International Journal of Health Systems Resilience

INJHSR International Journal of Health Systems Resilience

Original Research ISSN 2950-7405

Application Of Statistical Modelling To Interpret A Health System Crisis In Sri Lanka Due To COVID-19

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Submitted: 03/03/2022 https://doi.org/10.51595/INJHSR221

Published: 01/10/2022

Abstract

This paper will discuss the application of statistical modelling to interpret a health system crisis in Sri Lanka caused by COVID-19. A strong focus on the preventive approach and contact tracing, with the utilization of available resources in a rational manner, describes Sri Lanka's response towards the prevention and mitigation of COVID-19. The early contact tracing, pre-emptive quarantining, isolation, and treatment were implemented as a concerted effort. This approach, proven efficient during the early phase of the pandemic, was sustainable until the rapid increase in COVID-19 patients in July 2021, exceeding the health system's capacity. The country's COVID-19 situation during the period from 01st of August 2021 to 31st of October 2021 was taken into consideration. Variables used for analysis were: total number of cases, recovered cases, comorbid and O2 dependent patients, ICU patients, and deaths. The regression model was applied to analyse the data by using the EViews 12 (x64) software application. The correlation coefficients of all the independent variables under consideration implies that they have a strong positive relationship with the number of deaths occurred during the said period.

Keywords: *COVID-19, Health system, Multiple Linear Regression*

1. Introduction

COVID-19, first discovered in 2019, is an infectious disease caused by the virus SARS-CoV-2. Since the outbreak of the pandemic, it has infected over 276,593,547 people, with over 5,385,351 deaths worldwide as of 22nd December 2021. The World Health Organization (WHO) declared SARS-CoV-2 as a global pandemic on 11th of March 2020 as by that time it has spread to over 100 countries within a matter of weeks; creating the worst global crisis ever since the World War II. At the initial stage of the pandemic, the fatality rate of COVID-19 was estimated by the WHO to be approximately 2%, while being cognizant that the fatality rate is subjected to vary along with the mutations in coronavirus. In order to coordinate the public health response, the epidemic behavioural forecasting is particularly very supportive. This paper will discuss application of statistic modelling to interpret a health system crisis in Sri Lanka due to COVID-19.

A strong focus on the preventive approach and the contact tracing with the utilization of available resources in a rational manner describes Sri Lanka's response towards prevention and mitigation of COVID-19. The response to COVID-19 in the country needs to be understood within the context of the health systems existing in Sri Lanka. There exists a strong and a well-established public health system, through which the government provides health services free of charge (Karunathilake et al. 2020).

The early contact tracing, pre-emptive quarantining, isolation, and treatment can be recognized as an assertive and concerted effort in order to minimize the spread of the pandemic.

The salient features of the initial response of Sri Lanka to COVID-19 pandemic were;

1. Early intervention by the government and the Ministry of Health

2. Extensive contact tracing

3. Early isolation of all the possible contacts pending confirmatory tests

4. Provision of well- organized quarantine facilities free of charge for the contacts with a high level of exposure

5. Isolation of the more vulnerable communities

6. Hospitalization of all the patients with positive PCR reports until their PCR becomes negative

7. Provision of free health care to all the patients

This approach was proven efficient during the early phase of the pandemic, although later it was evident that it is not sustainable due to the rapid increase in the COVID-19 patients since July 2021. The number of daily reported COVID-19 positive patients exceeded 5000. This amounted to 220 cases per million population with a global rank of 50. The estimated actual number of new COVID-19 new patients per day was around 6000 to 9000 during the peak of the pandemic. The available bed capacity for COVID-19 patients in the country was increased to 34000 via the reallocations from the other units in the hospitals by rationing the rest of the services to non-COVID-19 patients as an immediate response in order to manage the crisis. Further, the prevention of deaths due to COVID-19 both at the hospitals and residencies of patients prior to admission became another challenging issue, as the number of oxygen dependent patients and patient who needed ICU (Intensive Care Unit) care was increasing beyond the health system capacity (Ministry of Health, 2021).

The available number of healthcare workers for the proper functioning of the health care system decreased significantly due to the infection of COVID-19 and the prevailing workforce had to struggle with physical and mental exhaustion amidst attempting to maintain smooth functioning of the healthcare services. Hence, Sri Lanka's healthcare system was reaching a tipping point with an unusual increase in the demand for the dwindling resources (Ministry of Health, 2021).

The dynamic nature in the pandemic highlighted the necessity for an accurate forecasting on how the pandemic will evolve. The Susceptible Infected Removed (SIR) epidemic model was proposed by Cooper, Mondal, and Antonopoulos (2020) was based on the evolution of time of distinct populations and then monitored various variables which resulted the spread of the pandemic in countries and territories such as Australia, USA, China, India, South Korea, and

Italy. In this particular study, the Multiple Linear Regression Model (MLRM) is used as the SIR model was not adequate to interpret the crisis situation as it was accurate in judging the development trend of the pandemic and not the impact (Atkeson 2020; Bhaduri et al. 2020; Cooper et al. 2020) but the MLRM provides a better accuracy and preciseness in understanding the associations of each individual factor with the outcome.

2. Methodology

The publicly available information on COVID-19 related information, and health outcomes consisting of the total number of cases, recovered cases, comorbid and O2 dependent patients, ICU patients, and deaths were extracted from official sources; Health Promotion Bureau, Ministry of Health, and the World Health Organization (WHO). The data existing from 01st of August 2021 to 31st October 2021 was considered in order to analyse, apply, and interpret a statistical modelling for the health system crisis caused by the COVID-19 pandemic.

Further the data on Sri Lankan healthcare capacity was also collected from the Annual Health Bulletins published by the Ministry of Health and Annual Reports of the Central Bank of Sri Lanka and it contained the information on the number of hospital beds, ICU beds, physicians, and nurses per million of population.

The unit of analysis in this particular study is the country itself i.e., Sri Lanka. The regression model has been used in this study in order to analyse the data more comprehensively by using the EViews 12 (x64) software application. Thereby, the regression model which is applied to the Sri Lankan data can be utilized in order to predict or project the epidemic situation in a more pragmatic manner.

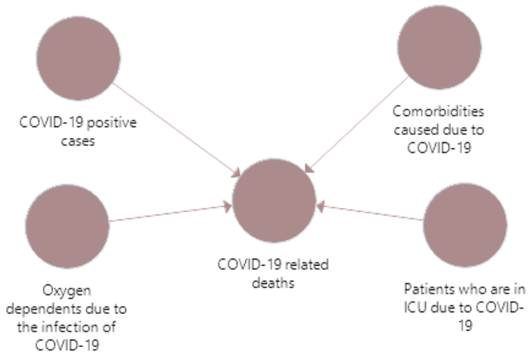

Figure 1: Conceptual framework

3. Results and Discussion

The following line graph depicts how the total number of COVID-19 positive cases and deaths occurred during the period under consideration in Sri Lanka.

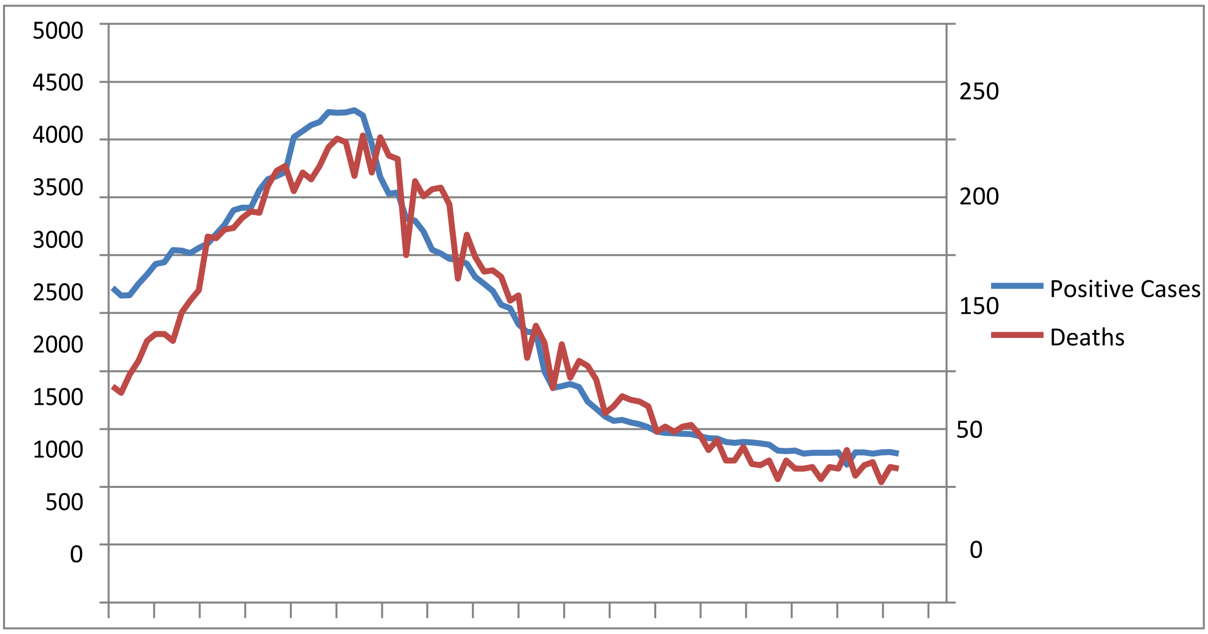

Figure 2: Total no. of confirmed positive cases and deaths in Sri Lanka (01.08.2021-31.10.2021)

Firstly, it is necessary to investigate the descriptive statistics of the data set in to allow for the micro level understanding of the study as it provides a brief and precise summary of the samples and measures under consideration.

Table 1: Descriptive Statistics of Confirmed Positive COVID-19 Cases and Deaths in Sri Lanka (01.08.2021- 31.10.2021

	Number of COVID-19 related deaths	Number of COVID-19 Positive cases	Number of O_2 dependents due to COVID-19 infection	Total number of patients in ICU due to COVID-19	Number of comorbid due to COVID-19
Mean	101.11	2135.22	522.90	148.08	2679.72
Median	92.50	2292.50	524.00	176.50	2946.50
Maximum	216.00	4621.00	1033.00	196.00	4647.00
Minimum	10.00	412.00	91.00	69.00	634.01
Std. Dev.	68.15	1380.14	315.05	47.66	1451.86
Skewness	0.24	0.28	0.01	-0.62	-0.18
Kurtosis	1.59	1.68	1.55	1.61	1.39
Jarque-Bera	8.43	7.86	8.03	13.18	10.36
Probability	0.01	0.02	0.02	0.00	0.01

Source: Processed data, 2021

The Skewness is identified as a measure of asymmetry of the distribution in the series around its mean value. In a normal distribution, the skewness of a symmetric distribution is zero. When there is a positive skewness, it is identified that the distribution has a long right tail while the negative skewness value denoted that the distribution has a long-left tail. Hence, in this study, it is recognized that the number of COVID-19 related deaths, positive cases and O2 dependents have a positive skewness while the number of ICU patients, and comorbid have a negative skewness in the distribution.

Kurtosis is the measurement of the peakedness or the flatness of the distribution of the series. In a normal distribution, the kurtosis is 3. If the distribution is peaked (leptokurtic) relative to normal, then the kurtosis will exceed 3. On contrast, if the distribution is flat relative to the normal i.e., platykurtic, then the kurtosis will be less than 3. In this particular computed data series, it is identified that the kurtosis values are all less than 3 which means that the data series is platykurtic.

Jarque- Brea is a test statistic which is used for testing in order to identify whether the data is normally distributed. This Jarque- Bera test can be identified as goodness- of- fit test in order to recognize whether the sample data have the skewness and kurtosis matching a normal distribution.

The test statistic JB can be defined as:

$$JB = \frac{n}{6}\left(S^2 + \frac{1}{4}(K-3)^2\right)$$

where the n is the number observations or degrees of freedom, sample skewness is denoted with the S and K is the sample kurtosis. Hence, according to Jarque-Bera statistic, all these variable data is not normally distributed as they do not exceed the probability value of 0.05.

The analysis on correlation coefficients can be used in order to measure the strength of the linear relationship between the two variables. If the correlation coefficient is greater than zero, it implies a positive relationship whereas if the correlation coefficient value is less than zero then it indicates a negative relationship. This can be further analysed using the scatterplot diagram in order to understand the nature and the direction of the relationship between the variables.

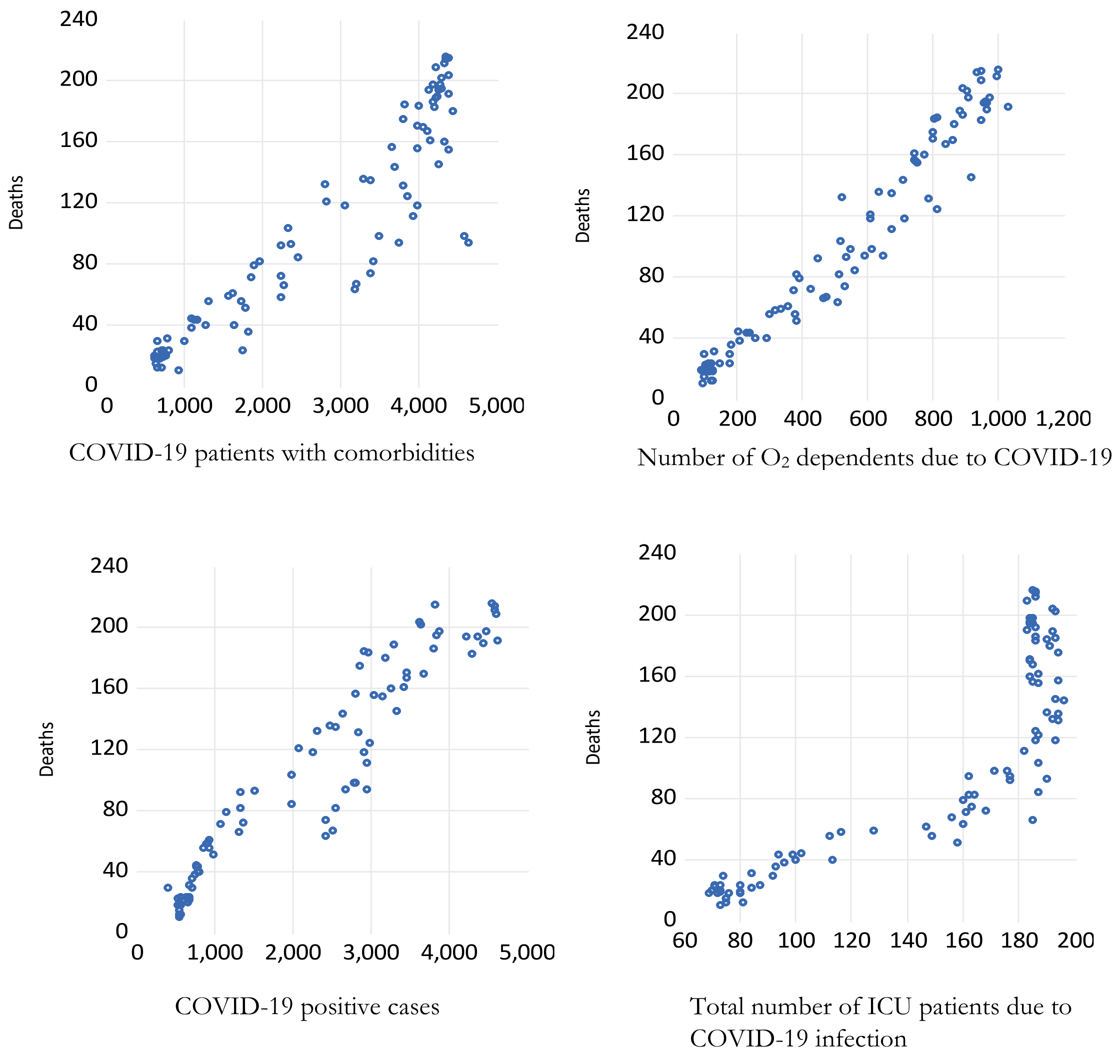

Figure 3: Scatter diagrams showing the relationship between the COVID-19 deaths and the selected independent

The summary of the correlation coefficients for the variables under consideration can be shown as follows.

Table 2: Summary table of the correlation coefficients

	COVID-19 positive cases	O_2 dependents due to COVID-19 infection	Number of patients in the ICU due to COVID-19	Comorbidities due to COVID-19
Deaths	0.954	0.976	0.862	0.921

Source: Processed data, 2021

According to the above computed correlation coefficient table, it is identified that the relationship of each of the independent variables have a high strong positive relationship with the dependent variable i.e., the number of COVID-19 related deaths as the coefficient correlation values are positive and higher than 0.75.

Multiple linear regression attempts to model the relationship between two or more independent or explanatory variables and one dependent or response variable by fitting a linear equation to the observed data. In the data series, every value of the independent variable x is associated with a value of the dependent variable y. Hence, the above table shows the strength of the independent variables with the dependent variable.

Table 3: Summary output

Regression Statistics	
R-squared	0.959
Adjusted R-squared	0.957
Standard Error of regression	14.138
Observations	92

ANOVA					
	df	SS	MS	F	Significance F
Regression	4	5.34	1.33	506.86	0
Residual	455	3.75			
Total	459	9.09			

	Coefficients	**Std. Error**	**t-Statistic**	**P-value**
Intercept (c)	1.207	7.205	0.168	0.868
COVID-19 positive patients	0.005	0.006	0.821	0.418
O_2 dependent COVID-19 patients	0.252	0.031	8.049	0

Total COVID-19 patients in the ICU	-0.077	0.098	-0.778	0.439
COVID-19 patients with comorbidities	-0.012	0.004	-2.632	0.010

Dependent Variable: Number of deaths caused due to COVID-19

Method: Least Squares

Source: Processed data, 2021

According to the computed multiple linear regression model, the coefficient values capture the estimates for the independent variables i.e., number of COVID-19 positive cases, O2 dependents, comorbid, and ICU patients and the intercept is denoted with (c). The positive signs of the coefficients imply that the variables of number of COVID-19 positive cases and O2 dependents have a positive relationship while comorbid and ICU patients have a negative relationship with the dependent variable which might have resulted due to very high multicollinearity among the independent variables. Therefore, the following multiple linear regression equation can be applied.

$Y = \beta 0 + \beta 1X1 + \beta 2X2 + \ldots + \beta iXi$

In which,

Y = Dependent variable

$\beta 0$ = Intercept

βi = Slope for Xi

X = Independent variable

Thus, the MLRM generated from this particular study will be,

$Y = 1.207 + 0.005X1 + 0.005X2 + 0.252X3 - 0.077X4 - 0.012X5$

In which Y is the number of Covid-19 related deaths.

According to the computed multiple regression model, it shows that the number of O2 dependents, and comorbid patients' due to COVID-19 has a p- value which is less than 0.05 which implies a higher level of confidence in rejecting the null hypothesis i.e. no statistical relationship existing between the observed variables while the p- value for the number of COVID-19 positive cases and ICU patients are higher than p- value of 0.05 which means that the null hypothesis can't be rejected for those particular independent variables which may have resulted due to the high multicollinearity among the independent variables.

The R- squared value of 0.959 gives the variation in the independent variables that are explained by all the independent variables. The higher the R2, the better the model and more predictive power the variables have.

4. Conclusion

The main purpose of this study was to apply a statistical model in order to investigate the impact of COVID-19 on the health system in Sri Lanka. Therefore, the country's COVID-19 situation during the period from 01st of August 2021 to 31st of October 2021 was taken into consideration. The analysis was done based on the multiple linear regression model. The correlation coefficients of all the independent variables under consideration implies that they have a strong positive relationship with the number of deaths occurred during the said period. According to the computed multiple linear regression model, the number of positive cases and O2 dependents have a positive relationship while comorbid and ICU patients have a negative relationship with the dependent variable. From the perspective of epidemiological control, these findings highlight the importance of keeping the number of cases within the limits of health system capacity as it implies a positive relationship between COVID-19 related deaths and positive cases. The significance of this study is that the health officials can get a better understanding on the factors which result the COVID-19 related deaths and thereby to implement policies and take preventive actions in order to reduce the COVID-19 related mortality. Further, the Ministry of Health can use this study in order to identify the gravity of the COVID-19 crisis and also to well-prepare for the crisis by forecasting the situation. The limitation of this study can be identified as the COVID-19 related deaths which were either unreported or unrecorded during the period under consideration due to administrative difficulties caused because of the limited health workforce available during the surge of the pandemic.

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