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A MATHEMATICAL APPROACH TO UNDERSTANDING THE EFFECTIVENESS OF CONTROL MEASURES IN MITIGATING CORONAVIRUS DISEASE 19 (COVID-19) SPREAD.

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Abstract: In less than five months, the world was stunned and suddenly it appeared every labour done over time faces collapse; health sector, sports, entertainment and global economy shaking and looks irrecoverable. The Coronavirus infectious disease 19 (commonly called COVID-19) is the reason for all these sudden imbalance and implode in the world today. We formulate a Mathematical Model that describes the possible dynamic of the disease spread. We first set up a basic Mathematical model describing the population dynamics of COVID−19 under the assumption of homogeneous mixing population. We perform the dynamical system analysis in the model, particularly obtaining the threshold quantity, R_0, the basic reproduction number, and studying the stability of the system. We extend the model by introducing palliative measures (control measures) such as self-isolation, social distancing and quarantining to ascertain its efficacy in reducing the embarrassing spread of COVID−19 with attention also paid to effect overture. Our analytical results supports the ongoing campaign to stay at home and isolation of the infectious individuals to mitigate further spread.

Keywords and phrases: COVID−19, Control measure , Stability.

1 Introduction

In the past years, outbreaks of several viral infectious such as Ebola and Lasser Fever have caused serious tension but this new case of infection has brought a global alarm. The ravaging Coronavirus disease−19 (commonly called COVID−19) is a transmittible viral infectious disease caused by severe acute respiratory Coronavirus 2 (SARSCOV2)[1] which emerged in Wuhan, China and has since spread across over 185 countries of the world.

The spread of the infection has rampaged several European, Asian, African, South American Countries. Top in the list with record of confirmed cases include, United States, Spain, Italy Garmany, France, China, Iran and United Kingdom [2] with varying number of deaths, with the top four countries based on confirmed cases recording over ten thousand deaths already as at the time of this writing.

Though the exact number of confirmed cases may not be known due to limited number of testing [3] but as at 10 : 04 : 2020,12 : 51 GMT, the number of confirmed cases, deaths and recoveries stood at 1,605,548;95,808 and 337,561 respectively [4]. This thus keeps the global death, recovery and carrier rate at 5.93%,21%*and*73.07% respectively. Many more deaths envisaged in the coming days looking at the infectious individual rates (with cases ranging from mild to severity).

The contact route includes from person to person through respiratory droplets (from the nose and mouth) and close contact. Its symptoms are but not limited to; trouble breathing, persistent pain in the chest, pneumonia, severe acute respiratory syndrome, kidney failure, bluish lips or face (severe cases) and runny nose, cough, fever, sore throat, shortness of breath(mild)[5].

Currently, the COVID−19 pandemic has no Vaccine nor cure but in order to shove the spread, self isolation and social distancing were advocated while the already confirmed cases should be quarantined (isolated from the entire society).

Consequent upon these known facts, we introduce the idea of Mathematical model to examine the effectiveness of the measures advocated and implemented to curtail the spread of COVID−19. These measures were first taken up by China at their Wuhan district, the epic center of the outbreak. They placed a 76-day lockdown in the city and this was able to reduce the number of new infections/cases [7].

We obtain the threshold quantities R_0[7] and R_0^c[7] the former examines the average number of new infections in a population by introducing a single infected person while the latter observes the effect of the control measures on

R_0.

The paper discusses the short and long term of impact of the threshold quantities R_0 and R_0^c with a view to support the mandatory implementation of the control on the populace or decline it.

This was carried out using the eigenvalue method [9] and Castilo-Chevez [10] approaches for local and global stabilities of a system.

2 Model Preliminaries, Development and Analysis

Here we formulate a Mathematical Model that describes the basic dynamics of Coronavirus infectious disease 19 (COVID−19). We consider a total population N partitioned into four distinct classes namely; Susceptible, Exposed, Infectious and Removed classes denoted by S,E,I and R respectively.The dynamics within the classes are as follows:

Individuals are recruited into the susceptible class at a rate Λ and the susceptible become exposed to the infection at a rate β (otherwise known or referred to as the force of infection), which significantly is the first latency stage. After undergoing the second incubation period which is about 8 days and counting away from the first incubation period, the exposed individual becomes a confirmed carrier of COVID−19 or infectious individual at a rate α. The infectious die a disease induced death at a rate δ. The infectious individual battles through with the strength of the immune system and recovers at a rate γ, thus becomes removed/immuned (suggestive since the antibodies produced by the system to fight the infection can stay up for more than one year). The classes are reduced by mortality or Natural death rate , μ.

On this premise, we present a chart (*Fig*1) showing the dynamics and the nonlinear differential equation (1) describing the change at each class.

Λ -S β -E α -I γ -R

????

$\mu\mu$ $\mu+\delta\mu$

*Fig*1: Model (1)

Nonlinear system model (1)

$$\begin{aligned} \frac{dS}{dt} &= \Lambda - \beta \ SE - \mu S \\ \frac{dE}{dt} &= \beta \ SE - (\alpha + \mu)E \\ \frac{dI}{dt} &= \alpha E - (\gamma + \mu + \delta)I \\ \frac{dR}{dt} &= \gamma I - \mu R \end{aligned} \quad (1)$$

Nonlinear system model (1) with control (2)

Here we extend (1) by introducing two different control/preventive measures simultaneously. We assume that the susceptible individuals that become prone to exposure to COVID−19 can be reduced through effective public enlightenment on self isolation and social distancing at a rate θ, while the exposed and infectious individuals can be separated/withdrawn from further spread within the society by getting them quarantined at a rate φ.

$$\begin{aligned} \frac{dS}{dt} &= \Lambda - \beta \ SE - (\theta + \mu)S \\ \frac{dE}{dt} &= \beta \ SE - (\phi + \alpha + \mu)E \\ \frac{dI}{dt} &= \alpha E - (\phi + \mu + \delta + \gamma)I \\ \frac{dR}{dt} &= \theta S + \phi E + (\phi + \gamma)I - \mu R \end{aligned} \quad (2)$$

2.1 Analysis for model (1)

The dynamical system analysis for model(1), with no control shows that the Disease free equilibrium is given by

$$E_\circ = (S^\circ, E^\circ, I^\circ, R^\circ) = (\frac{\Lambda}{\mu}, 0, 0, 0). \quad (3)$$

We obtain a threshold quantity R_0 as

$$R_\circ = \frac{\beta \ S^\circ}{\alpha + \mu}. \quad (4)$$

Note 1

If $\beta > S^\circ$ and $\alpha > \mu$, then $R_\circ > 1$ since increase in β increases α, but on the contrary $R_\circ < 1$.

As the basic reproduction number increases that is $R_\circ > 1$, then the Endemic equilibrium point (EEP) of (1) is given as

$$E_* = (S^*, E^*, I^*, R^*) = \left(\frac{\alpha + \mu}{\beta}, \frac{\Lambda - \mu S^*}{\beta \ S^*}, \frac{\alpha E^*}{\gamma + \mu + \delta}, \frac{\gamma I^*}{\mu}\right). \quad (5)$$

This can be rewritten as

$$E_* = (S^*, E^*, I^*, R^*) = \left(\frac{S^\circ}{R_\circ}, \frac{\mu}{\beta}(R_\circ - 1), \frac{\alpha\mu}{\beta \ (\gamma + \mu + \delta)}(R_\circ - 1), \frac{\alpha\gamma}{\beta \ (\gamma + \mu + \delta)}(R_\circ - 1)\right). \quad (6)$$

Note 2

From EEP (6) we see clearly that Endemic COVID 19 steady state exists only when $R_\circ > 1$; at $R_\circ = 1$, DFE coincide with EEP. It follows that at $R_\circ = 1$ there is a bifurcation (that is $R_\circ = 1$ is a bifurcation point).

We examine the short and long term dynamics of the disease by considering the stability of the system about the DFE and EEP respectively.

So we investigate the stability of the steady states with respect to the threshold quantity $R_\circ$.

Theorem 2.1 *The disease free equilibrium point is stable both locally and globally if* $R_\circ < 1$.

Proof:

We show that all eigenvalues of the Jacobian of (1) evaluated at DFE has negative real part. The Jacobian is given thus

$$J_\circ = \begin{pmatrix} -\mu & \beta\ S^\circ & 0 & 0 \\ \beta\ E^\circ & \beta\ S^\circ - (\alpha+\mu) & 0 & 0 \\ 0 & \alpha & -(\gamma+\mu+\delta) & 0 \\ 0 & 0 & \gamma & -\mu \end{pmatrix} \quad (7)$$

The eigenvalues of the Jacobian (7) evaluated at DFE gives

$$\lambda_1 = -\mu$$
$$\lambda_2 = -\mu \quad (8)$$
$$\lambda_3 = \beta S^\circ - (\alpha+\mu) = (\alpha+\mu)(R_\circ - 1) \quad \lambda_4 = -(\gamma+\mu+\delta)$$

Thus DFE is stable provided $\lambda_3 < 0$ if $R_\circ < 1$. This result implies that it is possible to eradicate Coronavirus disease if the threshold quality, $R_\circ < 1$ (that is less that one individual can be infected over a given time).

Lemma 2.2 *Consider a model system written in the form*

$$\frac{dX}{dt} = K(X,Y)$$
$$\frac{dY}{dt} = M(X,Y), \quad M(X,0) = 0$$

Where $X \in <^2, Y \in <^2$ and $X_\circ = (X;0)$ is an equilibrium of the system. Assume that

(H1) For $\frac{dX}{dt} = K(X,0),\ X^*$ is globally asymptotically stable;

(H2) $M(X,Y) = AY - M\tilde{}(X,Y) \geq 0$ for $X,Y \in \Omega$

Where the Jacobian $A = \frac{\partial M}{\partial Y}(X,0)$ is an N-matrix and Ω is the region were the model makes biological sense. Thus $X_\circ$ is globally asymptotically stable provide $R_\circ < 1$.

Proof:

We show that $(H1)$ and $(H2)$ holds when $R_\circ < 1$.

From model (1), $X = (S,R)$ and $Y = (E,I)$; $X^* = (S^\circ,R^\circ)$ The system ,

$$M(X,Y) = \begin{pmatrix} \beta\ SE & -(\alpha+\mu)E \\ \alpha E & -(\gamma+\mu+\delta)I \end{pmatrix}.$$

$M(X,Y)$ can be rewritten as

$$AY - M(X,Y)$$

. Where

$$A = \begin{pmatrix} \beta\ S - (\alpha+\mu) & 0 \\ \alpha & -(\gamma+\mu+\delta) \end{pmatrix}$$ and $M\tilde{}(X,Y) = \beta E(S^\circ - S)$.

Obviously, $M\tilde{}(X,Y) \geq 0$ since $S^\circ > S$. Let us verify the global stability of the system

$$\frac{dX}{dt} = K(X,0) = \begin{pmatrix} \Lambda - \mu S \\ -\mu R \end{pmatrix}$$

Proof:

$K(X,0)$ is a system of linear ordinary differential equations whose solution yields

$$S(t) = \frac{\Lambda}{\mu} + [S(0) - \frac{\Lambda}{\mu}]e^{-\mu t}$$
$$R(t) = R(0)e^{-\mu t}$$

It follows that

$$\lim_{t\to\infty} S(t) = \frac{\Lambda}{\mu} = S^{\circ}$$

and

$\lim R(t) = 0 = R^{\circ}$ $t\to\infty$

. Therefore X^* is globally asymptotically stable. Hence DFE is GAS provided $R_{\circ} < 1$. This shows that if $R_{\circ} < 1$, there is a significant possibility of complete elimination of COVID−19 from the system. However if nothing is done, and $R_{\circ}$ grows above 1, then the exposure rate (or force of infection) increases leading to an increase in the number of individuals testing positive (infectious individuals) .

Theorem 2.3 *The EEP (5) is stable, if* $R_{\circ} > 1$

We show that the eigenvalues of the Jacobian of model (1) evaluated at EEP have negative real parts yields

$$J_* = \begin{pmatrix} \beta E^* - \mu & \beta S^* & 0 & 0 \\ \beta E^* & \beta S^* - (\alpha+\mu) & 0 & 0 \\ 0 & \alpha & -(\gamma+\mu+\delta) & 0 \\ 0 & 0 & \gamma & -\mu \end{pmatrix} \quad (9)$$

To determine the eigenvalue, we solve the equation

$$|J_* - \lambda I| = 0$$

where λ is the eigenvalue and I the 4×4 identity matrix.

Solving we obtain

$\lambda_1 = -\mu$ $\lambda_2 = -(\gamma + \mu + \delta)$

$$\lambda_{3,4} = \lambda^2 + (A + C + D - B)\lambda + AD + CD - BC = 0 \quad (10)$$

Where $A = \beta E^*$; $B = \beta S^*$; $C = \mu$; $D = \alpha + \mu$

Then

$$\begin{aligned} A + C + D - B &= \beta E^* + \mu + \alpha + \mu - \beta S^* \\ &= \beta [E^* - S^*] + \alpha + 2\mu \\ &= \beta \left[\frac{\mu}{\beta}(R_{\circ} - 1) - \frac{S^{\circ}}{R_{\circ}}\right] + \alpha + 2\mu \\ &= \beta \left[\frac{\mu}{\beta}(R_{\circ} - 1) - \frac{(\alpha+\mu)}{R_{\circ}}\frac{R_{\circ}}{\beta}\right] + \alpha + 2\mu \\ &= \mu R_{\circ} - \mu - \alpha - \mu + \alpha + 2\mu = \mu R_{\circ} \end{aligned} \quad (11)$$

Also

$$\begin{aligned} AD+CD-BC &= \beta\ [(\alpha+\mu)E^{*}-\mu S^{*}]+\mu(\alpha+\mu) \\ &= \beta\ \left[(\alpha+\mu)\frac{\mu}{\beta}(R_\circ-1)-\frac{\mu S^\circ}{R_\circ}\right]+\mu(\alpha+\mu) \\ &= \beta\ \mu\left[\frac{(\alpha+\mu)}{\beta}(R_\circ-1)-\frac{(\alpha+\mu).R_\circ}{\beta\ .R_\circ}\right]+\mu(\alpha+\mu) \\ &= \mu[(\alpha+\mu)(R_\circ-1)-(\alpha+\mu)]+\mu(\alpha+\mu) \\ &= \mu[(\alpha+\mu)(R_\circ-1) \end{aligned} \quad (12)$$

Substituting (11) and (12) into (10), it reduces to

$$\lambda^2 + (\mu R_\circ)\lambda + \mu(\alpha + \mu)(R_\circ - 1) = 0 \quad (13)$$

In (13) if $R_\circ > 1$, then $\mu R_\circ > 0$ and $\mu(\alpha + \mu)(R_\circ - 1) > 0$.

Therefore (13)by Routh-Hurwitz criteria yields $\lambda_3 < 0$ and $\lambda_4 < 0$.

The above affirms that if $R_\circ > 1$, the infection will continue to spread with time needing imminent attention from health workers.

To illustrate possible action that could be taken to reduce the spread of COVID 19 outbreak we incorporated possible control measures into model (1) resulting to model (2).

2.2 Analysis of model (2)

The disease free equilibrium (DFE) for the model is

$$E_{\circ c} = (S_c^\circ, E_c^\circ, I_c^\circ, R_c^\circ) = \left(\frac{\Lambda}{(\theta+\mu)}, 0, 0, 0\right) \quad (14)$$

The basic reproduction number for control model denoted by $R_\circ^c$ is given as

$$R_\circ^c = \frac{\beta\ S_c^\circ}{\phi+\alpha+\mu} \quad (15)$$

When $R_\circ^c > 1$, we obtain a unique EEP (Endemic equilibrium point) in the control model.

The Endemic equilibrium point of (2) is given by

$$\begin{aligned} E_{*c} = (S_c^*, E_c^*, I_c^*, R_c^*) &= \Big(\frac{S_c^\circ}{R_\circ^c}, \frac{\theta+\mu}{\beta}(R_\circ^c-1), \frac{\alpha}{\phi+\gamma+\delta+\mu}\left(\frac{\theta+\mu}{\beta}(R_\circ^c-1)\right), \\ &\quad \frac{1}{\mu}\left[\frac{\theta S_c^\circ}{R_\circ^c}+\frac{\phi(\theta+\mu)}{\beta}(R_\circ^c-1)+\frac{(\phi+\gamma)\alpha(\theta+\mu)}{\beta\ (\phi+\gamma+\delta+\mu)}(R_\circ^c-1)\right]\Big) \end{aligned} \quad (16)$$

To illustrate the effectiveness of the control, we compare $R_\circ^c$ and $R_\circ$ to have

$$\begin{aligned} R_\circ^c = \frac{\beta\ S_c^\circ}{\phi+\alpha+\mu} &= \frac{\Lambda}{\theta+\mu}.\frac{R_\circ(\alpha+\mu)}{(\phi+\alpha+\mu).S^\circ} \\ &= \frac{\Lambda}{\theta+\mu}.\frac{(\alpha+\mu)}{\phi+\alpha+\mu}.\frac{\mu}{\Lambda}.R_\circ \\ &= \frac{\mu}{\theta+\mu}.\frac{\alpha+\mu}{\phi+\alpha+\mu}.R_\circ \le R_\circ \end{aligned} \quad (17)$$

Hence $R_\circ^c = R_\circ$ if $\theta = \phi = 0$, otherwise $R_\circ^c < R_\circ$ (for θ and φ greater than zero).

This shows that incorporating control/ preventive measures (effective public and enlightenment on self isolation and social distancing and quarantining of both the latency stage 1 (exposed/not confirmed but showing signs) and infectious (full blown/tests positive) surely reduces the increase in the number of exposed cases and infectious (confirmed) cases in the population.

2.3 Dynamics with time for the control model (2)

To investigate the short and long term dynamics of the control model, we carry out the stability analysis. **Theorem 2.4** *The COVID−19 free equilibrium point of the control model is stable if* $R_\circ^c < 1$

proof:

It suffices to show that all the eigenvalues of the Jacobian of the control model (2) evaluated at the DFE has a negative real part.

The Jacobian of model(2) is obtained as

$$J_{\circ c} = \begin{pmatrix} \beta \ E_c^\circ - (\theta+\mu) & \beta \ S_c^\circ & 0 & 0 \\ \beta \ E_c^\circ & \beta \ S_c^\circ - (\phi+\alpha+\mu) & 0 & 0 \\ 0 & \alpha & -(\phi+\gamma+\mu+\delta) & 0 \\ \theta & \phi & (\phi+\gamma) & -\mu \end{pmatrix}. \quad (18)$$

Solving $|J_{\circ c} - \lambda I| = 0$ evaluated at the DFE yields the eigenvalues as

$$\begin{aligned} \lambda_1 &= -\mu \\ \lambda_2 &= -(\theta+\mu) \\ \lambda_3 &= -(\phi+\gamma+\mu+\delta) \\ \lambda_4 &= \beta \ S_c^\circ - (\phi+\alpha+\mu) = (\phi+\alpha+\mu)\Big[\frac{\beta \ S_c^\circ}{(\phi+\alpha+\mu)} - 1\Big] = (\phi+\alpha+\mu)(R_\circ^c - 1) \end{aligned}.$$

Clearly, $\lambda_4 < 0$ if $R_\circ^c$ <1. Since λ_i's i = 1,...4 are all negative, it follows that DFE is stable if $R_\circ^c < 1$.

This analysis shows that it is possible to eliminate or stop new infection in the system/society in the presence of controls (when $R_\circ^c$ <1) if the initial size of the population is in basis of attraction of the COVID−19 free equilibrium point.

Hence massive attention should be paid to the palliative (control) measures. However, if the control measures are not effective enough and $R_\circ^c$ continues to increase, it will be extremely difficult to reduce exposure and thus new cases of the infectious become inevitable at this stage.

To gain more insight on the disease dynamics at the endemic stage of control, we examine the short and long term conditions about the EEP for the model (2).

Theorem 2.5 *The endemic equilibrium point of the control model is stable provided* $R_\circ^c > 1$.

Proof:

We show that all the eigenvalues of the control model evaluated at the EEP have negative real parts.

$$J_{*c} = \begin{pmatrix} \beta \ E_c^* - (\theta+\mu) & \beta \ S_c^* & 0 & 0 \\ \beta \ E_c^* & \beta \ S_c^* - (\phi+\alpha+\mu) & 0 & 0 \\ 0 & \alpha & -(\phi+\gamma+\mu+\delta) & 0 \\ \theta & \phi & (\phi+\gamma) & -\mu \end{pmatrix}. \quad (19)$$

To determine the eigenvalues, we solve the equation $|J_{\circ c} - \lambda I| = 0$ and obtained

$$\begin{aligned} \lambda_1 &= -\mu \\ \lambda_2 &= -(\varphi+\gamma+\mu+\delta) \\ \lambda_{3,4} &= \lambda^2 + (A^* + C^* + D^* - B^*)\lambda + A^*D^* + C^*D^* - B^*C^* = 0 \end{aligned} \quad (20)$$

Where $A^* = \beta \ E_c^*;\ B^* = \beta \ S_c^*;\ C^* = \theta+\mu;\ D^* = \phi+\alpha+\mu$

Then

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$$
\begin{aligned}
A^* + C^* + D^* - B^* &= \beta \ \ E^* + \theta + \mu + \phi + \alpha + \mu - \beta \ \ S^* \\
&= \beta \ \ [E_c^* - S_c^*] + \theta + \phi + \alpha + 2\mu \\
&= \beta \ \left[\frac{\mu}{\beta}(R_\circ^c - 1) - \frac{S_c^\circ}{R_\circ^c}\right] + \theta + \phi + \alpha + 2\mu \\
&= \beta \ \left[\frac{\theta+\mu}{\beta}(R_\circ^c - 1) - \frac{(\phi+\alpha+\mu)}{\beta \ \ .R_\circ^c}.R_\circ^c\right] + \theta + \phi + \alpha + 2\mu \\
&= \ (\theta+\mu)R_\circ^c - \theta - \mu - \phi - \alpha - \mu + \theta + \phi + \alpha + 2\mu = (\theta+\mu)R_\circ^c. \qquad (21)
\end{aligned}
$$

Also

$$
\begin{aligned}
A^*D^* + C^*D^* - B^*C^* &= \ (\phi+\alpha+\mu)\beta \ \ E_c^* + (\phi+\alpha+\mu)(\theta+\mu) - (\theta+\mu)\beta \ \ S_c^*] \\
&= \beta \ \left[[(\phi+\alpha+\mu)E_c^* - (\theta+\mu)S_c^*] + (\theta+\mu)(\phi+\alpha+\mu)\right. \\
&= \ (\theta+\mu)\beta \ \left[\frac{(\phi+\alpha+\mu)}{\beta}(R_\circ^c - 1) - \frac{(\phi+\alpha+\mu).R_\circ^c}{\beta \ \ .R_\circ^c}\right] + (\theta+\mu)(\phi+\alpha+\mu) \\
&= \ (\theta+\mu)[(\phi+\alpha+\mu)(R_\circ^c - 1) - (\phi+\alpha+\mu)] + (\theta+\mu)(\phi+\alpha+\mu) \\
&= \ (\theta+\mu)[(\phi+\alpha+\mu)(R_\circ^c - 1) \qquad (22)
\end{aligned}
$$

Substituting (21) and (22) into (20), reduces to

$$\lambda^2 + (\theta+\mu)R_\circ^c\lambda + (\theta+\mu)(\phi+\alpha+\mu)(R_\circ^c - 1) = 0 \qquad (23)$$

In (23) if $R_\circ^c > 1$, it follows that $(\theta + \mu)R_\circ^c > 0$ and $(\theta + \mu)(\varphi + \alpha + \mu)(R_\circ^c - 1) > 0$.
Therefore (23), by Routh-Hurwitz criteria has two solutions of $\lambda < 0$ (that is $\lambda_3 < 0$ and $\lambda_4 < 0$). Since λ_i's $i = 1,...4$ are all negative, then the model is locally stable at EEP.

This result shows that if the control measures are ineffective (people down play self isolation and social distancing and the individuals at latancy/incubation period 1 and infectious people are not well quarantined) such that $R_\circ^c > 1$, the COVID−19 infection will remain in the society.

3 Discussion

The novel Viral infection, commonly called ”COVID−19” has held the world at a stand still.

With close to two million confirmed infectious and above eighty thousand death recorded across the globe as at this time, the biggest challange is what ought to be done to alleviate the menace or stop the surge outright.

Here we made an attempt in understanding the dynamics of COVID−19 using mathematical model.

Formulating the model which describes the dynamics in a given population, we carried out a dynamical system analysis, computing the threshold quality, $R_\circ$. We also proved that the COVID−19 free equilibrium point is locally and globally stable when $R_\circ < 1$ showing that the infection can be reduced irrespective of the initial population size provided less than one person is infected with the virus by a single carrier. Suppose $R_\circ > 1$, we also proved it is obvious that there is a continuous spread of the virus in the system.

Next we extended the model by incorporating two control measures (public enlightenment on self isolation and social distancing and quarantining the exposed and infectious individuals. The analysis on the control model revealed the possibility of eliminating COVID−19 from the system with attention paid to the control measures if $R_\circ^c > 1$, we discovered that the COVID−19 pandemic remains established in the system.

Hence, the control model affirms that each of the strategy (control) have significant impact on reducing the spread of COVID−19.

4 Conclusion

COVID−19 has and have continued to stifle existence across the globe. Since the outbreak, effort put in place to suffocate the spread had failed but for public enlightenment on self isolation and social distancing and quarantining of the infected individuals.

This work supports that these measures are very effective in reducing the trend of spread which also suggests that the exposed individuals (those who show signs after 5 days) be quarantined also.

With these indeed, there is a resounding decrease in the number of new cases in general except for countries that do not want to take up the measures.

The reaction lies with the government to make policies that must insist on effective public enlightenment (self isolation and social distancing) and quarantining or take it up with laissez-faire attitude and the COVID−19

[7] diseases. Applied Ecology and Environmental Research, 16(2018),1621 − 1638.

[8] https: // edition.cnn.com

[9] C.Okoye, O.C. Collins and G.C.E Mbah (2020). Mathematical approach to the analysis of terrorism dynamics, Security Journal; https:*/doi.org/*10.1057/541284 − 020 − 00235 − 5.

[10] C. Okoye, S.E Aniaku, S.I Onah and G.C.E Mbah (2018). DNA Mutation and Tumor formation 11: Analysis of formulated model Global Scientific Journals, vol.6(1), Jan 2018.

[11] Castilo-Chovez C, etal.(2002), On the computation of $R_{\circ}$ and its role in global stability. Applied Mathematical letters . 2002;15 : 955 − 960.

spread will multiply more than influenza when it first broke out and may take more lives in due course.

5 References

[1]Muhammed, A.S, Sulima, K, Abeir,K, Nadia, B, Rabeea, S. (2020), COVID−19 infection:Origin, transmission and characteristics of human Coronavirus, Journal of Advanced, Research, Vol. 24, July 2020, pg 91 − 98 [2] https : // www.Coronavirus.jhu.edu.

[3] https : // OurWorldInData.Org/Coronavirus.

[4]https : // www.worldometer.info.

[5] https: // www.jhsph.edu.

[6] Collins O.C, Duffy K.J (2018). How Species diversity could reduce the prevalence of infectious