ISSN No:-2456-2165

Literature Review of Mathematical Model for Controlling the Spread of the Novel Covid-19 Virus: An Optimal Control Analysis: Case Study Ghana

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Abstract:- There are a lot of review articles addressing specific Covid-19 in diverse research using the mathematical models. This paper presents a thorough analysis of literature review on mathematical model for controlling the spread of the Novel Covid-19 pandemic.

Keywords:- *Mathematical models, Covid-19, World Health Organization (WHO), pandemic, transmission, dissemination dynamics.*

I. INTRODUCTION

In the last few years different individuals have developed many mathematical epidemiologicalmodels for the novel COVID-19 pandemic. This paper therefore presents the thorough literature review of the above topic stated.

II. LITERATURE REVIEW

Severe Acute Respiratory Syndrome Corona virus 2 (SARS-Cov-2) is a novel corona virus strain that is responsible for the corona virus disease of 2019 (COVID-19). The World Health Organization (WHO) designated COVID-19 as a pandemic on March11, 2020. It is a respiratory disease caused by a novel corona virus (SARS-CoV-2)that was discovered in late December2019 in Wuhan, Hubei province, China (Zhou et al., 2020). The virus, according to Surjawidjaja (2003), is a member of the Nidovirales order, a Coronaviridae family, and a subfamily of the Ortho corona virine. Corona viruses are enclosed viruses with a positive-sense, single stranded.

RNA and viral particles that resemble a crown, hence the name(Gumelet al., 2004). TheCOVID-19 pandemic virus is a highly infectious disease that can be transmitted directly or indirectly from an infectious person to a healthy person through the eyes, nose, mouth, and occasionally through the ears via droplets produced when coughing or sneezing, according to Srivastava and Gaur (2017). It's unclear what caused the condition. Many biologists, however, believe rodents and bats are to blame. (Zou et al., 2008). SARS-Cov-2 can live for up to 8-10 hours on porous surfaces (paper, wood, sponge, and fabric, etc) and somewhat longer on non permeable surfaces (glass, plastics, metals, etc), according to Srivastava and Gaur(2017) and normally takes 2-14 days for it to incubate. It has symptoms that are comparable to a cold or u with fever, dry cough, loss of breath, and pneumonia among the other symptoms, according to Zou et al. (2008). Depending on the age and health situation of the infected, the severity of the illness can range from mild tosevere symptoms, (Srivastava and Gaur, 2017). Almost 80% of COVID-19 patients are asymptomatic or have just minor symptoms, and they normally recover withintwo weeks. However, substantial fatality rates have been reported among the elderly and those with underlying chronic diseases.The Novel COVID 19 virus began to spread over the world on January 30, 2020, and the WHO designated the outbreak a Public Health Emergency of International Concern on January 30, 2020. (PHEIC). COVID 19 was subsequently declared a global pandemic by the WHO Director-General. Despite expectations that the virus did not thrive in hot climates, as of April 2020, practically every country on the planet has at least one positive case. Nigeria reported its first case on February 27, 2020,but by April 26, 2020, the number of illnesses had climbed to 1,314 with 45 deaths, barely 60 days later. COVID-19 had resulted in 4,271,689 confirmed cumulative cases as of May 11, 2020, with 287,613 recorded deaths. Europe (particularly Italy and Spain) became the hub of the outbreak, while the United States of America, Asia, and Australia saw hundreds of new infections per day and thousands of disease deaths, according to Gumel et al. (2004). As of May 2020, the new COVID-19 had grown into a global public health emergency, affecting 212 countries and territories worldwide (Worldometer, 2020).A differential equation is one with coefficients, (Bird, 2006).Over the years, mathematical models have proven to be trustworthy, successful, and efficient approaches for designing control strategies for infectious illnesses, epidemics, and pandemics such as Ebola, SARS, and MERS, among others. (Madubueze et al.,2018; Kim, 2016; Gumel et al., 2004). Mathematical modelling continues to play an important role in deciphering complicated systems with observable behaviours or features. Recently, a number of mathematical models based on real-world COVID-19transmission data have been constructed to detect disease-causing factors at various population levels. (Asamoah et al., 2020; Chen et al., 2020; Iboi et al., 2020; Dinget al., 2020; Srivastava et al., 2020; Xue et al., 2020). Forinstance, in Asamoahet al. (2020), researchers looked at COVID -19 dissemination dynamics with environmental influences utilizing cases from Ghana. Using the existing cumulativeCOVID-19 mortality data, a mathematical model for estimating the consequences of non pharmaceutical interventions (NPI) on the transmission dynamics of the emerging Corona virus pandemic in Nigeria was published in Iboi et al. (2020). Jia et al.(2020) presented a dynamical model of COVID-19 based on officially published Chinesed at a that took into account the effect of policy action and meteorological conditions.Srivastava et al. (2020) employed optimal control approaches to examine a mathematical model for the COVID-19 model using real data from Italy and Spainin another scenario. Some academics were unable to consider the effect of public health education, quarantine, and isolation on the transmission of COVID-19 because they were focused on determining the fundamental reproduction number (R0),(Li et al., 2020; Wu et al., 2020; Zhao et al., 2020). COVID-19, like SARS, is thought to be highly erratic in terms of the number of new infections, according to a study published by Imai et al. (2020). Using a set of simulated epidemic trajectories, there searchers evaluated the inconsistency of their model with reality of the outbreak degree. Their findings revealed and confirmed that COVID-19's human-to-human transmissibility is sufficient to sustain the novel virus in the absence of clear-cut control strategies. They also predicted that COVID-19 will have a shorter generation time if the majority of COVID-19 cases have mild to moderate symptoms. Shenet al. (2020) investigated the high detection rate and quick response by China and therest of the world in response to recent corona virus outbreaks. Using the national epidemic of Wuhan in China, they hypothesise that the novel COVID-19 virus is a weak species in the corona virus family, with a fatality and mortality rate of 11.02 % (9.26%-12.78 %), which is lower than SARS (14-15 percent) and MERS (34.4 %) with a total of 8042 (95% CI: 4199-11884) infections and 898 (368-1429) deaths, respectively. Chen et al. (2020) used their Bats-Hosts-Reservoir-people transmission model to investigate the potency of transmission of the COVID -19 virus from Bat (probable)source humans. Using the next generation matrix method, they discovered the basic reproduction number (R0), and their findings revealed that COVID-19 virus had ahigher transmissibility than MERs in Middle Eastern countries. COVID-19 viral propagation dynamics are perpetrated within the duration an infectious individual is exposed, according to Rabajante (2020). In their study, an infected person can spread the virus, especially in public and social gatherings in a distant community, within the 14-day infectious period. Rabajante (2020) advised the strictest adherence to control measures in public and social gatherings, based on early COVID-19 mathematical models. Mathematical epidemiological models with control measures have grown in importance. They used an SIR model to anticipate the size of the COVI9-19pandemic in Pakistan and compared it to the number of cases registered in Pakistan's national database. They predicted that 90 percent of the population would be infected with the novel virus if control policies aimed at stemming the outbreak are not pursued with enthusiasm and aggression. Peng et al. (2020) used SEIR compartments to create predictions using the SEIR model utilizing data from January 22, 2020 to March 3, 2020. Researchers looked at people's emotions, current disease trends, and economic and political repercussions as well. In the study by Lin et al. (2020), they developed conceptual models for the COVID-19 outbreak in Wuhan, China, taking into account a person's behavioural response as well as national government laws such as travel restrictions, hospitalization, holiday extension, and quarantine. The SEIR model was proposed in a paper published by Peng et al. (2020) by adding the inherent effect of hidden exposed and infectious cases on the entire epidemic procedure, which is difficult to analyse using typical statistical methods. Furthermore, using an age-structured SEIR model for various physical distancing measures, Prem et al.(2020) recreated the ongoing path of the COVID-19 outbreak in Wuhan.In thestudy by Victor (2020), a proposed compartmental model split the quarantined people into two sub-groups. R and U are quarantine-infected people who are predicted to recover and fulfil undetectable requirements, according to the study's SEIRU model. The undiagnosed infections in China about the transmission dynamics of COVID -19virus was taken into account in a published paper by Ivorra et al. (2020). In the case of Italy, a study by Giordano et al. (2020) proposed a novel epidemic model that differentiates infected people based on whether or not they have been diagnosed and the severity of their symptoms. Zhao et al. (2020) split susceptible individuals from Wuhan, China, into age groups and constructed an SEIARW model based on market-to-individual and individual-to-individual transmission trajectories in them study. Zhong et al. (2020) created a model based on epidemiological data and evaluated features of previous epidemics to generate an early prediction of the COVID-19outbreak in China in their paper. Wang et al. (2020) investigated multiple transmission trajectories in COVID-19 infection dynamics and developed a mathematical model that describes the role of the environmental reservoir in transmission and the use of non-constant transmission rates in conjunction with epidemiological and environmental conditions. Fang et al. (2020) investigated an SEIR epidemiological mathematical model for the transmission and spread dynamics of COVID-19 disease, including fitting, parameter estimations, and sensitivity analysis, while Rong et al.(2020) also investigated a deterministic model for COVID-19 that captures the impact of delayed diagnosis on disease transmission. In a study released by Mizumoto and Chowell (2020), the researchers used a statistical analysis of COVID-19 disease data to estimate the time-delay adjusted risk of death from the pandemic virus in Wuhan and China excluding Wuhan. Their findings suggested that suitable social separation and movement restrictions could help prevent disease spread. Roosa et al.(2020) predicted a real-time phenomenological model that studied transmission trajectories of COVID -19 infectious virus disease. In their study Provci (2020) reviewed SIR, SIRD, SEIR and SIDARTHE models. The SIR model accounts for the susceptible S, infected I, and recovered R compartments of population size. This model SIR does not incorporate the compartment of deceased persons, and as such as insufficient represents the transmission dynamics of COVID-19 virus disease. Provci(2020) also studied the SIRD mathematical model which compartmentalised the population into four variables; susceptible S, infected I, recovered R, and Deceased D, compartments. The SIRD is an expansion of SIR model. The driving factor to study the SIRD by Provci (2020) is twofold: it is important to consider number of deceased in a lethality, and even more so due to the minimization of the number significant in the optimization. The study found out that, in the case of COVID-19, reducing transmission rates are analogues to the introduction of quarantine, physical and social distancing, regulation of gatherings etc.(Provci, 2020).According to Provci (2020), the efficiency of the SIRD model is its inability to differentiates between different stages of infectivity with respect to infection rate, diagnosis and control. The study revealed that SIRD model is good for simulating new strategies which can be extended to more mathematical models if their form allows it, as well as the case with the SIDARTHE model, Provci (2020). Many optimal control strategies depending on cost of control were obtained by minimizing the total number of deceased. Therobust SIDARTHE mathematical model further disproves the usefulness of negative control in a closed system but shows proof of its utility in an open system where a population inflation is expected, (Provci, 2020). Shifting the infected peak earlier, is of course, not always optimal, and the opposite may be better if a cure or vaccineis expected. The study further revealed that external inflation could in this case be managed by already implemented policy of mandatory quarantine for migrants. According (Provci, 2020), the advantage of the SIDARTHE is its ability to take on various controls of the many 16 transmission coefficients in the model. In addition to minimizing the rate of infection of COVID-19. The susceptible - quarantine extended SEIRD mathematical model shares its merit in robustness with SIDARTHE model, with 12 rates of transmission and 4 virus factors which can all be adjusted with control. (Moore and Okyere, 2020). This model also takes into account the different rates of diagnosis in a different way. The manner the quarantine is modelled, however, is only appropriate for the analysis of the transition period and becomes unrealistic after the entirety of the susceptible populace becomes zero, (Provci, 2020). The susceptible-infected-quarantine- extended has lower rates of transmission to adjust than the previous two models, but contains the quarantine effect. In the same manner as the previously described mathematical models, it loses analytic importance after reducing the susceptible compartment zero, (Provci, 2020). From the comparative analysis between SIRD and SIDARTHE models, it is now known that the dimension of the quarantine implemented in the SEIRD models is far from optimal to minimise the number of deceased, (Provci, 2020). If the quarantine were to have a constant optimal control cost, it would not be optimal in that regard either. In their article, Moore and Okyere (2020) considered an optimal control of the COVID-19transmission model and assessed the effect of some control strategies that can lead to a reduction in the number of exposed and infectious people in the population. Four control measures were employed in the study. Personal protection, treatment when individuals are diagnosed early, effective environmental spraying, and cleaning possible infected surfaces are all part of the control set. The study revealed that optimal control strategies can reduce the spread COVID-19 virus significantly especially when diagnostic resources are improved, confirmed new cases can be reducedsignificantly, (Moore and Okyere, 2020). They employed a modified SEIR model, in which the population is split into susceptible S, self-quarantine susceptible, Exposed E, infections with prompt diagnosis, infectious with delayed diagnosis, Hospitalised H, recovered R, and viral dissemination in the environment. Super spreaders were not included in the model. Madubueze et al. (2018) conducted research to determine the efficiency of public education, quarantine, and isolation in slowing the spread of the dangerous COVID-19 virus, as well as the time it took to do so. According to the researchers, implementing a combination of control measures in the form of vaccination and treatment are more efficient and effective than either the control intervention of vaccination alone or the control strategy of treatment alone in reducingthe number of exposed subpopulations, (Madubueze et al., 2018). The study also discovered that when vaccination control and treatment become more widespread, the number of exposed and infected subpopulations decreases. The mathematicalmodel employed by Madubueze et al. (2018) is an enhanced SARS model produced by Gumel et al. (2004), which included public health awareness and the prospect of people being quarantined. The population is separated into compartments: susceptible(S), exposed (E), quarantine (Q), infectious not hospitalised (I), hospitalised (H)and recovered (R), (Madubueze et al., 2018). Tilahun and Alemneh (2021) research of COVID-19 transmission in Ethiopia and optimal control analysis. The disease-free equilibrium points, endemic equilibrium points, basic reproduction, stability analysis of the equilibrium points, and sensitivity analysis were all thoroughly examined. SEIR was the model utilised by Tilahun and Alemneh (2021). When $R0 = 1$, the disease-free equilibrium point was globally asymptotically stable, as demonstrated in the study. Bifurcation study of the mathematical model using centre manifold theory reveals forward bifurcation at beta. The study by Tilahun and Alemneh(2021) developed the essential conditions for optimal control of the spread of thepandemic COVID-19 virus using Pontryagin's Maximum Principle. The study discovered that integrated control is extremely effective and efficient in a short period of time. (Tilahun and Alemneh, 2021).The study's findings also suggested that if stake holders are unable to implement all of the control techniques at the same time, the pandemic virus may resurface, resulting in an increase in transmission instances across the country. This study did not include mass screening as a control approach, and the model did not account for super spreaders. Shah et al. (2020)proposed a generalised SEIR model of COVID-19 that investigated the transmission dynamics' behaviour under various control interventions. The study discovered that integrated control is extremely effective and efficient in a short period of time. (Tilahun and Alemneh, 2021). The study's findings also suggested that if stakeholders are unableto implement all of the control techniques at the same time, the pandemic virusmay resurface, resulting in an increase in transmission instances across the country. This study did not include mass screening as a control approach, and the model did not account for super spreaders. Shah et al. (2020) proposed a generalised SEIR model of COVID-19 that investigated the transmission dynamics' behaviour under various control interventions. Bermejo-Martin et al. (2020) developed a compartmental mathematical model for the COVID 19 pandemic virus, with a focus on super spreaders' transmissibility. The study determined the basic reproduction number threshold, local stability, disease free equilibrium in terms of reproduction number and investigated the sensitivity of the model with respect to the variation of each its key parameters. The study demonstrated the suitability of the formulated model of pandemic COVID -19 infectious disease outbreak in Wuhan, China (Bermejo-Martinet al., 2020).The work incorporated super spreaders and hospitalization into the SEIR model, but the study did not consider control intervention on the model. The aim of this paper seeks to add additional literature review on compartment to the SEIR model with applied optimal control intervention measures. The original study of this research used the extended SEIR model of the form SEIPHR where susceptible(S), exposed(E), infectious(I),super-spreaders(P), hospitalisation(H), and Recovered(R). To reduce the spread ofthe COVID-19 pandemic virus, the two-time dependent control variables introduced to the mathematical model are the prevention strategy targeted at preventing the pandemic virus from symptomatic, asymptomatic and hospitalised humans. This is accomplished by long-term public health campaigning for social distancing, good personal hygiene, the use of face masks in public areas, and the provision of protective equipment for health-care professionals. This was found out that, the management approach is the best control variable strategy for managing hospitalised individuals with the goal of ensuring quick recovery and preventing deaths from COVID-19 pandemic virus sequelae. For hospitalised persons suffering with severe COVID-19, this can be performed by providing supplementary oxygen or a breathing equipment as soon as possible.

III. CONCLUSION

This paper however, provides the limited analysis of the literature review on the mathematical model for controlling the spread of the Novel Covid-19 pandemic.

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