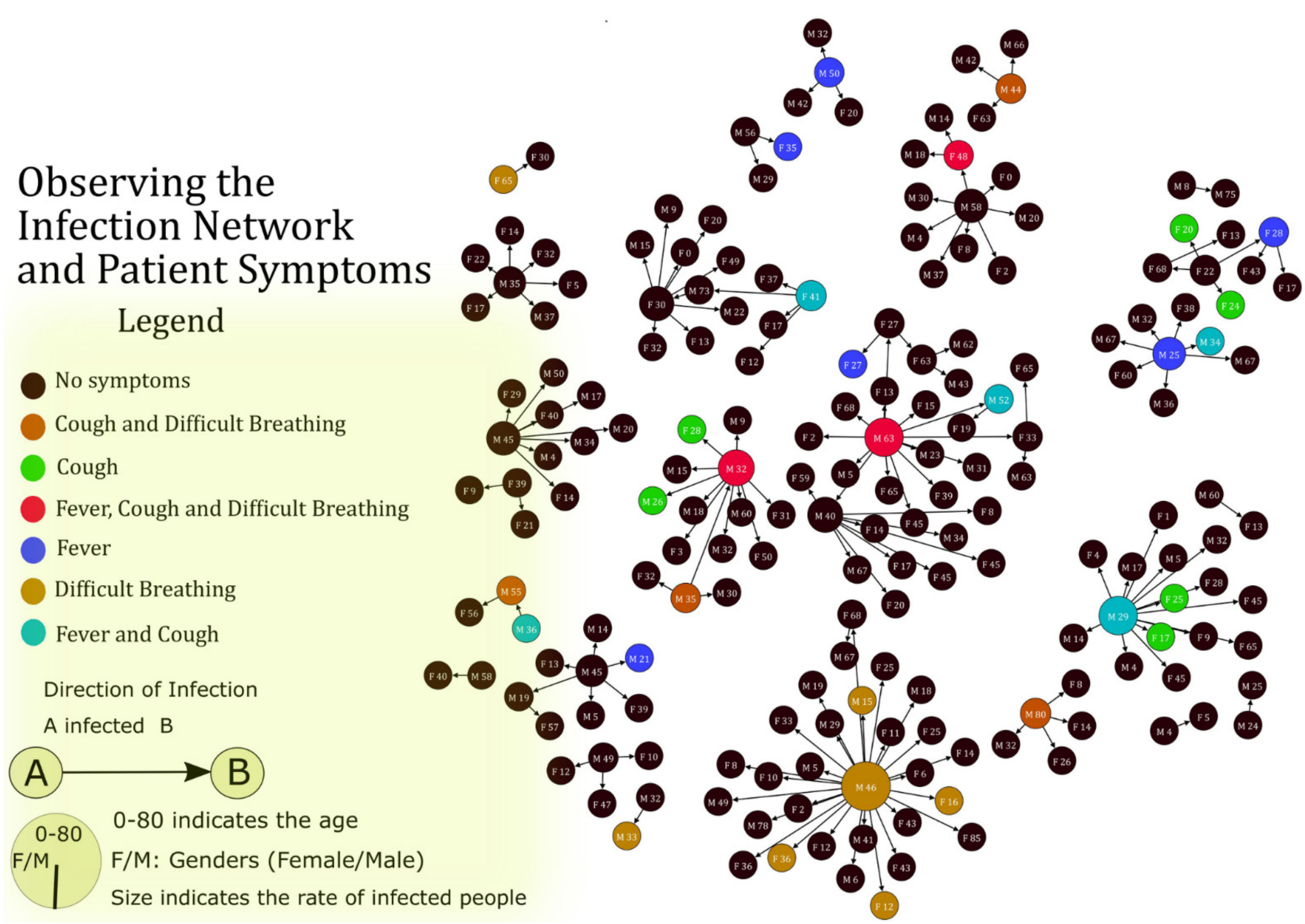
At the start of June 2020, the government reduced the restrictions on movements of individuals and mass gatherings, but maintained the closure of various businesses. The outcomes were not positive, and the average daily cases rose to up to 200 cases per day shown in Figure 1A. The impact led us to create a simulation to better observe the phenomenon.

Economic Considerations

For other economic considerations we recommend that important consumer sectors be partially reopened with a stringent mask covering policy, insofar as consumers cannot enter shops or buildings without wearing a mask. In addition, businesses wanting to reopen must present sanitation and employee safety plans to the government to ensure that surfaces and communal areas be constantly clean of possible virus particles. Poorly ventilated areas with opportunities for high occupancy should not be reopened.

Most of the economy of the Kurdistan region relies on net exports from the oil trade. The pandemic induced

Figure 10. Map of Infection of COVID-19 Patient Symptoms in Kurdistan Region, Iraq (March – May 2020).



global recession has put a damper on oil prices and demand as well as the untimely Saudi-Russian supply side price war. The only solution for smaller producers, i.e. Iraqi Kurdistan, is to wait until the price recuperates.

In the meantime, aggressive infrastructure investment projects could help move the local economy away from oil dependence. The Kurdistan regional government had a significant investment policy in place until budget deficits in 2016 and beyond prevented them from continuing the project. Since then the regional government has been forced to borrow from regional banks as international loans at healthy interest rates are not available. This has created significant crowding out for individual business investment as local interest rates have risen as the economy stagnates. To ensure the future of the Kurdistan economy regional banks will need more liquidity and the government must find other creditors with low-enough (< 10%) interest rates to continue its previous aggressive infrastructure projects.

Conclusions

Throughout our modeling and simulations we have reached into some fundamental points:

1. A complete open community is suicidal and will leave massive effects on each single individual. According to our results the virus spread will take less than a week to spread to all inhabitants of a medium size neighbourhood.

2. A fully closed community has the best performance in terms of prevention and controlling the infection. It indeed has negative influence on the economy of individuals and the government in general.

3. A semi-closed community where people can do their business and stay away from ritual and unnecessary situation, has shown to have fewer infection than an open community and would promise suitable economic advantages over a fully closed place.

According to our study, we recommend that the government must keep the places that mass gatherings are occurred, closed or limited. We suggest that the government evaluate the economic benefits of a place before deciding to open the location. Our models also suggest that the government encourages working online and remotely wherever it can be applied.

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Conflict of interests: No conflict of interests is declared.