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Modeling Daily Infected Cases of COVID -19 in Ukraine

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ABSTRACT

COVID-19 is the worst pandemic in the 21st Century after the Swine Flu in 2009-2010. The World Health Organization (WHO) declared COVID-19 to be a pandemic when it was spreading very fast over a wide area. Ukraine has reported the 8th highest European country and 3rd highest Eastern European country grabbed by COVID-19. Ukraine exceeds 3.5 million cases since 22nd January 2020. At present, the daily infected cases show a decreasing trend. This study is designed to model daily infected cases in Ukraine. The daily infected cases in Ukraine for the period of 22nd January 2020 to 12th December 2021 were obtained from the Humanitarian Data Exchange (HDX). The behavior of the data series is recognized by time series plots and Auto Correlation Function (ACF). It was found that the series follow irregular wave like patterns with increasing amplitudes as well as decreasing amplitudes. The Sama Circular Model (SCM), Seasonal Auto-Regressive Integrated Moving Average (SARIMA), and Holt's Winters additive and multiplicative models were tested to forecast the infected cases. The relative and the absolute measurements of errors were used to assess the ability of the models. The results of the study revealed that Holt's Winters models and the SCM are suitable for the purpose. It also found that the SCM outperformed Holt's Winters models. However, the literature revealed that the Damped Circular Model (DCM) and Forced Circular Model (FCM) would be more suitable to capture the behavior of series with decreasing amplitude and increasing amplitude respectively. Therefore it is recommended to test the DCM and FCM to forecast the daily infected cases of Ukraine and other countries with similar patterns.

Keywords: COVID -19, SCM, SARIMA, Daily Cases, Holt's Winters Model

1. INTRODUCTION

1.1 Background of the Study

The COVID-19 means Corona (CO), Virus (VI), Disease (D), and year 2019 (19) (Sugiyanto & Muchammad, 2020). World Health Organization (WHO) reports there were more than 271 million cases and 5.3 million death total reported globally within two years. This is the worst pandemic in the 21st Century after the Swine Flu in 2009-2010. Ukraine has reported the 8th highest European country and 3rd highest Eastern European country grabbed by COVID-19. Ukraine exceeds 3.5 million cases since 22nd January 2020. At present, the daily infected cases show a decreasing trend. Ukraine had exceeded more than 3.2 million recoveries and more than 91,215 death cases. The rate of daily infected cases in Ukraine is 8.1% approximately which is not a satisfactory level. The rate of recoveries is 89.9% approximately which is at a quite satisfactory level. The behavior of daily infected cases shows a decreasing trend at present. But the future of the pandemic is unpredictable.

1.2 Research Problem

The daily infected cases in Ukraine show a wave-like pattern with a quadratic trend. Konarasinghe, (2021-a):(2021-b):(2021-c):(2021-d):(2021-e): found that there were many repeating behaviors within the daily infected cases in the Philippines, Italy, Iran, Argentina, and in the UK.There could be similar or more repeating behaviors within the daily infected cases in Ukraine. It could be a symptom to find out the causes for the repeating behavior of the daily infected cases. It would be a guide to minimize or control the outbreak. Hence, modeling the future outbreak with the repeating behaviors of the pandemic would be a time requirement.

1.3 Objective of the Study

The objective of the study is to model daily infected cases of COVID-19 in Ukraine.

1.4 Significance of the Study

The results of this study can be applied to predict the future behavior of the pandemic. It would be a lighthouse to develop effective strategies to control the outbreak of the pandemic in Ukraine. It is a guide to work out the medical and healthcare requirements with minimum waste (Konarasinghe, (2021-a). The results of the study can be applied to schedule lockdowns, lockups, delivery systems, virtual activities, production capacities, working schedules, etc (Konarasinghe, (2021-d). It would be another guide for new business activities mainly, virtual business, E-commerce, etc, (Konarasinghe, (2021-e). The present business processes would be re-engineered by observing the future behavior of the pandemic to minimize both systematic and unsystematic risk in business (Konarasinghe, (2021-d).

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2. LITERATURE REVIEW

The review of the study was focused on modeling the outbreak of COVID-19 in Ukraine. Few studies were found related to the purpose.

2.1 Studies Based on Modeling COVID -19 Outbreak in Ukraine

Gankin et al (2021) have applied agent-based modeling to investigate the characteristics of the first months of the epidemic in Ukraine. Nesteruk, (2021-a) has applied the SIR (susceptible-infected-removed) model to examine the dynamics of the epidemic waves. Nesteruk, (2021-b) has applied the SIR model predict the infected cases. Nesteruk, (2021-c) has applied the SIR model to forecast cases of the new wave within the summer of 2021. Nesteruk, (2021-d) has applied a generalized SIR model to examine the dynamics of an epidemic wave of infected cases in Ukraine. Mohammadi, et al (2021) have applied SIR (Susceptible, Infected, Recovered) to model the spread. Kyrychko, et, al (2020) have applied the SEIR (Susceptible-Exposed-Infected-Recovered) to model the spread. Dumitru, et al (2020) have applied Auto-Regressive Integrated Moving Average (ARIMA) models to predict the epidemiological trend of COVID-19 in Ukraine, Romania, the Republic of Moldova, Serbia, Bulgaria, Hungary, USA, Brazil, and India. Issanov et al (2020) have applied a modified SEIR model to forecast a number of cases over a period of time of 10, 30, 60 days in 10 post-Soviet states. Nesteruk, (2020-a) has applied the SIR model to estimate the epidemic characteristics for a few selected countries including Ukraine. Nesteruk, (2020-b) has applied the SIR model to estimate the dynamics of the COVID -19. Nesteruk, (2020-c) has applied the SIR model to detect new waves after 1st September 2020. Nesteruk, (2020-d) has applied the SIR model to detect the pandemic waves in Ukraine and the remainder of the world. Konarasinghe (2021-f) has applied Holt's Winters three-parameter additive and multiplicative models to forecast daily infected cases in Ukraine.

The SIR model was highly applied to predict the outbreak of the pandemic in Ukraine. Besides, SEIR, ARIMA, and Holt's Winters additive and multiplicative models were other techniques applied for the aim. The applications of stochastic models were very limited during this context. Hence, capturing the uncertainty of the pandemic situation is extremely limited. The prevailing pandemic almost completed the second year. The repeating behaviors of the daily infected cases should be monitored, forecasted, and explore at this stage. But, the least attention has been observed during the review. There would be more attention on capturing such behaviors of the pandemic in Ukraine.

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3. METHODOLOGY

The daily infected cases of COVID-19 in Ukraine for the period of 22nd January 2020 to 12th December 2021 were obtained from the Humanitarian Data Exchange (HDX). The pattern of the data series paves the path for the model selection to predict daily infected cases in Ukraine (Konarasinghe, 2016-a; 2016-b; 2021-a; 2021-b; 2021-c; 2021-d; 2021-e) and (Konarasinghe, W.G.S., & Abeynayake, 2014).There could be seasonal, cyclical,

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trends, heavy and minor volatility within the period of the data set (Konarasinghe, W.G.S. & Abeynayake, 2014). Due to the above reasons, the data series would follow an irregular wave-like pattern with; constant amplitude, increasing amplitude, decreasing amplitude or a mix of them. The Auto Correlation Function (ACF) and time series plot was used to recognize the patterns, as done by Konarasinghe, W.G.S., & Abeynayake (2014). As per the pattern of the data series, Sama Circular Model (SCM), Seasonal Auto-Regressive Integrated Moving Average (SARIMA), and Holt's Winters three-parameter additive and multiplicative models were tested to forecast daily infected cases in Ukraine. The model assumptions were tested by Ljung-Box Q (LBQ) test, Anderson Darling test, and ACF, (Konarasinghe, W.G.S., et al, 2015). The forecasting ability of the model asses by three measurements of errors, as per Konarasinghe, (2018; 2016-c; 2015-a; 2015-b). They are; Mean Absolute Percentage Error (MAPE), Mean Square Error (MSE), and Mean Absolute Deviation (MAD) Konarasinghe, (2018; 2016-c; 2015-a; 2015-b). Log transformed data were used for the data analysis of the study.

3.1 Circular Model and Sama Circular Model

The development of the CM was based on; Fourier Transformation, the theory of Uniform Circular motion and Multiple Regression Analysis (Konarasinghe, W.G.S., 2016). The SCM is the improved version of the CM (Konarasinghe, W.G.S., 2020-a; 2018-b).

3.1.1 Circular Model (CM)

As explained in Konarasinghe, W.G.S.(2016),a variable Y_t, with an irregular wave pattern was modeled by the Circular Model ;

$$Y_t = \sum_{k=1}^{n} (a_k \sin k\omega t + b_k \cos k\omega t) + \varepsilon_t \qquad (1)$$

Model assumptions of the CM are; the series Y_t is trend-free, k is a positive real number, $\sin k\omega t$ and $\cos k\omega t$ are independent; residuals are Normally distributed and independent.

3.1.2 Sama Circular Model (SCM)

A limitation of the CM is that it is not applicable for a series with a trend. Konarasinghe, W.G.S. (2020-a; 2018-a; 2018-b) suggests the method of differencing to mitigate the limitation of the CM. In usual notation, differencing series of Y_t are as follows;

First differenced series: $Y_t^{'} = Y_t - Y_{t-1} = (1-B)Y_t$ (2)

Second differenced series:

$$Y_t^{''} = Y_t^{'} - Y_{t-1}^{'} = (Y_t - Y_{t-1}) - (Y_{t-1} - Y_{t-2}) = Y_t - 2Y_{t-1} + Y_{t-2} = (1-B)^2 Y_t \qquad (3)$$

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Similarly, d^{th} order difference is, $Y_t^d = (1-B)^d Y_t$ (4)

Where, B is the Back Shift operator; $BY_t = Y_{t-1}$.

Assume Y_t^d is trend-free. Let, $Y_t^d = X_t$ then X_t could be modeled as;

$$X_t = \sum_{k=1}^{n}(a_k \sin k\omega t + b_k \cos k\omega t) + \varepsilon_t \quad (5)$$

Hence; $$(1-B)^d Y_t = \sum_{k=1}^{n}(a_k \sin k\omega t + b_k \cos k\omega t) + \varepsilon_t \quad (6)$$

the model (6); improved Circular Model, was named as “Sama Circular Model (SCM)”.

3.2 Seasonal Auto Regressive Integrated Moving Average (SARIMA)

ARIMA modeling can be used to model many different time series, with or without trend or seasonal components, and to provide forecasts (Box & Jenkins, 1970); (Box, & Jenkins, 1976). The model as follows;

An ARIMA model is given by:

$$\phi(B)(1-B)^d y_t = \theta(B)\varepsilon_t$$

Where; $\phi(B) = 1 - \phi_1 B - \phi_2 B^2 ....\phi_p B^p$

$$\theta(B) - 1 - \theta_1 B - \theta_2 B^2 ......\theta_P B^q \quad (7)$$

$\varepsilon_t =$ Error term

D = Differencing term

B = Backshift operator ($B^a Y_t = Y_{t-a}$)

Analogous to the simple SARIMA parameters, these are:

Seasonal autoregressive - (Ps)

Seasonal differencing - (Ds)

Seasonal moving average parameters - (Qs)

Seasonal models are summarized as ARIMA (p, d, q) $(P, D, Q)_s$

Number of periods per season - S

$$(1-\phi_1 B)(1-\varphi_1 B^s)(1-B)(1-B^s)Y_t = (1-\theta_1 B)(1-\theta_1 B^s)\varepsilon_t \quad (8)$$

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3.3 Holt's Winters Three Parameter Models

This model may be applied when both trend and seasonality are present, with these two components being either additive or multiplicative (Holt, 1957). Winters' Method calculates dynamic estimates for 3 components; level, trend and seasonal which denotes α, β, and γ (with values between 0 and 1) (Holt, 1957). Formulae of Winter's multiplicative model is;

$$L_t = \alpha (Y_t / S_{t-p}) + (1-\alpha) [L_{t-1} + T_{t-1}] \quad (9\text{-}1)$$

$$T_t = \beta [L_t - L_{t-1}] + (1 - \beta)T_{t-1} \quad (9\text{-}2)$$

$$S_t = \gamma (Y_t / L_t) + (1 - \gamma) S_{t-p} \quad (9\text{-}3)$$

$$\hat{Y}_t = (L_{t-1} + T_{t-1}) S_{t-p} \quad (9\text{-}4)$$

Where,

L_t = is the level at time t, α is the weight for the level, T_t = is the trend at time t, β is the weight for the trend, S_t = is the seasonal component at time t, γ is the weight for the seasonal component, p = is the seasonal period, Y_t = is the data value at time t, $\hat{Y}_t$ = is the fitted value, or one-period-ahead forecast, at time t.

Formulae of Winter's additive model is;

$$L_t = \alpha (Y_t - S_{t-p}) + (1 - \alpha) [L_{t-1} + T_{t-1}] \quad (10\text{-}1)$$

$$T_t = \beta[L_t - L_{t-1}] + (1 - \beta)T_{t-1} \quad (10\text{-}2)$$

$$S_t = \gamma (Y_t - L_t) + (1 - \gamma) S_{t-p} \quad (10\text{-}3)$$

$$\hat{Y}_t = L_{t-1} + T_{t-1} + S_{t-p} \quad (10\text{-}4)$$

Where,

L_t = is the level at time t, α is the weight for the level, T_t is the trend at time t, β is the weight for the trend, S_t = is the seasonal component at time t, γ is the weight for the seasonal component, p = is the seasonal period, Y_t = is the data value at time t, $\hat{Y}_t$ = is the fitted value, or one-period-ahead forecast, at time t.

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4. RESULTS

The analysis contains two main parts:

4.1 Pattern recognition of daily infected cases in Ukraine.
4.2 Forecasting daily infected cases in Ukraine.

4.1 Pattern Recognition of Daily Infected Cases in Ukraine

Figure 1 is the time series plot of daily infected cases of Ukraine for the period of 22nd January 2020 to 12th December 2021. The first confirmed case was reported on 3rd March 2020. After 27th August 2020 daily infected cases are growing exponentially. It increased till 28th November 2020. There have been 616,181 infected cases reported within 94 days during the first growth. Exponential decay has been observed afterward till 8th February 2021.The second exponential growth began after 8th February 2021 till 3rd April 2021. There have been 494,500 infected cases reported within 55 days during the second growth. The third exponential growth began after 9th August 2021 till 4th November 2021. There have been 801,451 infected cases reported within 87 days during the third growth. There was a declining trend with fluctuations afterward.

Figure 1: Time Series Plot of Daily Cases in Ukraine

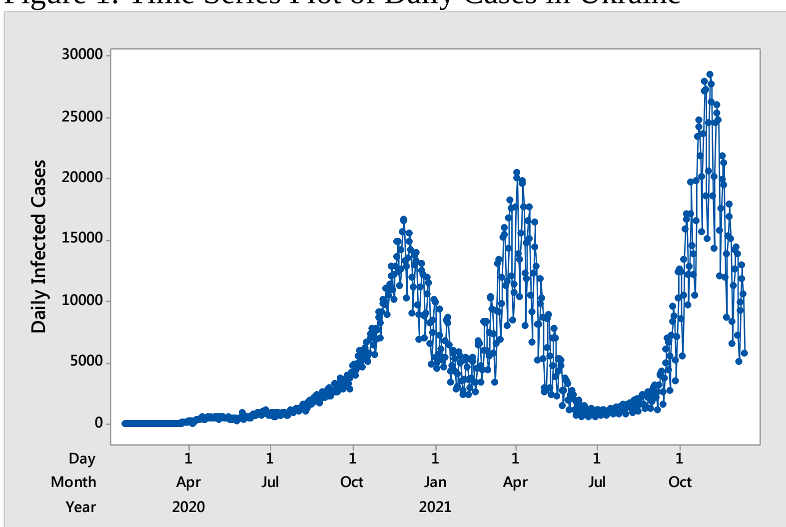

Figure 1 shows that the recent pattern of infected cases after 30th September 2021 is that the most fitted a part of the data series to forecast daily infected cases in Ukraine. Hence, the period of 30th September 2021 to 12th December 2021 was examined furthermore. Figure 2 is that the time series plot of daily infected cases of Ukraine for the chosen period. According to Figure 2, there is volatility with a quadratic trend of daily infected cases in Ukraine. The behavior has confirmed the declining trend of the daily infected cases.

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Figure 2: Daily Cases of 30th September to 12th December 2021

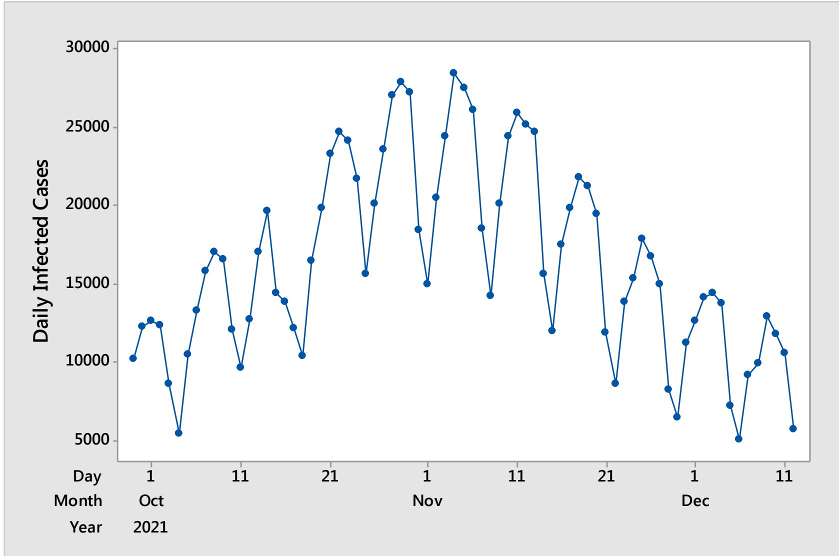


Figure 3 is the ACF of the daily infected cases. It shows a seasonal or repeating behavior of daily infected cases accommodated after 7 days. ACF shows that there might be one repeating visible behavior. There are few significant lags. The series has confirmed the weak stationary consistent with Figure 3.

Figure 3: ACF of Daily Cases (DC)

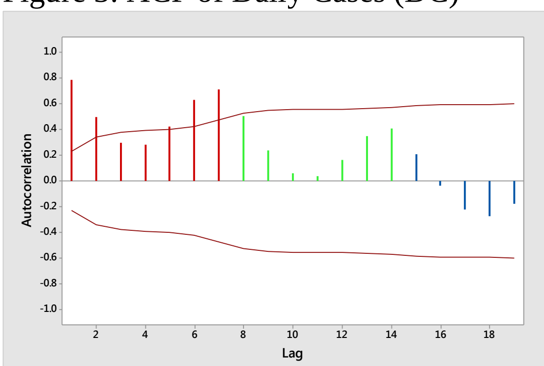


Figure 4: Plot of 1st Difference of DC

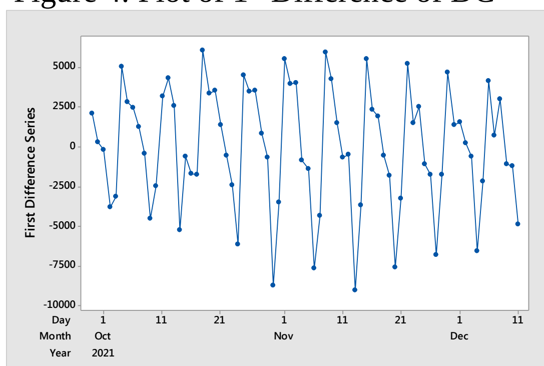


Figure 4 has shown the first different series of daily infected cases in Ukraine. The first difference series is required to look at the wave-like pattern of the series to use SCM (Konarasinghe, W.G.S., 2019; 2020-b). The high volatility of the wave pattern has been observed in Figure 4. This behavior could be a solid evidence to pick and apply SCM to forecast the daily infected cases in Ukraine. Stationary of the series is another evidence to pick and apply SARIMA for the aim.

4.2 Forecasting Daily Infected Cases in the Ukraine

The selected wave breaks into 56 wave packets or trigonometric series from sin $0.25\omega t$ to sin $7\omega t$ and cos $0.25\omega t$ to cos $7\omega t$. The results of the Table 1 revealed that there was just one significant trigonometric series out of 56.

Table 1: Model Summary of SCM

Model	Model Fitting		Model Verification	
$Y_t = Y_{t-1}$ - $0.1715 \sin \omega t$	MAPE	1.8958	MAPE	3.1992
	MSE	0.0523	MSE	0.1427
	MAD	0.1806	MAD	0.2906
	Normality	P = 0.866		
	Independence of Residuals	Yes		

$\sin \omega t$ is that the significant trigonometric series within the SCM. The model satisfied the validation criterion of normality and independence of the residuals. The measurements of errors were low under the fitting and verification. Actual Vs. fits of SCM are shown in Figure 5. The fits of the daily infected cases follow an analogous pattern of the actual series in Figure 5. The deviation between actual and fits are very low. Figure 6 is that the actual Vs. forecast of SCM. The pattern of forecast almost follows the similar pattern of the actual series. The deviation between actual and forecast is extremely less.

Figure 5: Actual vs. Fits of SCM

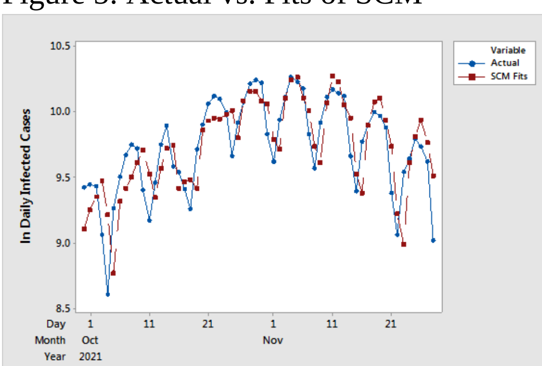
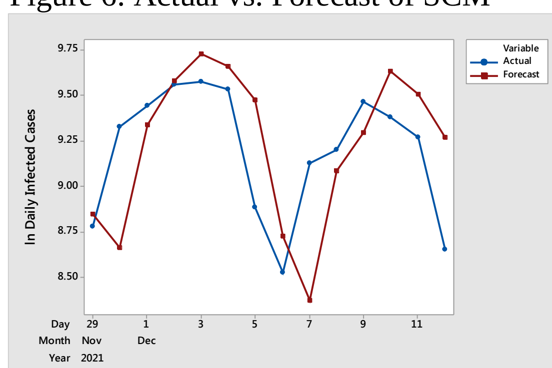


Figure 6: Actual vs. Forecast of SCM



The SCM satisfied the model assumptions, forecasting ability, and capturing the behavior of fits and forecast with actual behavior were highly satisfactory. Figure 6 is another solid evidence to prove that the SCM is capable to follow wave-like patterns (Konarasinghe, W.G.S. 2020-b). Hence, SCM is suitable to forecast daily infected cases of COVID -19 in Ukraine. The fitted SCM is;

$$Y_t = Y_{t-1} - 0.1715 \sin \omega t \quad (11)$$

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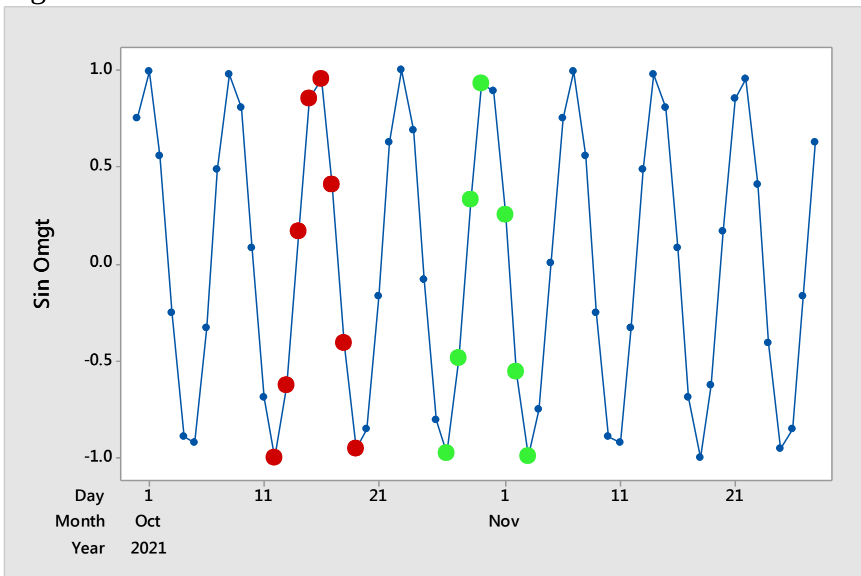
Figure 7 indicates that there are wavelengths of 7 and 8 days. Which means daily infected cases in Ukraine are repeated in 7 and 8 days intervals.

Figure 7: Plot of $\sin \omega t$



The SARIMA model tested with several repeating behaviors. But the model was not significant. Then the Holt's Wintesters additive and multiplicative models were tested with several of repeating behaviors. The models were significant for the 7 days of repeating behavior. The performances show in Tables 2 and 3.

Table 2: Model Summary of Holt’s Winters Additive Model

Model	Model Fitting		Model Verification	
Additive (7) α (level) 0.60 γ (trend) 0.16 δ(seasonal) 0.40	MAPE	0.9170	MAPE	4.3921
	MAD	0.0874	MAD	0.4039
	MSE	0.0143	MSE	0.2186
	Normality	P= 0.092		
	Independence of Residuals	Yes		

The fitted Holt’s Winters additive model of α; 0.60, γ; 0.16 and δ; 0.40 satisfied the validation criterion of normality and independence of the residuals. The measurements of errors were low under the fitting, but it is high in the verification. Actual Vs. fits of Winters additive model shown in Figure 8. The fits of the daily infected cases follow a similar pattern to the actual cases. The deviation between actual and fits are very low.

Figure 9 is the actual vs. forecast of the Winters additive model. The pattern of the forecast is quite similar to the actual. The deviation between actual and forecast is less.

Figure 8: Actual vs. Fits Winters Additive Model

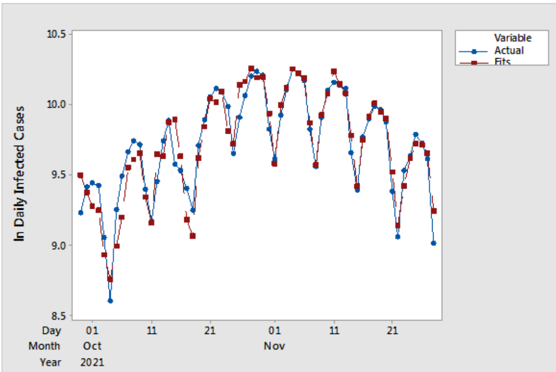
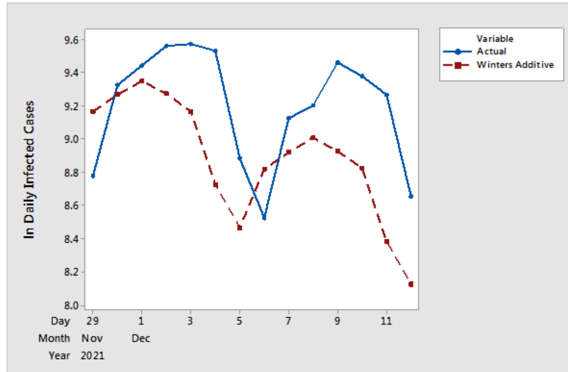


Figure 9: Actual vs. Forecast Additive Model



The performances of the Holt's Winters multiplicative model available in Table 3.

Table 3: Model Summary of Holt's Winters Multiplicative Model

Model	Model Fitting		Model Verification	
Multiplicative (7)	MAPE	0.9393	MAPE	4.5208
α (level) 0.60	MAD	0.0895	MAD	0.4163
γ (trend) 0.16	MSE	0.0151	MSE	0.2254
δ(seasonal) 0.40	Normality	P= 0.060		
	Independence of Residuals	Yes		

The Holt's Winters multiplicative model of α; 0.60, γ; 0.16 and δ; 0.40 satisfied all model validation criterion. The ability of the model is similar to the additive model. Figures 10 and 11 are the actual vs fits and forecast consecutively. The behaviors are almost similar to the additive model. The performances of Holt's Winters additive and multiplicative models are almost similar. But, both models were capable to capture one repeating the behavior.

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Figure 10: Actual vs. Fits Winters Multiplicative Model

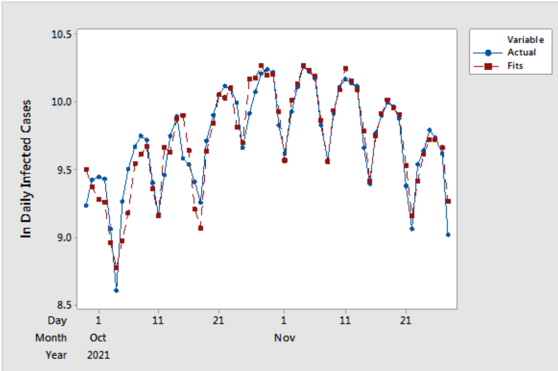
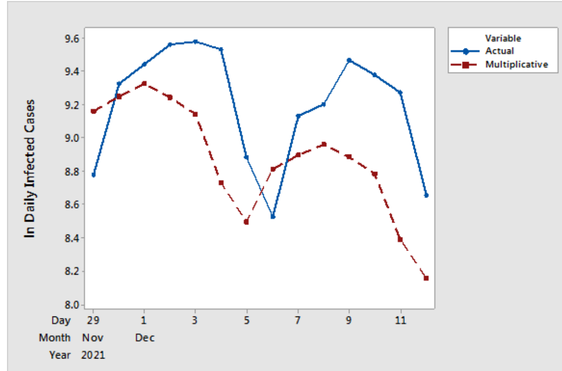
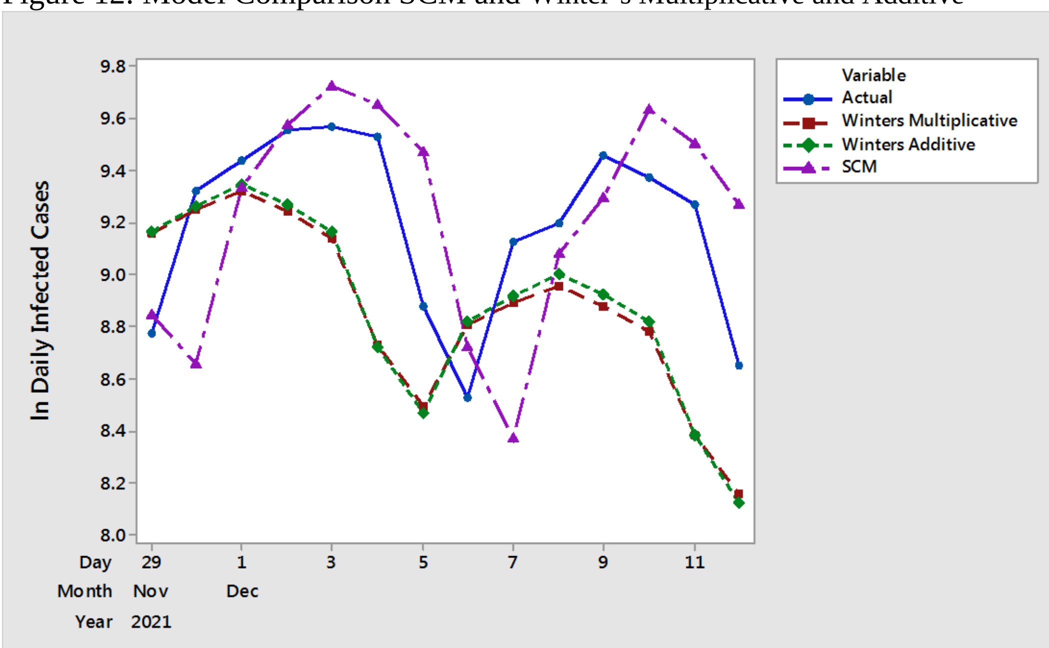


Figure 11: Actual vs. Forecast Multiplicative Model



In this study, SCM and Holt's Winters additive and multiplicative models were found suitable to forecast the daily infected cases of COVID-19 in Ukraine. The model comparison between SCM and Holt's Winters additive and multiplicative models is in Figure 12.

Figure 12: Model Comparison SCM and Winter's Multiplicative and Additive



The SCM has follows quite similar behaviors with the least deviation of daily infected cases in Ukraine. Whereas the performances of Holt's Winter's additive and multiplicative models are contrasted with SCM. The deviations between actual cases and forecast were more in Holt's Winter's additive and multiplicative models. Also the forecasts of Holt's Winter's models are underestimates.

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Figure 12 is a solid evidence to say that the SCM outperformed Holt's Winter's additive and multiplicative models.

5. CONCLUSION AND RECOMMANDATIONS

The SCM is the best-suited model for forecasting daily infected cases of COVID-19 in Ukraine .The least measurement of errors, satisfying the model validation criterion, and capturing the wave-patterns are main criterions to consider the best fitting model. This study is another evidence to prove that the SCM is capable in capturing daily infected cases of COVID-19. The SCM has the ability to capture many repeating behaviors at once with minimum effort. This study has captured two repeating behaviors of 7 and 8 days. This repeating behavior would be one of the perfect guidelines to control the outbreak of the pandemic in Ukraine. Controlling movements of the general public, lockdown schedules transportation schedules for the essential services, preparing an effective working schedule for the employees in both the public and private sector etc.(Konarasinghe, 2021-d).A vaccine is a part of medical care. Medical care constitutes only 10% to 20% of health outcomes, approximately (AIM, 2019). The remaining 80% to 90% incorporates several social factors, including other healthcare practices (AIM, 2019).Food habits, healthy lifestyles, working styles and other non-pharmaceutical activities are a few factors associated with healthcare practices (AIM, 2019). Medical care is not sufficient to prevent the outbreak of the pandemic. The general public should practice healthcare to prevent the disease. Non-pharmaceutical interventions are the primary mitigation strategy to control and minimize the outbreak of the COVID-19 pandemic (Kantor & Kantor, 2020). Sneeze on tissues/elbows, avoid touching the face and avoid handshakes, wear masks, wear protective glasses, wash hands, hand sanitizer, (Kantor & Kantor, 2020). Logistic support is another supportive factor to controlling the outbreak of the pandemic. The results of this study would be a guide to work out the logistic requirements effectively and efficiently Authorities can work out the requirements by observing the repeating behavior of the daily cases. This would facilitate minimizing the waste and the cost of the productions. The rate of daily infected cases in Ukraine soaring and it is not favorable to the sleek function. Hence, to control the outbreak effective quarantine procedures should be imposed, followed strictly, and monitored by the authorities. Further, the results of the study would be a guide to take initiative to develop and implement proactive measures to control the outbreak in Ukraine.

The COVID-19 pandemic almost completed the second year. There could be repeating behaviors of daily infected cases in many countries. The length of the data sets were sufficient to capture the repeating behaviors. Hence, it is strongly recommended to explore the repeating behaviors of the outbreak in other countries without any delay.

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Figure 13: Behaviors of the Amplitudes

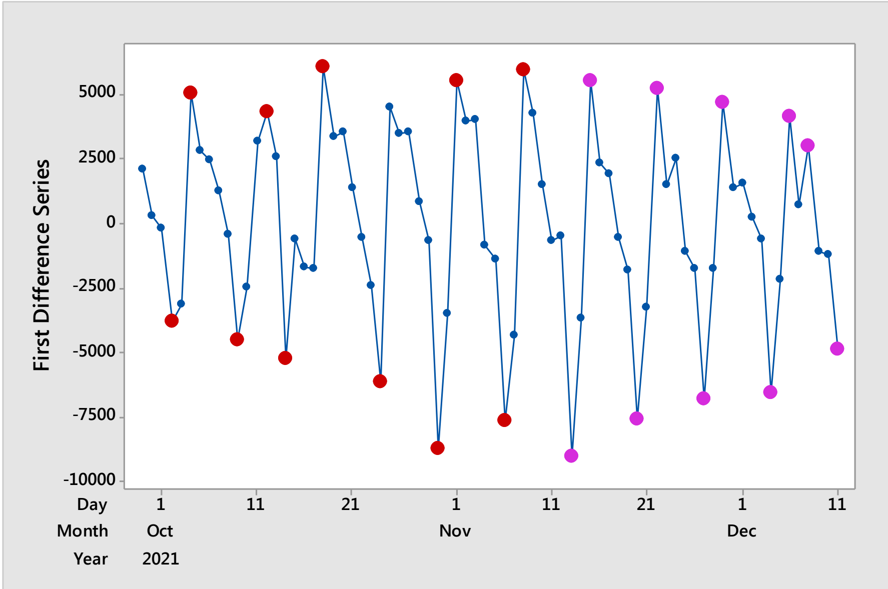

Figure 13 clearly shows the combination of wave patterns with increasing and decreasing amplitudes. The Damped Circular Model (DCM) and Forced Circular Model (FCM) would be more suitable to capture them (Konarasinghe, & Konarasinghe, 2021). It is recommended to test the DCM and FCM to ensure more accuracy in forecasting daily infected cases in Ukraine and other countries furthermore.

REFERENCES

Annapolis Internal Medicine (AIM). (2019). *What is Health Care?* https://annapolisinternalmedicine.com/posts/news/what-is-health-care/.

Box, G. E., & Jenkins, G. M. (1976). Time series analysis: forecasting and control. Taiwan, Republic of China.: Holden-Day.

Box, G.E.P. and Jenkins, G.M. (1970) Time Series Analysis: Forecasting and Control. *Holden-Day*, San Francisco.

Dumitru, O.I.,Oana, R.C., Ciobica, A., Loan, T., Loannis, M., & Doroftei, B. (2020). Forecasting the Spreading of COVID-19 across Nine Countries from Europe, Asia, and the American Continents Using the ARIMA Models. *Microorganisms*. 8, 1158. doi:10.3390/microorganisms8081158.

ISSN 2719-2385 (Online)

Gankin,Y., Nemira, A.,Koniukhovskii,V.,Chowell,G.,Weppelmann,T.A.,Skums,P., Kirpich, A.(2021). Investigating the first stage of the COVID-19 pandemic in Ukraine using epidemiological and genomic data. *Infection, Genetics and Evolution*. 95,(105087). doi.org/10.1016/j.meegid.2021.105087.

Holt, C.C.(1957). *Forecasting seasonal and trends by exponentially weighed moving average*. Office of Naval Research, Research memorandum, 52.

Issanov,A. Amanbek,Y.,Abbay,A., Adambekov,S.,Aljofan, M., Kashkynbayev,A., & Gaipov,A. (2020). COVID-19 Outbreak in Post-Soviet States: Modeling the Best and Worst Possible Scenarios. *MedRxiv*, doi.org/10.1101/2020.04.19.20071704.

Konarasinghe, K.M.U.B. (2021-a). *Forecasting COVID-19 Outbreak in the Philippines and Indonesia*. Journal of New Frontiers in Healthcare and Biological Sciences, 2(1), 1-19.

Konarasinghe, K.M.U.B. (2021-b). *SCM and SARIMA on Forecasting COVID-19 Outbreak in Italy*. Journal of New Frontiers in Healthcare and Biological Sciences, 2(1), 20-38.

Konarasinghe, K.M.U.B. (2021-c). *Forecasting Wave-like Patterns of COVID-19 Daily Infected Cases in Iran*. Journal of New Frontiers in Healthcare and Biological Sciences, 2(1), 39-56.

Konarasinghe, K.M.U.B. (2021-d). *Model Base Analysis of COVID-19 Daily Infected Cases in Argentina*. Journal of New Frontiers in Healthcare and Biological Sciences, 2(1), 57-75.

Konarasinghe, K.M.U.B. (2021-e). *Modeling Wave-Like Patterns of Daily Infected Cases of COVID-19 in the UK*. Journal of New Frontiers in Healthcare and Biological Sciences, 2(2), 1-15.

Konarasinghe, K.M.U.B. (2021-f). *Forecasting COVID-19 Daily Infected Cases in Ukraine.* Conference Proceedings of Institute of Mathematics and Management Conference on Mathematical & Biological Sciences (IMMCMBS) 2021.Canberra, Australia.1 (1).9. ISSN: 2756 - 9144(Online). 10.5281/zenodo.5637626.

Konarasinghe, W.G.S., & Konarasinghe, K.M.U.B.(2021). Model Development for Damped and Forced Type of Oscillations in Time Series. *Journal of New Frontiers in Mathematics and Statistics*.2 (2)20-35.

Kyrychko, Y.N., Blyuss, K.B., & Brovchenko, I. (2020). Mathematical modelling of the dynamics and containment of COVID‑19 in Ukraine. *Scientific Reports*.10, 19662. doi.org/10.1038/s41598-020-76710-1.

ISSN 2719-2385 (Online)

Kantor, B.N., & Kantor, J. (2020). Non-pharmaceutical Interventions for Pandemic COVID-19: A Cross-Sectional Investigation of US, General Public Beliefs, Attitudes, and Actions. *Front. Med*, 7:384. doi: 10.3389/fmed.2020.00384.

Konarasinghe, W.G.S. (2020-a).*Improved Circular Model on Forecasting Arrivals from Western European Countries to Sri Lanka.* Communications in Computational and Applied Mathematics (CCAM).2(2). https://fazpublishing.com/ccam/index.php/ccam/article/view/41

Konarasinghe, W.G.S. (2020-b).*Comparison of Forecasting ability of Sama Circular Model, ARIMA, and Decomposition Techniques*. Journal of New Frontiers in Mathematics and Statistics, 1(1), 1-15.

Konarasinghe, W. G. S. (2019). *Sama Circular Model and ARIMA on Forecasting BSE Sensex.* International Journal of Novel Research in Physics Chemistry & Mathematics, 6(2), 1-7. https://www.noveltyjournals.com/issue/IJNRPCM/Issue-2-May-2019-August-2019.

Konarasinghe K.M.U.B. (2018). *Forecasting Foreign Guest Nights in Hill Country of Sri Lanka.* Review of Integrative Business and Economics Research, 7(4):41-56.

Konarasinghe, W.G.S. (2018-a). *Sama Circular Model on Forecasting Tourist Arrivals to Sri Lanka.* Mathematical Sciences International Research Journal, 7(2), 191-193.

Konarasinghe, W.G.S. (2018-b). *Sama Circular Model on Forecasting Sri Lankan Stock Market Indices*. Mathematical Sciences International Research Journal, 7 (Special issue), 1-4.

Konarasinghe, W.G.S.(2016). *Model Development for Stock Returns*. Doctor of Philosophy Thesis, University of Peradeniya, Sri Lanka.

Konarasinghe K.M.U.B. (2016-a). *Patterns of tourist arrivals to Sri Lanka from Asian countries.* International Journal of Research and Review, 3(11), 69-79.

Konarasinghe, K.M.U.B. (2016-b). *Time Series Patterns of Tourist Arrivals to Sri Lanka.* Review of Integrative Business and Economics Research, 5(3): 161-172.

ISSN 2719-2385 (Online)

Konarasinghe, K.M.U.B. (2016-c). *Decomposition Techniques on Forecasting Tourist Arrivals from Western European Countries to Sri Lanka.* Conference Proceedings of the 13th International Research Conference on Business Management (ICBM) – 2016, Faculty of Management Studies and Commerce, University of Sri Jayawardanapura, Sri Lanka. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2910291.

Konarasinghe, W.G.S., Abeynayake, N.R., & Gunaratne, L.H.P. (2015). Forecasting Share Prices of Banks of Colombo Stock Exchange. *International Journal of Research & Review*, 2(6), 372-378.

Konarasinghe, K.M.U.B. (2015-a). *Trend Analysis of Direct Employment in Tourism Industry of Sri Lanka*. Conference Proceedings of the 4th International Conference of the Sri Lankan Forum of University Economists, 31. ISSN: 2279 - 2406.

Konarasinghe, K.M.U.B. (2015-b). Lin-Log Model for Forecasting International Tourism Income in Sri Lanka: Post-War Period.12th International Conference on Business Management (ICBM) 2015, https://ssrn.com/abstract=2699689. http://dx.doi.org/10.2139/ssrn.2699689.

Konarasinghe, W .G. S., & Abeynayake, N. R. (2014). Time series patterns of Sri Lankan stock returns. *Proceedings of the 11th International Conference on Business Management, Phd Consortium*, Faculty of management studies and commerce, University of Sri Jayewardenepura. 78-95.

Mohammadi, A.,Chumachenko,T., Makhota, L., & Chumachenko,D.(2021). Compartment Model of COVID-19 Epidemic Process in Ukraine. CEUR Workshop Proceedings. IT&AS'2021: Symposium on Information Technologies & Applied Sciences, Bratislava, Slovakia.

Nesteruk, I. (2021-a). *Detections and SIR simulations of the COVID-19 pandemic waves in Ukraine*. Comput. Math. Biophys.9 (46–65). doi.org/10.1515/cmb-2020-0117.

Nesteruk, I.(2021-b).*Visible and real sizes of the COVID-19 pandemic in Ukraine*. medRxiv. doi.org/10.1101/2021.03.19.21253938.

Nesteruk, I. (2021-c).Simulation and predictions of a new COVID-19 pandemic wave in Ukraine with the use of generalized SIR model. *MedRxiv*. doi.org/10.1101/2021.10.13.21264949.

Nesteruk, I. (2021-d). Estimates of the COVID-19 pandemic dynamics in Ukraine based on two data sets.MedRxiv.doi.org/10.1101/2021.02.18.2125200.

ISSN 2719-2385 (Online)

Nesteruk, I. (2020-a). Simulations and predictions of COVID-19 pandemic with the use of SIR model. Innov Biosyst Bioeng. 2020. 4(2) 110–121. doi: 10.20535/ibb.2020.4.2.204274. http://ibb.kpi.ua/article/view/204274.

Nesteruk, I. (2020-b). *Long-term predictions for COVID-19 pandemic dynamics in Ukraine, Austria and Italy*. MedRxiv.doi.org/10.1101/2020.04.08.20058123.

Nesteruk, I. (2020-c). COVID-19 pandemic dynamics in Ukraine after September 1, 2020. MedRxiv.doi.org/10.1101/2020.12.21.20248627.

Nesteruk, I. (2020-d).Waves of COVID-19 pandemic. Detection and SIR simulations. MedRxiv. doi.org/10.1101/2020.08.03.20167098.

Sugiyanto, S., & Muchammad, A. (2020). A Mathematical Model of the Covid-19 Cases in Indonesia. *Biology, Medicine, & Natural Product Chemistry*, 9(1), 15-19. doi: 10.14421/biomedich.2020.91.15-19.

ISSN 2719-2385 (Online)