Short-Term Forecasting of COVID-19 Statistics in Malaysia Using Time Series Analysis Model

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***Abstract*— COVID-19 has been one of the most serious global health crises in world history. During the pandemic, healthcare systems require accurate forecasts for key resources to guide preparation for patient surges. This paper showcases a multivariate approach to forecast key COVID-19 statistics of the next 15 days for new daily cases and new daily death counts in Malaysia by incorporating some of the statistics released by the Ministry of Health of Malaysia like hospital capacity and daily MySejahtera check-in details. By evaluating the model performance against the hold-out 15-day test set, the models are able to provide accurate forecast with RMSE of 1752.6482 for new cases and RMSE of 7.7241 for new death count.**

Keywords*— *Time Series Analysis, SARIMAX, COVID-19, Malaysia, MySejahtera.

I. Introduction

The Novel Coronavirus Disease (COVID-19) caused by the spread of SARS-CoV-2 [1] has resulted in a global pandemic with a death toll of over 4.2 Million worldwide and over 10 thousand individuals have succumbed to the disease as of August 2021 [2]. The highly infectious nature of the SARS-CoV-2 virus has lead to a nationwide outbreak of the pandemic with infected individuals showing symptoms like cough, fever, shortness of breath and worst case of all, fatality [3]. The impact of the pandemic goes beyond the sickness of the individuals. In an attempt to curb the community outbreak, restrictive measures like Movement Control Order (MCO) [4] has major social and economic disruptions towards the nation [5] and arguably it is yet another pandemic that will shape human history[6] after the 1665 great plague[7] and the 1918 Spanish flu pandemic[8].

Malaysia has experienced three waves of infections with the first wave and second wave of infections in late January 2020 and March 2020[9]. The shift action of immediate isolation nationwide lockdown known as the Movement Control Order (MCO), which came into effect on 18 March 2020 to May 2020 has led to the gradual decline in daily infections[10] with eventually zero local transmission recorded on Jul 1 2020 [11]. However, the third wave which started in September through the Sabah state election has led to a major outbreak and surging of positive cases despite the effort of a more lenient MCO 2.0 in Jan 2021 [12] and Total Lockdown in Jun 2021 [13]. The country is currently ranked third in the number of cases in Southeast Asia, behind Indonesia and the Philippines and fourth in terms of deaths due to COVID-19, behind Indonesia, Philippines and Myanmar. All this justifies the heightened need for scrutiny and academic attention to help the country surfing out the wave of the COVID-19 pandemic.

The goal of this paper is to forecast key COVID-19 statistics in Malaysia including the daily confirmed cases and daily fatality count in an attempt to provide an additional reference for policymakers to making a more informed decision and grasp better control of the outbreak of the disease before the collapse of the healthcare system and the further exacerbated of mortality rate.

II. Related Works

Many models have been used to forecast the outbreak and key statistics of COVID-19 epidemic like daily confirmed cases and death count. The SIR model is one of the simplest mathematical models to predict the properties of the spread of infectious disease by dividing the population into three major compartments: Susceptible, Infectious and Recovered. Azrul at al. [14] have make use of a simple SIR model to visualise the spread of COVID-19 with the assumptions of no human intervention and vaccine developed. Wong et al. [15] take a different approach to visualise the different efficacy level of vaccine intervention towards the spread of COVID-19 epidemic.

Other than pure mathematical models, several studies has make use of time series analysis model in predicting future cases of COVID-19. For instance, Rauf and Hannah [16] found out that ARIMA (2,2,2) model produced the most accurate result compared to others for cases in India. Apart from that, Singh et al. [17] has implemented ARIMA model fitted for 17-day forecasting for COVID-19 cases in Malaysia with a Mean Absolute Percentage Error (MAPE) value of 16.01 and a Bayes Information Criteria (BIC) value of 4.170. Kamarudin et al. [18] explored different predictive models including ARIMA and found that the multilayer perceptron has outperformed all models in estimating the number of positive cases. However, the approaches above are made with simple assumptions where future value is dependent of its previous history. To better model the real-world scenario, I will incorporate several epidemic related statistics into my model that takes into account of number of travelling individuals, positivity rate as well as hospitalisation rate to forecast the 7-day averaged daily confirmed cases and daily death count for the next 15 days.

III. Methodology

A. Dataset

The dataset of all key statistics is obtained from the GitHub Repository [19] managed by Malaysia's Ministry of Health with daily updates and maintenance. Since we are forecast with the number of confirmed cases and death count, there are several area of focus that we wish to incorporate in our model which includes Cases and Testing, Healthcare Capacity and Mobility & Contact Tracing.

For Cases and Testing, other than the two key point of interest of Daily Confirmed Cases and Daily Mortality, number of daily testing and the positivity rate which is further calculated can be a more reflective measure of the country's COVID-19 situation. In earlier 2021, to not put further strain on the healthcare system, the Ministry of Health of Malaysia has reduce the testing regime to only symptomatic close contacts [20] which implies that the actual number of confirmed cases are more than the statistics and positivity rate might be more indicative.

With COVID-19 cases spikes in Malaysia, the healthcare system is put on trial as more individuals are hospitalised with needs of immediate medical attention. Healthcare capacity and the medical instrument available can directly impact the survivability of a COVID-19 patient [21]. Unfortunately, several incidence have been reported where the healthcare workers have to make decision on prioritising patients with higher survivability rate for better medical support like getting beds in ICU and ventilator [22].

Lastly, the Mobility data reflected from the daily check-ins from the MySejahtera application is taken into account to model the number of travelling individuals and the human activity rate in Malaysia. MySejahtera is an mobile application developed by the Government of Malaysia which aid contract tracing ability by enforcing a QR Code Check-In solution in all premises and work location in Malaysia [23].

The final daily dataset is obtained after some data wrangling and merging of different files based on the common day. The training data is recorded from 1 March 2021 to 22 July 2021 and the testing data is recorded from 23 July 2021 to 6 August 2021 (15 Days). Table 1 shows the data dictionary of the final data.

TABLE I. DATA DICTIONARY

Features	***Descriptions***
date	Date of Covid Statistics
cases_new	Number of new cases reported in 24h since the last report
deaths_new	Number of new deaths due to COVID-19 reported in 24h since the last report
total_test	Sum of Number of test done using Antigen Rapid Test Kits (RTK-Ag) and Real-time Reverse Transcription Polymerase Chain Reaction (RT-PCR) technology
checkins	Number of checkins at all locations registered on MySejahtera
unique_ind	Number of unique accounts which checked in
unique_loc	Number of unique premises checked into
casual_contacts	Number of casual contacts identified and notified by CPRC's automated contact tracing system
total_beds_available	Sum of available hospital beds with related medical infrastructure and beds for non-critical care
admitted_covid	Number of individuals admitted to hospitals because of COVID-19
discharged_covid	Number of individuals discharged from hospitals because of COVID-19
hosp_covid	Number of individuals in hospitals currently because of COVID-19
bed_icu_covid	Total critical care beds dedicated for COVID-19
icu_covid	Total number of individuals under intensive care because of COVID-19
vent_covid	Total number of individuals on mechanical ventilation because of COVID-19

B. Exploratory Data Analysis

With the data properly loaded, I have performed some basics visualisation to analyse the trend and some insights that we can gain from the data.

1) COVID-19 Cases Statistics

Since our data starts from March 2021, we didn't manage to capture the first two wave of COVID-19 infection. I do manage to capture the latest third wave of infection that are growing exponentially for all key statistics like daily new cases and daily death counts as shown in Fig 1.

Another interesting trend that I have discovered is the immediate decrease of number of daily cases when the 'total lockdown' restriction was introduced in June 1 2021 [24]. However, the decrease of reported cases can be attributed to the reduced amount of testing which is reasonable as more individuals are not exposed to testing regime. This can be further corroborated by the increasing positive rate despite the implementation of 'total lockdown' which implies the underlying community clusters and sporadic cases of over 84.3% in June [25].

Lastly, the exponential increase of the COVID-19 statistics despite the 'total lockdown' restriction clearly indicates the inability of the curbing measure in flattening the curve. To investigate this further, I will visualise the MySejahtera check-ins details in attempt to understand the human traffic in Malaysia.

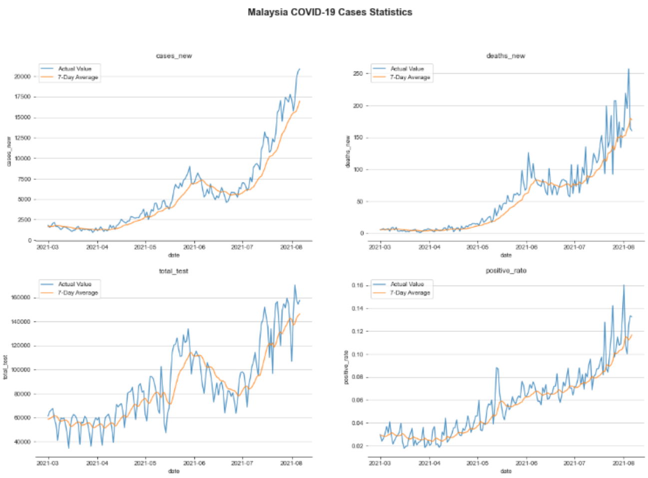

Fig. 1. Malaysia COVID-19 Cases Statistics

2) MySejahtera Check-in Statistics

From the MySejahtera check-in statistics we can analyse the daily number of check-ins count, daily unique number of accounts and unique premises which have checked in through the system. From Fig 2 I have noticed at June 1, the number of unique individuals and premises has decreased significantly as the 'total lockdown' measure was introduced back in June. However, both the number of unique individuals and premises has been increasing which implies more individuals are expose in outdoor activities and more location and workplaces has been given the green light to operate.

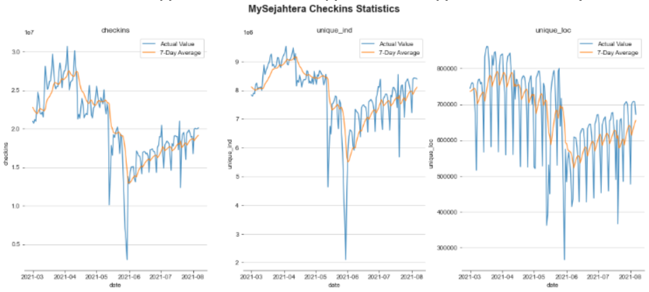

Fig. 2. MySejahtera Check-in Statistics

From reports released by the Ministry of Health, workplace clusters remain high and they form more than 55 per cent of all the clusters identified since the total lockdown was imposed on June 1. Cases contributed from workplaces are due to the green light given to many industries to operate during the "total lockdown" [26]. Nevertheless, the check-in statistics can be helpful for us to determine the infectious rate in a country. Given the two to 14 days incubation cycle [27], I have decided to shift the check-in details 15 days later which allows me to forecast the number of confirmed cases in the next 15 days based on the check-in details in the past 15 days.

3) Hospitalisation Details

Lastly, hospitalisation details can directly impact the survivability of a patient by investigating the hospital admission and capacity. Fig 3 have shown that both normal hospital bed capacity as well as the ICU bed capacity has increased proportionally as the country facing the third wave of COVID-19 infection. For the sake of generating prediction with exogenous variable using SARIMAX model, I will use the same approach of shifting data 15 days later in order to forecast the death count in the next 15 days.

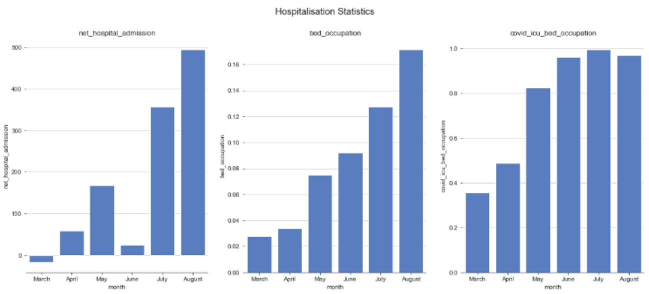

Fig. 3. Malaysia Hospitalisation Statistics

C. Time-Series Modelling

1) 7-Day Rolling Average

By observing the key COVID-19 statistics, I realise the daily new cases and daily death count have certain degree of fluctuation which could be attributed to different human factors like the amount of test performed each day. Hence, to better model the general trend instead of being too caught up with the human factors for the two key COVID-19 statistics, I will be taking a 7-day rolling average across the training and testing set. To the moving average for each timestamp, y_t, we need to take the mean of the actual value from the current timestamp, x_t to the actual value of 6 timestamp before x_{t-6}.

$$y_t = \frac{1}{7}\sum_{i=0}^{7} x_{t-i}$$

$$y_t = \frac{1}{7}(x_t + x_{t-1} + \cdots + x_{t-6})$$

2) Stationary Time-Series and Autocorrelation Function(ACF) & Partial Autocorrelation(PACF)

Before committing to the actual modelling of the SARIMAX model, it is commendable to first plot out the Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) with the goal of visualising potential trend of our targeted variable as well as interpret the initial orders for my time series model.

Before we execute the function, we need to first ensure stationarity in my time-series that is the mean, variance and covariance does not vary with time. For that, I will be utilising the augmented dickey-fuller test to enforce stationarity. Since the trend of the key COVID-19 statistics seems to be growing exponentially, I first take a natural logarithm of the 7-day average value before applying differencing until the time-series is considered stationary from the augmented dickey-fuller test with confidence level of 95%.

After applying differencing twice to the natural logarithm of the 7-day rolling average, both COVID-19 statistics are considered stationary with p-value of 0.029674 for *cases_new* and 0.000071 for *deaths_new* as shown in Table 2.

TABLE II. AUGMENTED DICKEY-FULLER TEST RESULT

Variables	***P_Value***	***Stationarity***
cases_new	0.029674	True
deaths_new	0.000071	True

After stationarity is enforced, I have plotted the ACF and PACF plot with 95% confidence interval (CI) as shown in Fig 4. For PACF plot of the *cases_new* series, the partial autocorrelation has fallen out of the CI after 2 Lags, implying that there might only be 2 significant AR components where as for *deaths_new* series, the partial autocorrelation dropped after 4 Lags which leads to 4 AR components. As for the ACF plot, autocorrelation for both *cases_new* and *deaths_new* drop after 1 Lags and hence our model will have just 1 MA component. Moreover, I have also noticed a 7-day seasonality for both of the timeseries. Appropriate seasonal AR component of 2 and 1 is chosen for *cases_new* and *deaths_new* respectively. As for the seasonal MA component, 1 is chosen for both of our series.

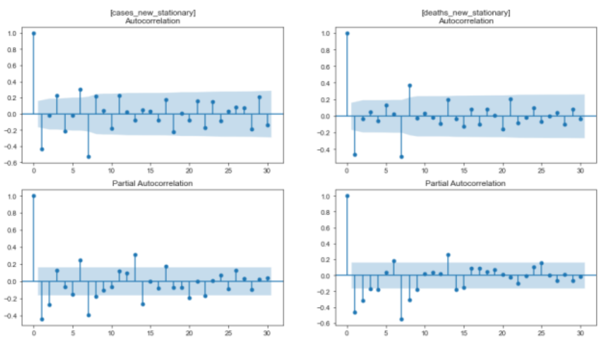

Fig. 4. ACF Plot and PACF Plot

3) SARIMAX Modelling

I will be using Seasonal Auto-Regressive Integrated Moving Average with eXogenous factors (SARIMAX) for my modeling process since from the previous findings, we have successfully identified AR, MA and Seasonal component in our time-series. Besides, eXogenous variables are also incorporated into our modeling to increase the robustness of our model as well as provide important context towards the prediction of key COVID-19 statistics. For the prediction of *cases_new* series, *positive_rate*, *checkins*, *unique_ind*, *unique_loc* and *casual_contacts* will be used as the exogenous variable whereas for the prediction of *deaths_new* series, *positive_rate*, *bed_occupation* and *covid_icu_bed_ occupation* will be used as exogenous variable instead.

In addition to the interpreted the parameters based on ACF and PACF plot, I have also performed with hyperparameters tuning by using expanding window technique with 5 split and test_size of 15 days as the time-series cross validation to find out the best set of hyperparameters for SARIMAX model by minimizing the Root Mean Squared Error (RMSE) and Akaike Information Criterion (AIC).

IV. DISCUSSION

A. Model Evaluation and Error Analysis

Based on the results of time-series cross validation using expanding window technique, SARIMAX(2,1,1)(2,1,1,7) is chosen with lowest RMSE of 0.16456 (RMSE after taking natural logarithm of the orignal series) and AIC of -472.50 for *cases_new.* SARIMAX(3,1,1),(2,1,1,7) is chosen for prediction of *deaths_new* with lowest RMSE of 0.2846 and AIC of -268.77. Table 3 shows a clearer summary of the performance of the model evaluated on the hold-out test set which consist of 7-day average of 23 July 2021 to 6 August 2021 (15 days).

TABLE III. SARIMAX MODEL EVALUATION ON TEST SET

Model	***RMSE***	***AIC***
SARIMAX(2,1,1),(2,1,1,7)	1752.6482	-555.5006
SARIMAX(3,1,1),(1,1,1,7)	7.7241	-301.1125

Fig 5 shows the visualisation of the prediction on the test set as well as the 95% CI of the prediction generated. I realised that the forecasting generated is able to capture the general trend without extremely large deviation.

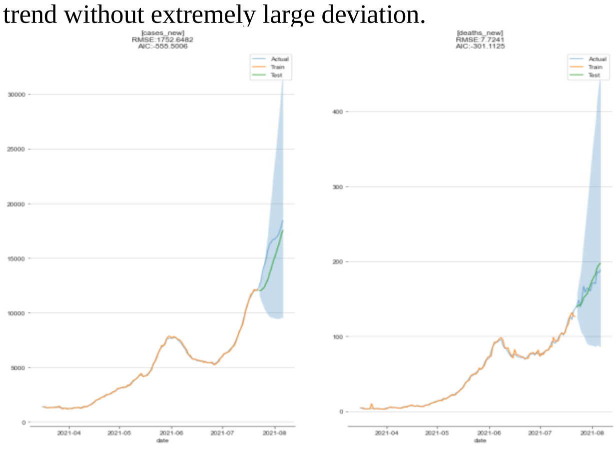

Fig. 5. Test set Forecasting Visualisation

Analysis of the residuals for SARIMAX(2,1,1)(2,1,1,7) (Fig 6) and SARIMAX(3,1,1),(2,1,1,7) (Fig 7) shows that the model fits the data reasonably well with normally distributed residuals and no residuals falling outside of the 95% CI except at lag 3 for SARIMAX(2,1,1)(2,1,1,7) and lag 8 for SARIMAX(3,1,1),(2,1,1,7). I am satisfied with the result for now and the model is ready to generate the next 15-day forecast.

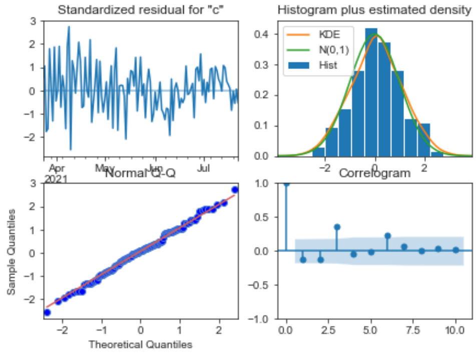

Fig 6 : SARIMAX(2,1,1)(2,1,1,7) Error Analysis

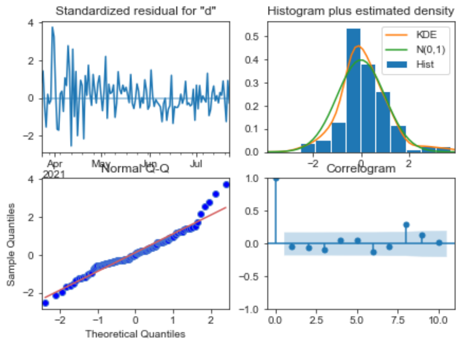

Fig 7 : SARIMAX(3,1,1),(2,1,1,7) Error Analysis

B. Model Interpretation

One key benefit of using a SARIMAX model is the ability to dissect the model and interpret the coefficients.

Table 4 below shows the estimated coefficients used to forecast the 15-day averaged daily new positive COVID-19 cases. Table 4, also shows that several of the exogenous variables like *positive_rate*, *checkins* and *casual_contacts* have close to zero coefficients, reviewing that it's impact towards the final prediction is minimal.

TABLE IV. MODEL PARAMETERS FOR SARIMAX(2,1,1)(2,1,1,7)

Parameters	***Coefficients***	***SE***	***p-value***
positive_rate_shift15	-0.0038	0.008	0.629
checkins_shift15	0.0056	0.026	0.827
unique_ind_shift15	-0.0306	0.052	0.553
unique_loc_shift15	0.0223	0.022	0.318
casual_contacts_shift15	0.0013	0.006	0.842
ar.L1	0.2260	0.323	0.485
ar.L2	0.5978	0.261	0.022

Parameters	*Coefficients*	*SE*	*p-value*
ma.L1	0.4679	0.349	0.180
ar.S.L7	-0.8288	0.113	0.000
ar.S.L14	-0.4424	0.107	0.000
ma.S.L7	-0.6393	0.151	0.000
sigma2	0.0004	7.14e-05	0.000

Table 5, on the other hand, shows the estimated coefficients used to forcast the 15-day averaged daily new death COVID-19 count. By interpreting the coefficients, only *positive_rate* has close to zero coefficient, consistent with the finding of the previous model.

TABLE V. MODEL PARAMETERS FOR SARIMAX(3,1,1)(2,1,1,7)

Parameters	*Coefficients*	*SE*	*p-value*
positive_rate_shift 15	0.0126	0.034	positive_ rate_shift 15
bed_occupation_s hift15	0.1629	0.245	bed_occu pation_sh ift15
covid_icu_bed_oc cupation_shift15	-0.0234	0.172	covid_icu _bed_occ upation_s hift15
ar.L1	0.3776	0.578	ar.L1
ar.L2	0.1763	0.211	ar.L2
ar.L3	0.1490	0.153	ar.L3
ma.L1	-0.1092	0.556	ma.L1
ar.S.L7	-0.4948	0.092	ar.S.L7
ma.S.L7	-0.9947	3.470	ma.S.L7
sigma2	0.0033	0.011	sigma2

C. 15-Day Forecast

Fig 8 shows the 7-day averaged forecast and 95% confidence band for new daily positive COVID-19 cases and new death count in the next 15 days from 23 July to 6 August 2021. By interpreting the diagram, it shows that both key COVID-19 statistics are increasing exponentially with the daily positive COVID-19 cases reaching 30000 mark. Hence, more stringent and proactive measure should be taken immediately to curb the spread of COVID-19 in Malaysia as well as ensures continuous supplies towards COVID-19 facilities in Malaysia to ensure the patient are given the best healthcare support for their survival.

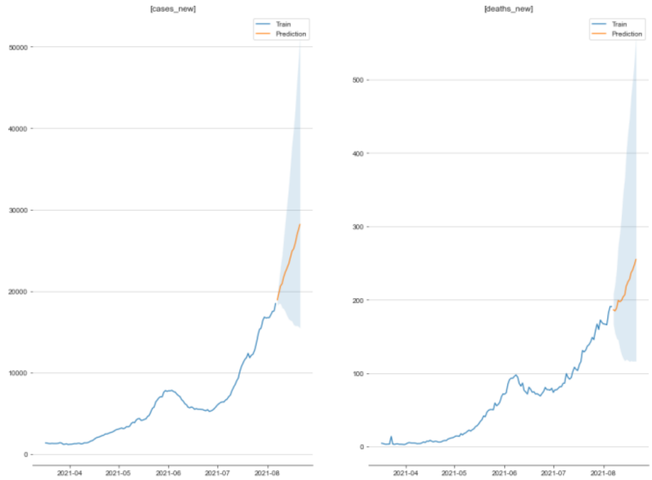

Fig. 6. 15-Day Forecast Visualisation

V. CONCLUSIONS

In summary, I have presented a model that is able to forecast key COVID-19 statistics of new daily positive cases and new death count in Malaysia using multivariate SARIMAX model with RMSE of 1752.6482 for new cases and RMSE of 7.7241 for new death count, evaluated using hold-out test set.

However, there are still some gaps in my modelling as the data obtained only only establish upward trend, I am uncertain of the model performance when the COVID-19 situation in Malaysia subside with the key statistics flatten out. Besides, a lower granularity modelling could be taken by model the COVID-19 statistics for different states such that the authorities could adopt a more targeted approach and channel the resources or implement a more stringent restriction to a specific area than a full-scale nation-wide lockdown.

Finally, I wish to publish the findings and deploy the model as an interactive web application as a reminder to urge all citizens to abide the COVID-19 restrictions and reduce unnecessary travelling arrangement to stay safe and take care.

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