Euroasia Journal of Mathematics, Engineering, Natural & Medical Sciences
International Indexed and Refereed
ISSN 2667-6702

IMPACT OF SOCIAL BEHAVIOR ON THE DYNAMIC SPREAD SARS-COV-2 IN LEBANON ACCORDING TO THE SIR MODEL

Mohamad Hamieh[1,b], Ali ElMoussaoui[1,a], Hassan Ayoub[2, a], Hicham Aboudaya [3, b], Zeinab Hamie[4,c]

[a]Faculty of Economics and Business Administration (Branch 1), Lebanese University LU, Lebanon

[b]Engineering and science department, Islamic University IUL, Lebanon,

[c]Faculty of Sciences (Branch 1), Lebanese University LU, Lebanon.

** Corresponding author: Mohamad Hamieh*

Geliş Tarihi / Received: 20.02.2022 *Araştırma Makalesi/Research Article*
Kabul Tarihi / Accepted: 24.03.2022 *DOI: 10.38065/euroasiaorg.943*

ABSTRACT

Analyzing the dynamics of Sars-Cov-2 spread in the Lebanese society is what this article mainly aspires and points to, where the study was predicated on a compartmental model, namely SIR, the widely known model in epidemiology. SIR. (Susceptible-Infected-Recovered) materializes a basic conceptional structure for theoretically investigating the virus spread and its dynamics within a community, through focusing on the interaction and communication between infected and recovered people. Consequently, providing the necessary attempts to overcome the epidemic, and diminishes its expansion to rescue lives. In which, limiting contact absolutely reduces the possibility of transmitting or contracting an infection. This investigation on a representative sample of the Lebanese population highlights the various drivers and dynamics of this proliferation. These drivers or factors clarify the behavior of the population (wearing a mask, washing their hands) in experiencing the epidemic crisis and their abuse for measures (safety distance, closures) adopted by the authorities to combat the epidemic. So, it turns out that the careless and incautious attitude of the Lebanese population, besides the unsatisfactory control to fulfill the government rules against the dynamics of virus spread was shown by the modeling of Sars-Cov-2 dynamics through the SIR model.

Keywords: SIR Model, Data Analysis, Sars-Cov-2 spread, population behavior, infection transmission.

INTRODUCTION

An outstanding propagation was manifested by the Covid-19 pandemic, this rapidity in the spread and time of development of the Sars-Cov-2 virus does not leave enough time to respond. Wherefore, the tackling time of this epidemic through human organizations, such as hospitals, industries or scientific research was considered late in comparison with the action time of the coronavirus. This was evident by April 2020, where hospitals in many countries were full as an outcome of the pandemic, resulting in a global loss of lives, and critically threatening the health of millions of human beings. Therefore, mathematical models and simulations were designed to be a valuable tool for forecasting the feasibility and harshness of the epidemic, as well, affording suitable information to study the dynamics of transmission of infectious diseases such as foot-and-mouth disease, SARS, Ebola and Zika. [1, 2].

This paper focuses on clearly recognizing the transmission dynamics of the virus and assisting the progress of control measures through utilizing the real data from May 2020 to January 2021. We were studying the basic number of reproduction of the virus in the current epidemic. That is important to keep in mind here that supporting the Ministry of health's preventive and control efforts lie in critically forecasting the epidemiological trajectory of Covid-19 in Lebanon. To cope with this situation, experts cannot bet simply on elaborate computational models, where their implementation, reaction, and data collecting of which demands weeks of acquisition and high processing expenses. Otherwise, utilizing actual databases gathered from various tracks and in many countries, in order to realize the potential of coronavirus pandemic is substantial concerning the chronological aspects which allow a cheaper mathematical model employment with regard to data collection and calculation time. Accordingly, in the case of the epidemic, models based on partial differential equations may not be sufficient. Secondly, it has already been found also that the age of an infected individual doesn't quite create a pivotal influence in viral dissemination (as certainly per the recent information); rather, it is determined only by illness progression, aggressiveness, and fatality.

METHODOLOGY

Through simulations employing the SIR model, Din et al. [3] demonstrated how rates of protection, exposure, death, and recovery influence the susceptible, infected, and cured population over time that involves immigration. Such that, results indicated a rapid growth rate of the infected population as an outcome of higher immigration rate and vice versa. In the last publication related to our work [4], we explained the dynamic development of Sars-Cov-2 in many countries of the world using the SIR model, which prompted us to build this work to reproduce our study on one sample of the cluster which is Lebanon, and we try to apply the SIR model to each zone of this country. The reproducibility of the results in different Lebanese regions shows similar results to our pre-study [4]. Going to notice that the core of this task actually starts in China and grows in that too [5, 6], and that's what several investigators had already explored utilizing various models through integers, stochastic, and fractional order. For instance, Atangana–Baleanu–Caputo (ABC) derivative with fractional order was conducted by Thabet et al. [7] in order to fully understand the actual results. What's more, is the Adams Bashforth quantitative approach which has been used to visualize the performance of the two well-known Chinese cities, Wuhan and Huanggang. Interestingly, fractional models seem more likely to be reliable in forecasting future outbreak trajectories. Besides this, adopting stochastic methodologies in the SIR model is effective in generating results that diverge from deterministic models each time the model is run for specific parameters. Also, it can be said that often the stochastic Covid-19 model's threshold is fulfilled by small and big noise.

It is not commonsensible to base the models only on the number of detected or confirmed cases, as a result of the difficulty of conducting viral tests in large numbers, which contributes to the focus of the examination procedure on cases that have serious problems. Though, there is no assurance that this indicator is proportionate to the total number of infected cases, due to the evolution of the capacity to conduct such tests and the discovery tactics used. Nevertheless, a comparison of the transmission evolution curve in different countries and populations can certainly be recognized as markers that accurately express the evolution of the epidemic, and grant notable evidence of virus evolution. Therefore, based on the foregoing observations, our evolution model is actually grounded on the progression of the cumulative number of patients, where this suggestion is a discrete deterministic evolution model over time and as a "one day" time period. The coefficients of susceptibility (S), the newly infected cases (I), and the total cases over the number of populations in each country (R) are a number of parameters involved in this model. Moreover, the continued spread of the virus could be predicted by the time index, as well, the data collected through this model discovered the delays in time. Also, The collected data permits the measurement of a dynamic marker called the peak time "Tc", which is used to assess the significance of the administered measures, along with playing a principal role in expecting the proceed of the pandemic from diverse schemes and in developing a technique to control them regardless of preserving permanent extreme measures [8, 9]. In particular, the accelerated time growth in the early stage was observed in all predominantly affected areas; on the contrary, the number of deaths is believed to follow a behavioral law of force. This could be a consequence of absolutely medical grounds; likewise, the chance of survival relies upon the received therapy and detection stage [10].

RESULTS: SPREAD EVOLUTION

We demonstrate in figure 1 the evolution of the virus over time for various regions in Lebanon. Wherefore, acquiring an actual observation of the dynamic's progression between these different regions was possible by employing a standardized model. Actually, the exponential pattern appears to be realized within the first stage of the disease outbreak, rising towards a time of nearly 50 days (almost pretty similar for all regions); this trend remains applicable and facilitates the adjustment of the exponentially growing curves. Over and above 50 to 100 days, an interruption in the exponential evolution occurs, resulting in an improper process. Whilst some researchers have associated this situation with the containment of Coronavirus cases [11]. Further, the exponential trend resumes after 100 days. Concurrently, three regimes were recognized regarding the pandemic performance displayed in figures (a, b, c, d). The first regime is represented by the curves following an exponential law with a "downward concavity" which increases until 50 days, where this evolution style was shown in the twenty Lebanese regions; this can be described through the accurate control of the zero point at the onset of the epidemic. It should be noted that it is actually possible through identifying the zero point and its origin; which is a fundamental parameter for examining the pandemic evolution in the initial state, to control the evolution with a minimum processing time. Alternatively, the second regime reported that all regions show exponential growth with increasing "upward concavity" before the 100-day duration, this could be described through the accurate control of the zero point at the onset of the epidemic. It should be noted that it is actually possible through identifying the zero point and its origin; which is a fundamental parameter for examining the pandemic evolution in the initial state, to control the evolution with a minimum processing time. Alternatively, the second regime reported that all regions show exponential growth with increasing "upward concavity" before the 100-day duration, this can be related to the lag of reporting the cases, besides the zero point of infection, and hence the cumulative number of patients last secret a long time, which may affect the human response to combating this epidemic. In addition, significant growth of the curves was observed below this convolution in a form symmetric to the first system.

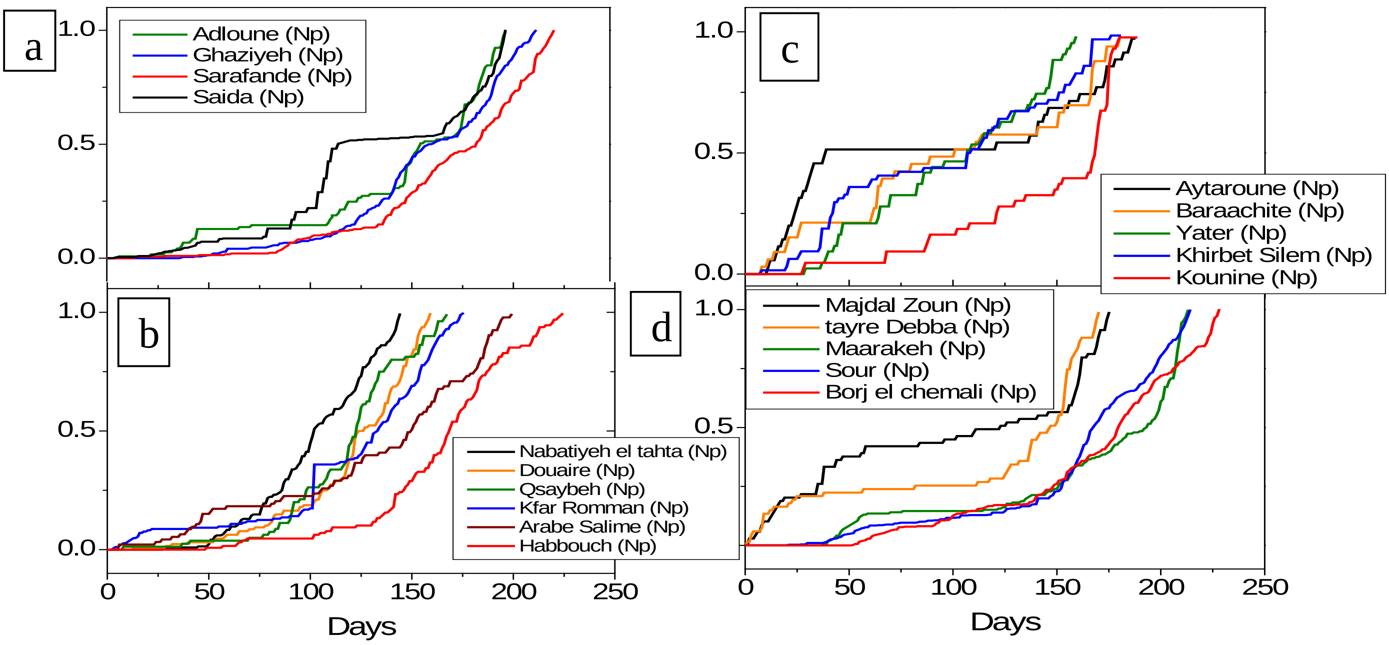

Figure 1. Standardization Of Covid-19 Outbreak For 20 Regions In Lebanon (A, B, C, D). The First Lockdown Was At 50 Days.

Later, a positive "downward concavity" act of the second regime was realized, where this deformity can be attributed to several extrinsic factors including the plan of action to resist the Covid-19 transmission, human demeanor, and social interaction between people. Accordingly, responding actions and decisions of some countries in order to battle against the epidemic are limited, such as Lebanon and Iran which are experiencing economic hardship and abnormal social behavior. For that reason, a prolonged time is induced in these areas, which is also an influential factor. Furthermore, a zigzag shape above 150 days was shown through the collected data which can be linked to the diverse mutations over time in the genetic code of the Coronavirus. It's worth mentioning here based on our previous study [4] that this mutation is reproducible as evidenced by the relative behaviour of the curves between Italy, Germany, the United Kingdom and France, which have a dominant zigzag effect, further, China, Italy,

the UK and Germany were in a better condition concerning their development in a slower growth trend, hence different from the USA, France, Russia, Iran and Lebanon which have a propensity to grow swiftly.

Investigational database schema adjustments

In the matter of this class of contagious disease, the common model that will be considered is the "Susceptible-Infected-Recovered" (SIR) type, because a person generally catches the disease once, and consequently, the sufferer either dies or resuscitates. Where the inhabitants of a place in accordance with this model are classified into: susceptible, infected and recovered marked as S, I, and R respectively, being dependent on the time t; further to that, the overall population together with mortalities does not change. Remarking here that at the beginning of the outbreak everyone in the population, in theory, is susceptible to the disease, however, when infection progresses the vulnerable individuals are probably gotten to be infected, sequentially, who become contagious either recuperate or succumb, in which both recovered or died individuals are considered alike, creating the deleted category which could be illustrated by the overall infected population over time. So, for modeling what happens over time here are some valuable equations:

$$\boldsymbol{I} = \frac{\boldsymbol{dR}}{\boldsymbol{dt}} \tag{1}$$

And,

$$\boldsymbol{S} + \boldsymbol{I} + \boldsymbol{R} = \mathbf{1} \tag{2}$$

The factor "I" is associated with the people who currently carrying the infection in a real situation, where this factor exhibits a moderate growth at the beginning, suddenly it undergoes an intense increase with time; in which growing stage is correlated with exponential conduct, then, the path goes ahead toward achieving the ultimate level stability, thus confirming the end of the outbreak. It's noteworthy to mention that the phase of stabilization was already satisfied in China when many other countries still haven't arrived at this level.

On the contrary, the steady-state regarding the accumulated data results of "R" is attained when the maximal point is eclipsed.

In which, data fixation could be as follows:

$$\boldsymbol{R}\,(\boldsymbol{t}) = \frac{\boldsymbol{a}\, e^{\left(\frac{t}{T}\right)}}{\left[1+\boldsymbol{c}\, e^{\left(\frac{t}{T}\right)}\right]} \tag{3}$$

$$\boldsymbol{T_c} = \boldsymbol{T} * \boldsymbol{ln}\left(\frac{1}{c}\right) \tag{4}$$

Where adjustment of the curves affiliated with several regions, permits the deduction of $\boldsymbol{a}$, $\boldsymbol{c}$, and $\boldsymbol{T}$ curve fit criterions, which aid in finding the time "$\boldsymbol{T_c}$" (Equation 4) resembling the half time of the spread for every zone.

In regard to the number of newly infected people, the data inputs are more scattered and instead of a direct fitting, this can be calculated by differentiating "R" from "t". Furthermore, the highest point value of $\boldsymbol{I}$ could be determined by calculating the maximum derivative of $\boldsymbol{R}$ (equation 1), also the time $\boldsymbol{T_c}$ could be situated where the peak appears, as presented in figure 3.

DISCUSSION

In figure 2, data on the total fraction of R cases are plotted as a function of time for different regions in Lebanon. Where, by a fit curve, we obtain the total number of cases divided by the total population N for each region and compare it with the data from different articles [12, 13] for which daily reports are available as of January 21, 2020 (ie: day zero).

A reproducible exponential law was noticed in several Lebanese areas, through curve fittings of the actual inputs, confirmed in figure (2).

Moreover, an alteration of the curve's track as concerns the change of cumulative number with time was required, with a view to adjusting curves to the same exponential law depicted in the dotted black offset curves. Drawing attention that the deviation from normality was evidently seen in figure (2 e, f) by reason of the limited number of contagious inhabitants, conversely, this unusual effect was feebly manifested in other regions, where it is supposed to be caused by a large number of Sars-Cov-2 influential individuals, which may contribute to reducing this effect.

It's important to note here, that the incompatibility seen between the two adjustments could perhaps be a consequence of virus metamorphoses during the widespread disease; this goes back to the spiky protein of SARS-Cov-2, which appears to be quite susceptible to mutagenicity, where these genetic variations tend to differ from one infected region to another, with their number constantly changing.

Otherwise, figure (2d) shows another effect, where the observation seems to be not reproducible from one region to another, so it cannot be explained by a mathematical development, however, we have noticed that in the region called Baalbek, the input data for the infected persons were not saved correctly, that is why this is a natural course manner. Then, if we view the overall evolution, with an adaptation error of 6%, we also get the same curve for the Baalbek region and this gives information like the other regions and not necessarily explanations.

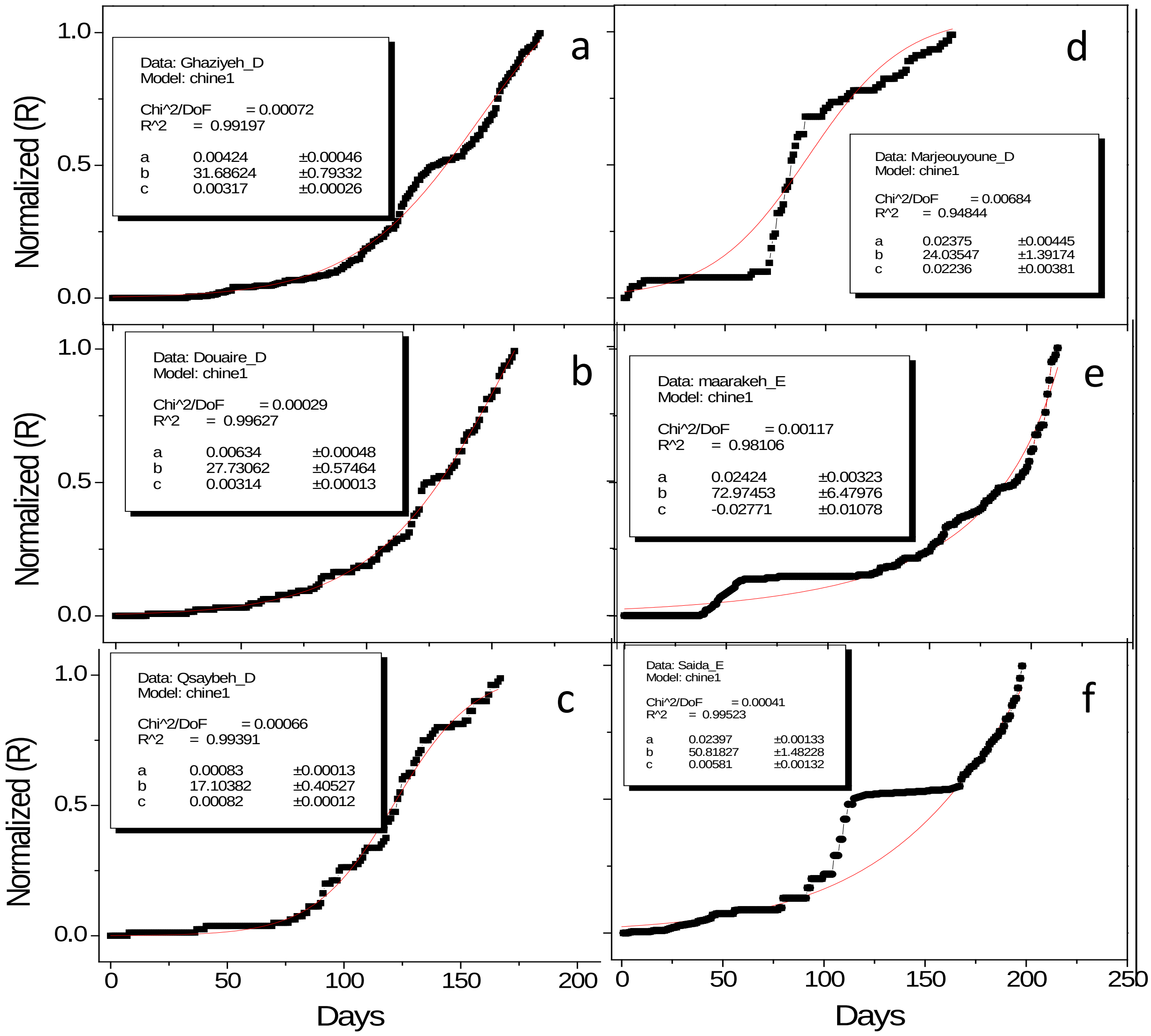

Figure 2. Adjustment (Red Line) Of Standardized Data (Black Point) For The Covid-19 Pandemic By Sir Model In Six Different Regions; Where A, B And C Fit Correctly The Data, Whereas D, E, And F Show Anomaly Evolution Behavior.

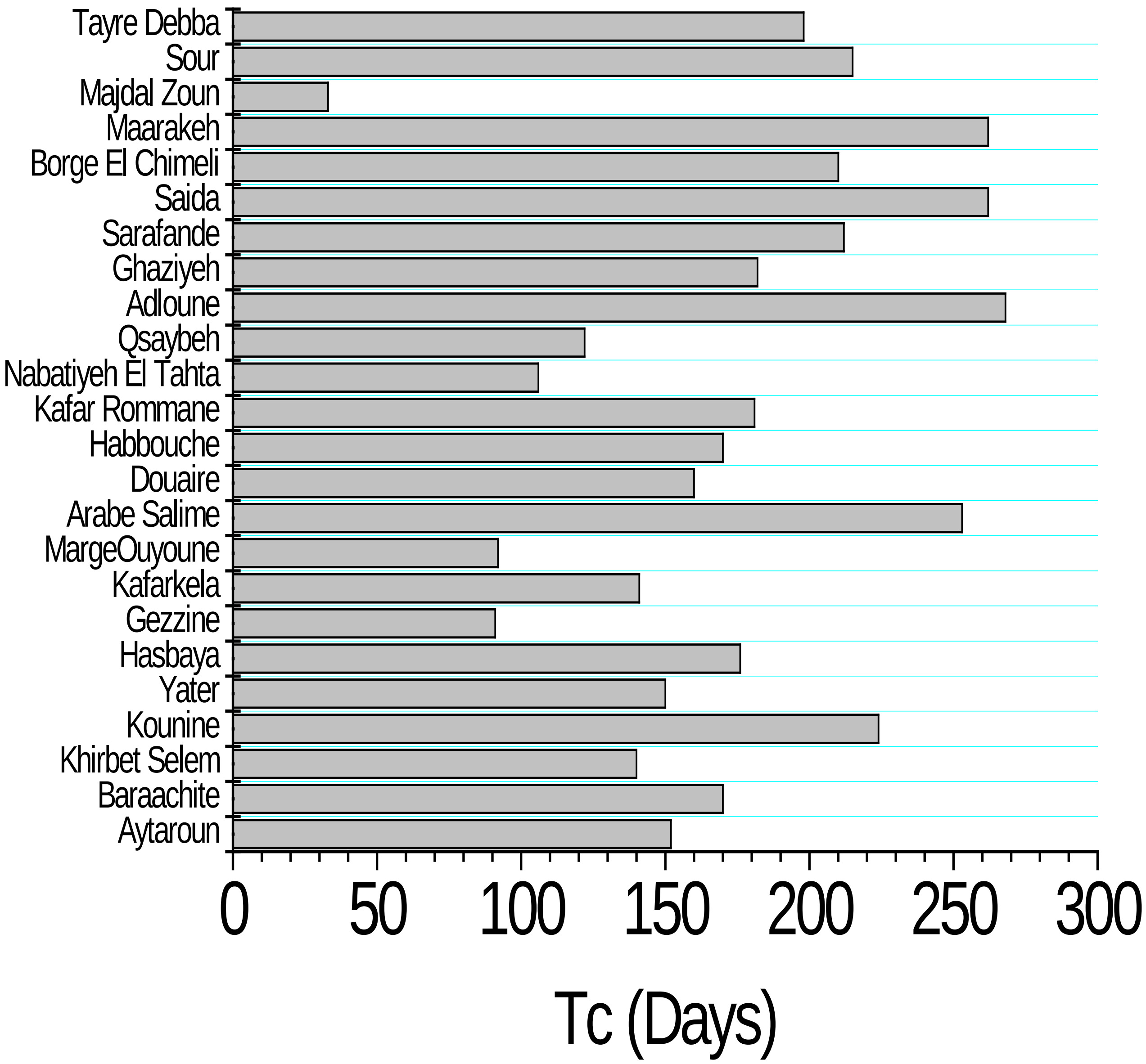

Figure 3. Bar chart displaying the dynamic marker T_c (Days) in various Lebanese regions.

The daily reproduction rate evolution

The model detailed below relies heavily on estimations based on the time-varying reproduction number, especially daily reproduction rates. In which this rate generally depends on several factors, taking into consideration the decreasing manner of the outbreak till its ending.

The following factors are considered:

1) The percentage chance of secondary infections, which means virus spreading.

2) How long is the period of infection with the virus.

3) The typical number of infected individual contacts behind a particular day.

The phase where the passage into an absolute closure was indicated, provides a preliminary perception, calling that a total lockdown accompanied with radical preventive actions, results in reproduction rates scarcely underneath of the limit esteem 1. This observation confirms that the assessments based on pandemic data permit the evaluation of the actions efficacy took and forsee sensible master plans.

Findings show that containing the epidemic in long run will be difficult without extreme steps, this was firmly established through the results showing values significantly bigger than one, including periods with very sizable readings, and apart from the severe constraints regime. This explains; based on the aforementioned evaluations, that even moderate closures will cause a fluctuation at a rate greater than one.

A clarification was reached through this study, which indicates that the extreme measures are insufficient to explain the progression of the pandemic in the locations examined.

To mention that, there is a lot of discretion in reducing the measures taken while preserving an epidemic control, so, a zigzag approach which comes as a result of every lockdown escape method stays a reproducible factor over time.

On the other hand, the percentages of people in each location, as well as the isolation times enables the construction of a plot that depicts the pandemic's progression with time. In which figure (2) illustrates the full extent of dynamic spread in each location, discussed in the second half of this study in such a quantitative statistics section.

Ultimately, the model used in this study can successfully categorize the assessment protocols used in various locations. Such that, all these are factors that affect the dynamic transmission of SARS-CoV-2, which progresses throughout three different periods:

(1) The pandemic's progress following an exponential law with a turning point that resembles natural behavior.

(2) The Unusual conduct caused by societal constraints enforced by the human response in each civilization.

(3) The validation using the same exponential rule to comply with the reproduction of the daily rate of infection once again.

This could be related to Coronavirus mutation in its worldwide dissemination, which enables the pandemic to resume as a wave of propagation with time, according to this study.

Part II: Analysis study on the social causes of the transmission of the COVID-19 in the Lebanese society according to scientific indications on index cases

Until February 2021 about 355,000 people tested positive with covid-19 in Lebanon [14]. The sample size n and margin of error E are given by:

$$\boldsymbol{x = Z(c/100)2r(100 - r)} \tag{5}$$

$$\boldsymbol{n = N\,x/((N-1)E2 + x)} \tag{6}$$

$$\boldsymbol{E = Sqrt[(N - n)x/n(N-1)]} \tag{7}$$

Where N is the population size, r is the fraction of responses that you are interested in, and Z(c/100) is the critical value for the confidence level c. For analyzing, the contamination circumstances based on index cases we conducted a questionnaire, which we sent, via SMS to 10,029 individual tested positive with Covid-19.

We retained for the analysis 957 questionnaires (9.55%), with 5% margin of error, and 95% confidence level.

Respondents are 49% female and 51% male (figure 4), 80% of them are 15-44 year olds and 19% are 45-65 years old as presented in (figure 5). In addition, figure 5 shows their smoking habits were 41.32% of the respondents are smoker and 58.68% of them do not smoke.

Moreover, we can see in (figure 7) that most of the participants, 77% of them, do not have chronic diseases, 7% of them have pressure disease, 3% suffer from diabetes, and 12% suffers from some other diseases.

The social-professional groups in (Figure 8) distributed as follows: 15% of the respondents are in the homemaker group, 1% of them were farmers, 17% retired or unemployed (inactive), 4% are managers. In addition, 3% hand workers, 44% of the respondents were employees, which show us the majority of social-professional groups, 9% of them works in intellectual professions (professor, writer, ... etc.), where 5% of them are either businessmen or dealers (traders), and 1% have a craftsman work profession as shown in (figure 7).

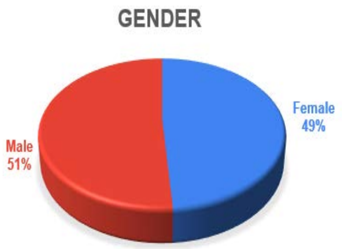

Figure 3. Respondents Gender

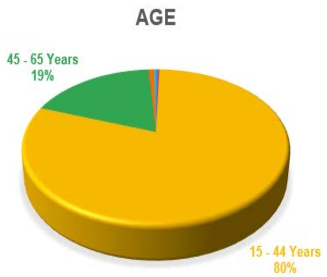

Figure 4. Respondents Age

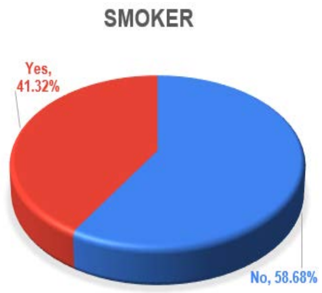

Figure 5. Respondents Smoking Habits

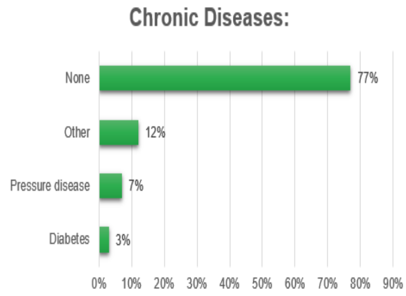

Figure 6. Respondents Chronic Diseases

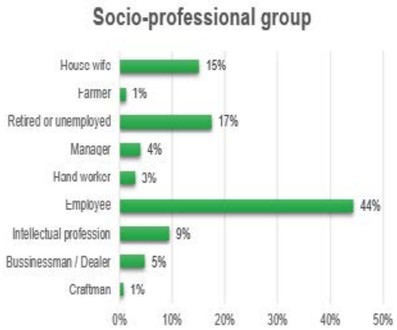

Figure 7. Respondents Socio-Professional Group

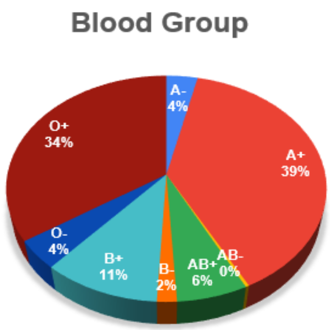

Figure 8. Respondents Blood Group Distribution

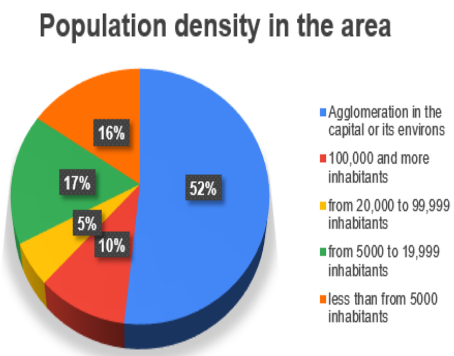

Figure 9. Respondents Population Density

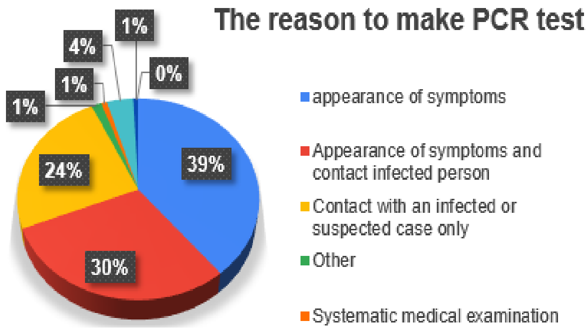

Figure 10. Respondents Reason To Make Pcr

The blood group distribution among participants is presented in (Figure 9) where (A+) blood group with 38.81% of the respondents have the highest occurrence, 34.41% in (O+) blood group, 10.56% in (B+) blood group, 6.38% in (AB+) blood group, 4.18% in (O-) blood group, 3.56% in (A-) blood group, 6.38% in (AB+) blood group, and 0.31% in (AB-) blood group.

Population density is a determining factor in our analysis. The results of our survey (Figure 10) reflect the following points: (a) 51,78% of respondents live in the capital (Beirut and its suburbs); (b) 10,36% of them are in areas of 100.000 or more inhabitants; (c) 5.44% resides between 20.000 and 99.999 inhabitants; (d) 16.63% lives between 5000 and 19.999 inhabitants; (e) 15.79% of them live in areas with less than 5000 inhabitants.

Concerning the reason which prompted the participants to carry out the PCR test, we obtained the following answers (Figure 11): (a) 39.12% (the onset of symptoms); (b) 29.71% (the onset of symptoms and contact with infected people); (c) 24.27% (the contact with a single infected or suspected case); (d) 3.86% (a check); (e) 0.84% (during a systemic medical examination); 0.73% (for travel); (f) 1.46% (others reasons).

By mid of March Lebanon went through lockdown programs, the government closed the airport for 100 days, most of the reports in the TV and social media was distributing recommendations for isolation, contamination, and hand washing after touching any item [14].

These measures encouraged the majority of respondents (98.5%) to apply isolation. However, the Lebanese citizens did not have the same attitude and behavior in terms of isolation. We can summarize this situation as the follow:

(a) 37.34% didn't isolate themselves before performing the PCR test. Among these, 22% started isolation immediately after performing PCR test, but 15.27% did so later because they waited for the results. In the case of a positive result, they apply isolation (see Figure 12).

(b) 33.4% immediately isolated themselves as soon as the first symptom appeared;

(c) 27.8% when they learned of their contact with an infected case (the only warning sign).

Isolation should have resulted in limited movement. But, only 20.7% of respondents avoided contact with vulnerable people by wearing a mask in family and friend's circle. 60.25% of them wash their hands less than 10 times per day.

Unfortunately, 79.2% did not wore mask in the family and friends circle all the time, where about 20% more than half the time, 18.5% less than half the time spent with family and friends.

The disaster stems from the fact that 41% either never or rarely wore masks in the family or friends circle.

Analysis of responses (Figures 13 and 14) reveal the bad applications by citizens of government measures relating for wearing masks. Indeed, the Lebanese government has taking strict measures to deal with the spread of the Covid-19. In addition, he imposed fines for citizens who do not respect them.

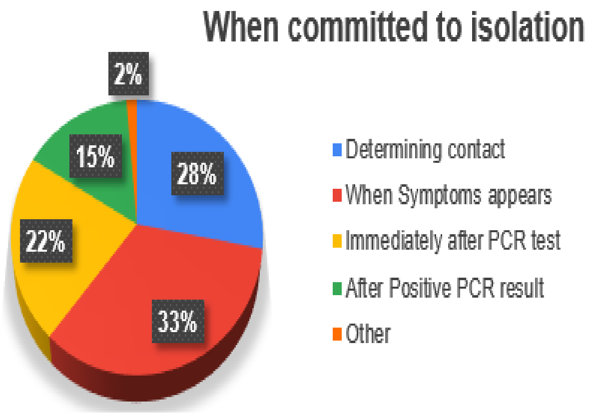

Figure 11. When Respondents Started Isolation

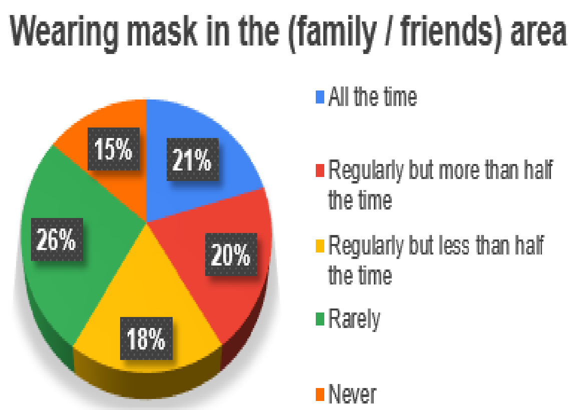

Figure 12. Respondents Wearing Mask In Family And Friends Circle

Figure 13. Respondents Hand Washing

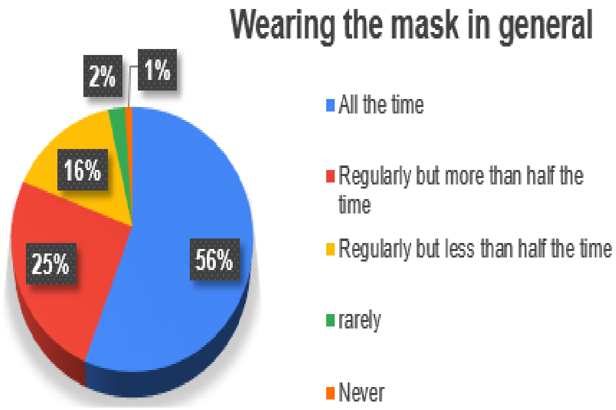

Figure 14. Respondents Wearing The Mask In General (Mandatory / Recommendation)

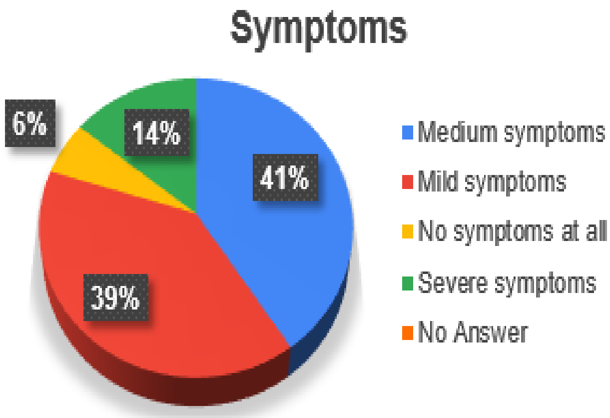

Figure 15. Respondents Experienced Symptoms

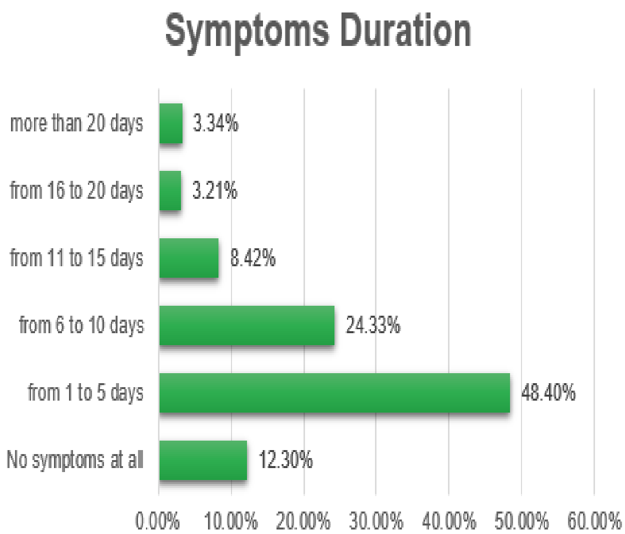

Figure 16. Respondents Symptoms Duration

By comparing with the results relating to circles of family and friends, the analysis of the responses (Figure 15) show a relatively responsible behavior of the respondents towards the wearing of the mask in general (recommended or compulsory).

In fact, the responses relating to the behavior of wearing a mask can be summarized as follow: (a) For 56% of respondents (all the time); (b) For 25% (more than half the time); (c) For 16% (less than half the time; (d) For 2.5% (rarely) and (e) for 1% (never).

It is widely accepted that wearing masks by citizens is a very relevant indicator of the spread of the virus.

Figure (16) shows the following results:

(a) 94% of respondents had symptoms. For 80% of them, these symptoms are moderate or mild. In other words, for only 14%, the symptoms are severe.

We believe that the symptoms of long duration will increase the potential for the spread of the virus if it left unchecked.

We went through checking the symptoms duration, as symptoms with long duration will increase the potential of infection spread if not controlled.

Indeed, the graphs show the irresponsible behavior of infected citizens, especially in the circles of family and friends.

Analysis of the results (figure 17) shows that 87.7% of respondents suffered from symptoms during different period. The results can be summarized as follows:

(a) For 48%, the period of suffering can range from one to five days; (b) For 34.3%, it varies from six to ten days; (c) For about 15%, it lasts for more than ten days.

Subsequently, we analyzed the behavior of people who show symptoms and who did not comply with the measures of wearing a mask even after being infected with the COVID-19 virus. It should be noticed that this type of irresponsible behavior can make the spread of the infection worse.

Figure 18 illustrates the results of the citizen’s behavior in terms of wearing masks according to the degree of symptoms, a behavior considered to be potential cause of the spread of the infection, especially in circles of family and friends.

Observation of the graphs make it more possible to see the results: (a) more than 50% of people often wear masks, all categories of symptoms combined; (b) Between 20% and 25% wear masks more than half the time; (c) 22% of those infected without symptoms wear masks less than half the time; (d) 6.8% never or rarely wear masks.

On the other hand, for all categories of symptoms, more than 40% of those infected people that have been asked answered that they rarely or never wear a mask in the circles of family and friends.

In addition, 27.2% of respondents with no symptoms wore the mask less than half the time in the family and friends circle, with 18% more than half the time.

Moreover, 17% of the respondents with mild symptoms wore the mask less than have the time while 19.4% wore the mask more than half the time in the family and friends circle.

Similar percentages with the respondents who were infected with covid-19 and had medium symptoms where 17.4% of the respondents with mild symptoms wore the mask less than have the time while 22% wore the mask more than half the time in the family and friends circle.

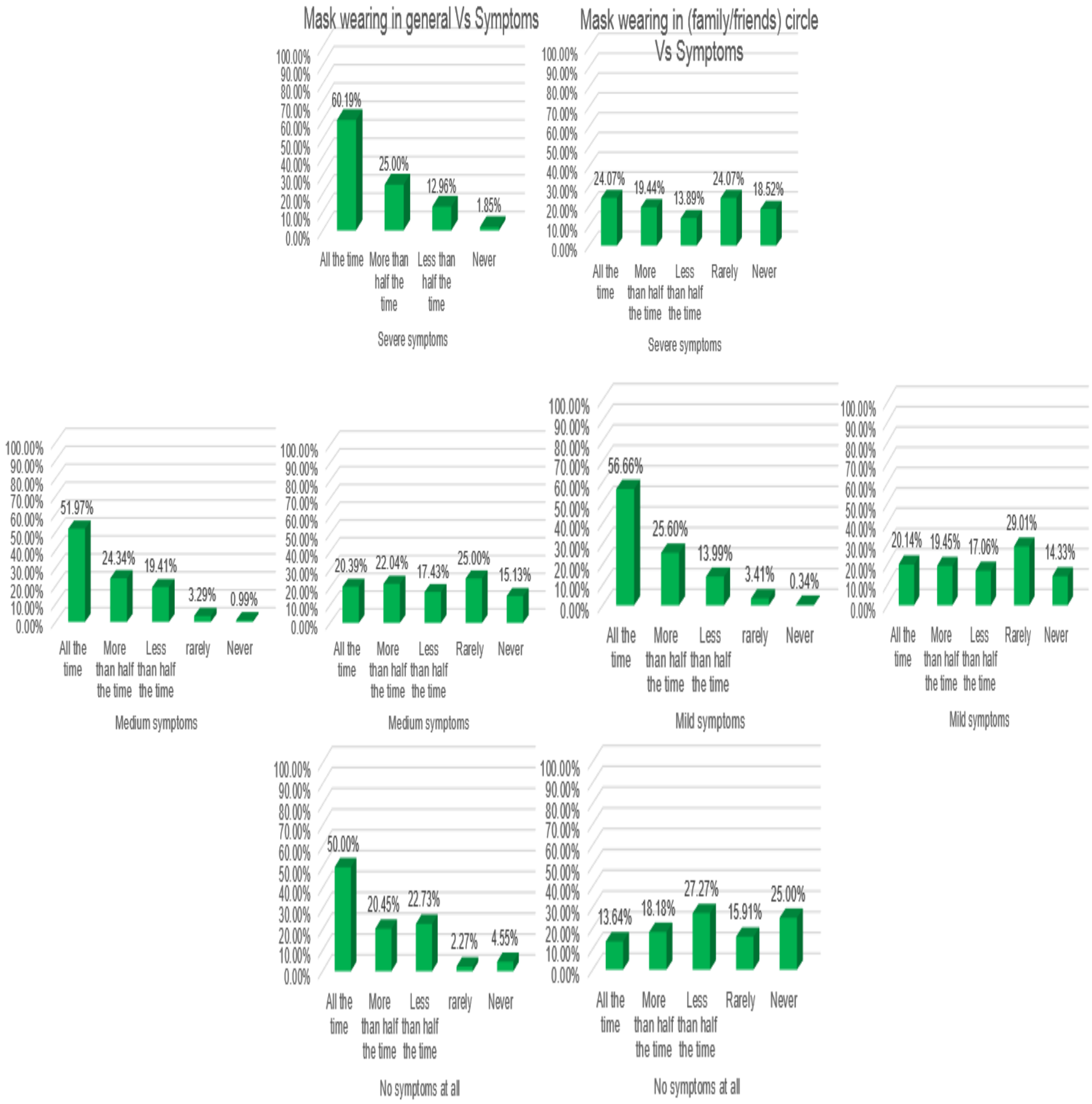

Figure 17. Respondents Mask Wearing Vs. Symptom

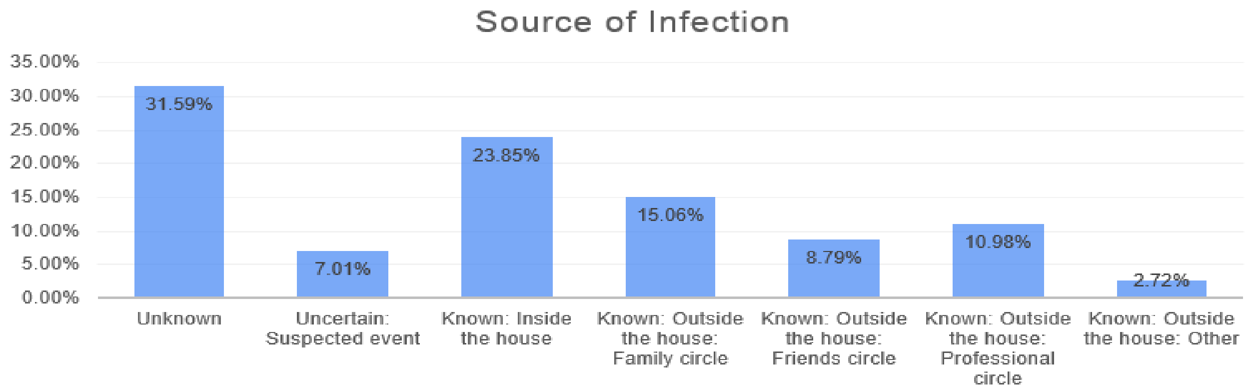

Figure 18. Respondents Infection Sources

Unfortunately, it was clyster clear that in the family and friends circle there is a shortening in wearing masks among covid-19 infected respondents with or without symptoms. This context leads us to investigate the source location of the infection.

The contamination location source of citizens by the COVID-19 virus is a key question in our study. According to the results of our survey, 62% know the place of contamination. While 31.59% do not know him. There remain 7% have doubts. Among the 62% of respondents, 24% are contaminated inside their homes, and 38% outside. Among the 38%, it is emphasized that 15% are infected in a family circle; 9% in that of friends; 11% in the professional one and 3% other occasions.

Where Chi-square test determines the relationships between the qualitative variables in our study. Analysis of these results (table 1) shows that there is an existence of a relationship of dependence between the place of contamination and these several factors (the gender, the smoking habits, the socio-professional group, the district, the area population density, the reason to make PCR test, symptoms experiencing, isolation, wearing mask, and respondents distance working).

Table 1. Pearson Chi-Square Sig. Results

	Pearson Chi-Square Value	Pearson Chi-Square Sig.
Gender	47.299	0.000
Age	35.916	0.211
Chronic Disease	51.138	0.585
Smoker	14.241	0.027
Blood Group	37.895	0.652
Socio-Professional Group	282.565	0.000
District	71.702	0.003
Population Density in Area	36.744	0.046
Reason to PCR test	330.848	0.000
Experienced Symptoms	37.641	0.039
Symptoms Duration	45.156	0.141
Committed Isolation	224.396	0.000
Wearing Mask in General	40.414	0.019
Wearing Mask in Family/Friends Circle	28.446	0.242
Hand Cleaning	16.339	0.565
Distance working	15.532	0.000

In addition, there was no dependency relationship between the place of contamination and others factors (the age, the chronic diseases, the blood group, the duration of their symptoms, wearing masks in the circles of family and friends and the frequency of hand washing per day). These factors explain the behavior of population in terms of protection against contamination.

As we conduct significant relation between source location and behavior factors, we will present below the distinguish relation between behavior factors categories and place of contamination. Indeed, the behavior of population is one of causes of dynamics of propagation of contamination.

Observing the places of contamination by sex, we expect the men to be infected outside the homes, while the women are inside. The (Figure 20) shows the following points: the majority of men are infected either in an unknown place, or in the workplace, or in the circle of friends. In addition, women are the majority compared to men infected outside the home (the family circle, uncertain or suspected events), and generally by infection from inside it.

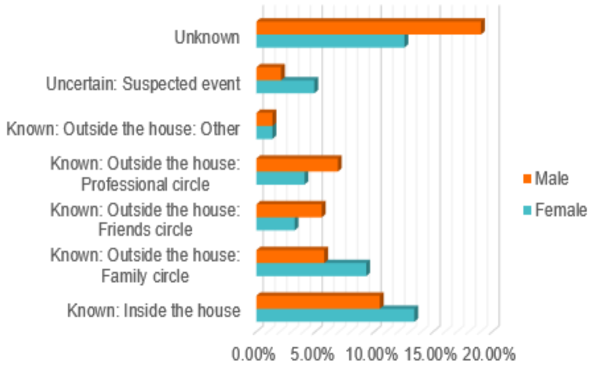

Figure 19. Respondents Infection Source Vs. Gender

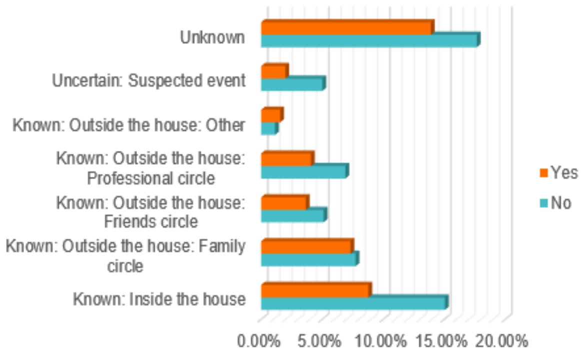

Figure 20. Respondents Infection Source Vs. Smoking Habits

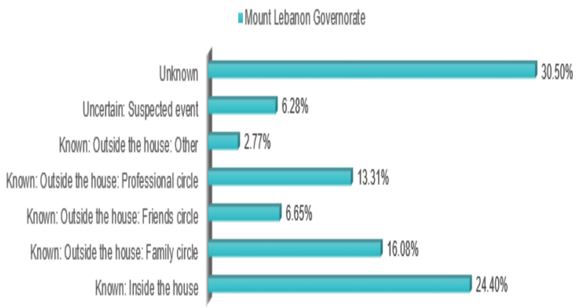

Figure 21. Respondents Of Infection Source Vs. Mount Lebanon District

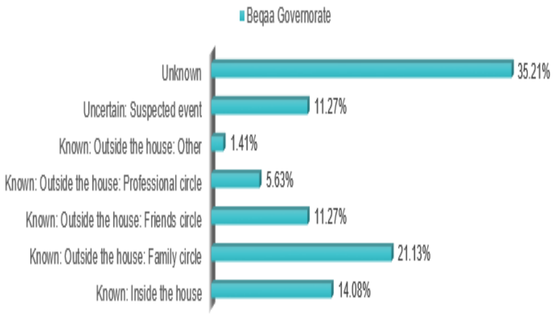

Figure 22. Respondents Infection Source Vs. Bekaa District

According to the figure 21, Smoking behavior shows significant relatedness to source of infection. It was unexpected finding that none smokers are majority in all the source of infection. As it is known, the smokers keep distances among themselves.

Spatial analysis shows difference of dynamics contamination between the big town and countryside (or small municipalities). In Mount Lebanon region, we found more contamination inside homes and in the workplace than in Bekaa. In the other hand, in the small towns and countryside presented by Bekaa district has 46.48% respondents were infected from unknown or uncertain source. This higher percentage than the capital and its suburb shows different behavior of Lebanese population in terms of governmental and municipality control of measurement against Covid-19 and their citizen respect. In others words, the weak governmental implementation of the rules and irresponsible citizen behavior explain this dynamic of propagation.

We showed previously the shortening in mask wearing for respondents with symptoms and committing isolation that oriented us to investigate the association relatedness significance.

Table 2 shows the results of the dependence test between the place of contamination and the period of wearing masks showing symptoms and compliance with isolation measures. The existence of a dependency relationship between these variables and person contact with another infected. The isolation of infected people with COVID-19, the figure 24 shows that very few of them wore the Mask in presence of other people, and this case surprising was present in all places of infected (inside and outside home, familial and friend circles). The above analysis shows that the majority of the population doesn’t respect the mask wearing rule that protect them from the contamination. This result show that the Lebanese population behaves irresponsibly and don’t respect the governmental rules against propagation and its dynamics.

Table 2. Chi-Square - Infection Source Vs. Wearing Masks In General Vs. Committing Isolation

I committed to isolation:		Value	df	Asymptotic Significance (2-sided)
Determining contact	Pearson Chi-Square	54.139[b]	24	.000
	Likelihood Ratio	31.576	24	.138
	N of Valid Cases	266		
Immediately after PCR test	Pearson Chi-Square	13.978[c]	24	.947
	Likelihood Ratio	16.285	24	.877
	N of Valid Cases	211		
Other	Pearson Chi-Square	10.971[d]	9	.278
	Likelihood Ratio	9.905	9	.358
	N of Valid Cases	14		
Positive PCR result	Pearson Chi-Square	30.810[e]	20	.058
	Likelihood Ratio	28.835	20	.091
	N of Valid Cases	146		
Symptoms appears	Pearson Chi-Square	29.429[f]	24	.204
	Likelihood Ratio	28.082	24	.257
	N of Valid Cases	319		
Total	Pearson Chi-Square	40.414[a]	24	.019
	Likelihood Ratio	39.316	24	.025
	N of Valid Cases	956		

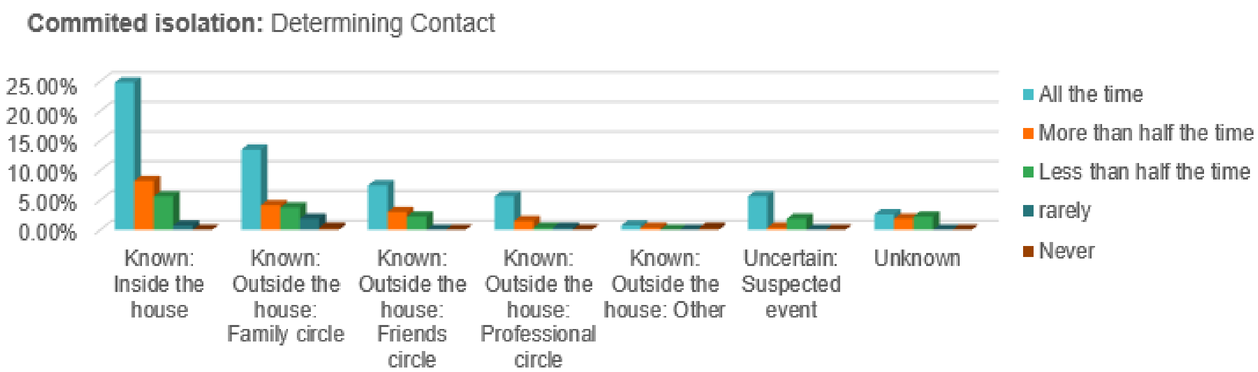

Figure 23. Respondents Responses - Infection Source Vs. Wearing Masks In General Vs. Committing Isolation

CONCLUSION

For a better understanding of temporal dynamics for contamination propagation the Susceptible-Infected-Recovered" (SIR) mathematical model has been used. This model has classified into susceptible, infected and recovered; the total population, therefore three categories. However, SIR model helps in showing the development of infection between the various Lebanese territories. The adopted mathematical model shows that there are three stages for SARS-CoV-2 development. The first, the natural behavior for the Covid-19 pandemic, second the unnatural behavior due to the lack of awareness of the people in addition to the reproduction of the daily rate of infection.

The difference in results between regions prompted us to study the reasons that led to this difference. The virus has spread widely in Lebanon and this is due to many reasons, the behavior of the people, the failure of the state to implement preventive measures as necessary, in addition to that, the absence of the role of the citizen, so that he became irresponsible and reckless, especially within the same family.

Our analysis shows a relationship between place of contamination, and the following variables: gender, smoking habits, socio-professional group, the area of population density, making PCR test reasons, isolation, wearing mask, and respondents distance working. Moreover, results show that there is no relationship between place of contamination and age of the respondents, their chronic diseases, their blood group, the duration of symptoms, and their behavior in protecting themselves against contamination.

In addition, we found a significant relationship between the place of contamination and these two variables: period of wearing masks by people showing symptoms and compliance with isolation measures.

Corona pandemic had already affected the entire world: economically, socially, and hygienically. Each day it is becoming more dangerous where it has saturated the hospital capacities in different countries increasing the number of deaths around the world and affecting millions of people health.

REFERENCES

[1]. B. Pell, Y. Kuang, C. Viboud, G. Chowell, “Using phenomenological models for forecasting the 2015 Ebola challenge,” *Epidemics*, Vol. 22, pp. 62–70, 2018.

[2]. E. Bonyah, O. O. Kazeem, “Mathematical modeling of Zika virus. Asian Pacific Journal of Tropical Disease,” *Asian Pacific Journal of Tropical Disease*, Vol. 6, no. 9, pp. 673-679, 2016.

[3]. R. U Din, K. Shah, I. Ahmad, T. Abdeljawad, “Study of Transmission Dynamics of Novel COVID-19 by Using Mathematical Model,” *Advances in Difference Equations*, 323, 2020.

[4]. Study of genetic mutations and dynamic spread of SARS-CoV-2 pandemic and prediction of its evolution according to the SIR model (PPRID: PPR272360) and EUROPE PMC EMSID: EMS114043. https://arxiv.org/abs/2011.06694v1

[5]. World Health Organization (WHO). Coronavirus. Available online: https://www.who.int/health-topics/ coronavirus (accessed on 6 August 2020).

[6]. Ministry of Health, Covid19 Command and Control Center CCC,https://www.moh.gov.sa/en/CCC/Pages/default.aspx (cited date, November 22, 2020).

[7]. S.T.M Thabet, M.S Abdo, K. Shah, and T. Abdeljawad, “Study of transmission dynamics of COVID-19 mathematical model under ABC fractional order derivative,” *Results in Physics*, Vol. 19, 103507, 2020.

[8]. G.O. AGABA, Y.N. KYRYCHKO AND K.B. BLYUSS, Time-delayed SIS epidemic model with population awareness, Ecological Complexity 31 (2017) 50–56.

[9]. N. FERGUSON ETAL. , Impact of non-pharmaceutical interventions (NPIs) to reduce COVID19 mortality and healthcare demand, report, Imperial College COVID-19 Response Team (20).

[10]. H. SALJE, C. TRAN KIEM, N. LEFRANCQ, N. COURTEJOIE, P. BOSETTI, ET AL., Estimating the burden of SARS-CoV-2 in France, preprint, HAL, (2020).

[11] Tahar Z. Boulmezaoud, Un modèle de prédiction de l’épidémie Covid-19 et une stratégie zig-zag pour la contrôler Url: http://boulmezaoud.perso.math.cnrs.fr/

[12] https://www.who.int/emergencies/diseases/novel-coronavirus 2019/situation-reports

[13] Baoquan Chen, Mingyi Shi, Xingyu Ni, Liangwang Ruan, Hongda Jiang, Heyuan Yao, Mengdi Wang, Zhenhua Song, Qiang Zhou, Tong Ge, Visual Data Analysis and Simulation Prediction for COVID-19, arXiv:2002.07096

[14] Daily report on Covid-19, Disaster Risk Management Unit, www.drm.pcm.gov.lb.

We dedicate this article to the spirit of Dr. Hicham ABOUDAYA who died during this study.

We thank Claude Aboudaya for her contribution to working on the team.