COVID-19 Risk Minimization Decision Making Strategy Using Data-Driven Model

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Abstract: In order to establish social resilient and sustainable cities during the pandemic outbreak, it is essential to forecast the epidemic trends and trace infection by means of data-driven solution addressing the requirements of local operational defense applications and global strategies. The smartphone based Digital Proximity Tracing Technology (DPTT) has obtained a great deal of interest with the ongoing COVID-19 pandemic in terms of mitigation, containing and monitoring with the population acceptance insights and effectiveness of the function. The DPTTs and Data-Driven Epidemic Intelligence Strategies (DDEIS) are compared in this paper to identify the shortcomings and propose a novel solution to overcome them. In terms of epidemic resurgence risk minimization, guaranteeing public health safety and quick return of cities to normalcy, a social as well as technological solution may be provided by incorporating the key features of DDEIS. The role of human behavior is taken into consideration while assessing its limitations and benefits for policy making as well as individual decision making. The epidemiological model of SEIR (Susceptible–Exposed–Infectious–Recovered) provides preliminary data for the preferences of users in a DPTT. The impact of the proposed model on the spread dynamics of Covid-19 is evaluated and the results are presented.

Keywords: Decision making, Data-driven technology, Covid-19, epidemic control, SEIR, Digital Proximity Tracing Technology

1. Introduction

In 723 countries across the globe, around 1483 epidemic events were recorded by the World Health Organization (WHO) between 2011 and 2018 [1]. In the affected nations, the economy

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and health of the population may be severely affected due to the epidemic-prone diseases. The pandemic causes a global impact based on several factors such as efficiency of the healthcare system, pollution levels, food quality, sanitary conditions and strength of the pathogen [2]. The origination of Severe Acute Respiratory Syndrome–Coronavirus–2 (SARS-CoV-2), informed by the Chinese government to the WHO at the end of December 2019 has led to a global health crisis. The pandemic was caused when the virus spread beyond the borders of China during January 2020. Several people have died and many are infected by this virus worldwide [3]. Coronavirus Disease–2019 (COVID-19) is the official name of the pandemic caused by SARS-CoV-2 virus. The social stability, economy and global trade are impacted by this pandemic in a devastating manner [4]. The world has faced the worst social, economic and health crisis since World War II. Despite being successful in controlling the spread of infection, several countries are facing the recurrence of virus as a second wave. [5] The threat has been contained by several strategies and measures while coping up with the massive requirement of vaccines. The virus transmission has been reduced to a large extent by means of total lockdown and quarantine after the outbreak of Covid-19 [6]. Accurate data collection is required to implement control measures such as restriction of public gatherings, sanitization, appropriate physical distancing and so on.

2. Related Works

Several counter-measures has been implemented by various health organizations as the pandemic spread. In a fully susceptible population, a single primary infection leads to several secondary infection represented by the basic reproduction number R0 which is in the spotlight [7]. The epidemic fades away if the value of R0 is less than 1 and rises when the R0 population level is greater than 1. To lower the index of R0, quarantine and other restrictive measures are to be taken. When the restrictions are lifted or relaxed, a complete resurgence may be caused with the increase in R0 [8]. Treat, trace and test, forming a combination of measures provides a conventional strategy for keeping the critical threshold value R0 under control. New and potential cases are found by monitoring and testing for the symptoms in people by tracking down anyone in contact with an infected person or exposed to SARSCoV- 2. The public health officials perform the manual process of contact tracing. Various infected subjects are interviewed manually while deploying this protocol while they are assisted towards recalling

their prior interactions and movements [9]. This process is labor intensive, time consuming and resource demanding while providing limited and inaccurate outputs. The spread of SARS-CoV-2 can be suppressed with efficient population screening. However, equipment, infrastructure and personnel are required in large capacity to perform community testing [10].

People with acute symptoms that required hospitalizations were only tested in the European Union (EU) as reported by the ECDC (European Centre for Disease Prevention and Control) [11]. The transmission control is not attained as the infection rates per capita is underestimated vastly due to the shortage in the testing kits at the initial stages leading to testing only of the highly symptomatic individuals who formed a small portion of the crowd [12]. The self-isolating people, recovered patients, asymptomatic carriers and mild symptomatic people and their cases were uncertain due to this reason. This affects effective forecasting of the spread and total cases expected with respect to Covid-19. Even before the symptoms begin, the infectiousness starts in the individuals [13]. Due to this reason, it is impossible to stop the epidemic just be the total isolation of all symptomatic individuals as suggested by several studies. Contacts in the asymptomatic stage and pre-symptomatic stage transmits over half of Covid-19 according to other researchers.

3. Proposed Work

In order to reduce the spread of infection, the epidemic dynamics is analyzed while the effects of DDEIS and DTTTP are investigated. The public health policymakers are provided with valuable information for making the required disease control and intervention measures impacting public health by comparison and assessment of the effectiveness of the mathematical model developed for estimating the dynamics of the epidemic as suggested by the WHO [14]. The dynamics of the Covid-19 disease is investigated by adopting several mathematical models. The renowned SEIR (Susceptible–Exposed–Infectious– Recovered) model is used for developing a deterministic compartment model for this purpose. This paper proposes an extended model of SEIR where mutually exclusive compartments are used for describing the flow of people through a simplistic compartment model. The entire population is categorized into ten compartments including Susceptible (S), Confined (C), Exposed (E), Asymptomatic (A), Symptomatic (I), Quarantined (Q), Hospitalized (H), Recovered (R), Deceased (D) and

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Vaccinated (V). S indicates people with a possibility to be exposed to the virus, E indicates infected people who may be exposed, symptomatic or asymptomatic and have the possibility of infecting susceptible individuals. A portion of the susceptible individuals are restrained without causing the spread as indicated by C. I indicates individuals who exhibit symptoms and A indicates those with no or mild symptoms. The self-isolated individuals are categorized under Q. Hospitalized under H, recovered under R and vaccinated individuals under V. The individuals who lost their life due to Covid-19 are categorized under D. The graphical diagram of the categorization is as represented in figure 1.
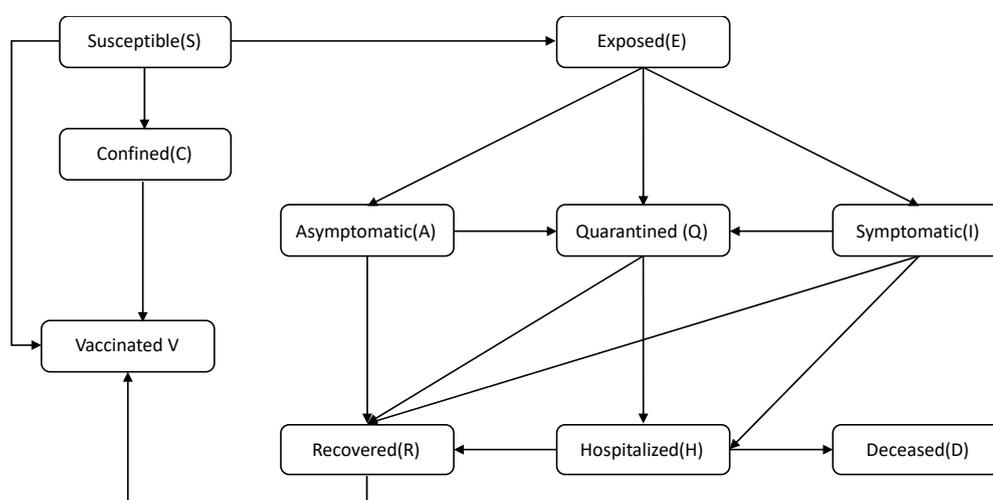

Fig. 1. Compartment categorization and flow of individuals between them

A well-mixed, homogeneous and closed population is considered in this model. The evidence of recovered individuals being re-infected is negligible. However, vaccination would provide better immunity towards the disease [15]. The transition of individuals across the compartments are controlled by the model parameters that are homogeneous over the population considered. Various literature regarding the pandemic are still under debate due to the inhomogeneous features of the dynamic factors of the population. Thus the epidemic dynamics is not modelled accurately. The disease spread may be controlled effectively using the positive features of DDEIS in an efficient manner. The common SEIR models does not consider the transition of people between the compartments in most of the literature that are available [16]. This is overcome by introducing the vaccination factor along with the existing model in this paper. Factors like relative probability of transmission of disease, rate of transmission, rate of

movement between various compartments and rate of self-isolation are considered for this analysis.

4. Results and Discussion

The social and technological effectiveness of the proposed model in enabling quick return to normalcy while minimizing the resurgence of epidemic and guaranteeing the health and safety of public is clarified in this paper. Power towards mitigation of infection, guarantee in personal data protection, social impact, spatial data requirements and technical feasibility aspects are considered for the purpose of analysis. Inferring the epidemic trend and evolution under multiple scenarios helps in understanding the impact of the proposed model and to compare the efficiency of the strategy towards combating the virus spread. The number of infected individuals decrease remarkably with an additional flux of individuals in the confined and quarantined compartments on comparison of the epidemic dynamics under various scenarios. Based on these results it is evident that the disease spread may be reduced considerably through a valuable intervention of digital proximity tracing that can help in overcoming the overwhelming capacity of intensive care unit (ICU), lockdowns and other mass intervention over the entire course of epidemic. There is a significant reduction in the spread of the disease with an active protection strategy for the people who are susceptible or potentially exposed and are in confinement or quarantine.
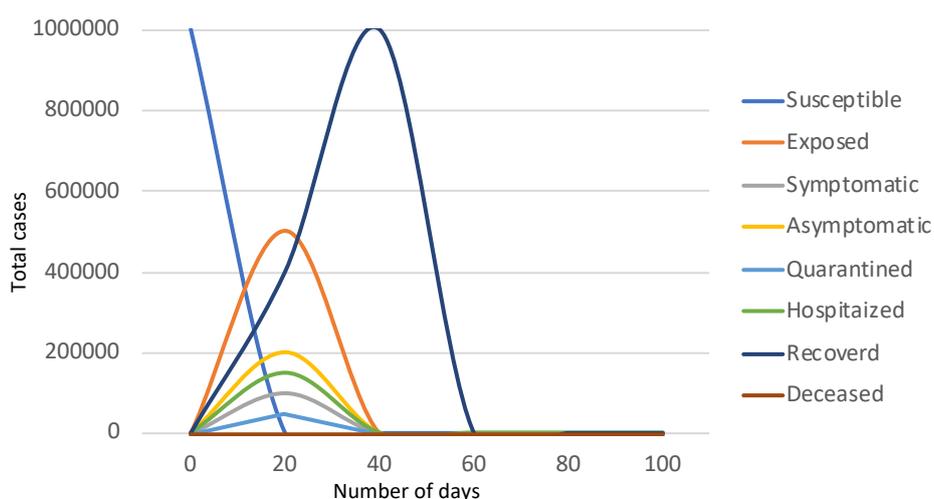
Fig. 2. Evolution of the spread over a duration of 100 days

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The contact between the infected and susceptible individuals lead to a remarkable increase in the number of exposed people during the initial stages of the epidemic. The flow of population towards symptomatic, asymptomatic and exposed compartment increased over 15 days. Further, during the next 50 days, peaks were evident in the hospitalized, quarantined, asymptomatic, symptomatic and exposed count. Over the first and second wave of the epidemic, there has been huge variation in the number of deceased individuals. There is a peak in the hospitalized individuals out of the susceptible individuals population. The evolution of the overall spread over a duration of 100 days in each compartment is as represented in figure 2. The non-quarantined infected individuals are reduced by a large number thereby reducing the flow from susceptible individuals. Figure 3 represents the early detection scenario of the epidemic evolution. At the end of simulation, the total deceased people has reduced by a fraction when compared to the total individuals exposed. An early detection strategy is implemented for increasing the number of quarantined people and thereby reducing the risk of exposing susceptible individuals to the spread on comparing Figure 2 and 3.

A 20 question based online survey is considered for the design. Factors like data collection and anonymous processing are researched along with assessment of the acceptance degree, user preferences, user profiles and demographic data. The implementation potentialities, simulation model, advantages, limitations, privacy and technological concerns of various models are analyzed. The paper supports the decision-makers in weighing the effects, prerequisites and several other aspects as well as their potential impacts through an extended comparison. As several variable factors are involved in decision making such as the preferences of citizens, national laws, government strategies, medical and infrastructural facilities. The DPTTs and Data-Driven Epidemic Intelligence Strategies (DDEIS) are compared to identify the shortcomings and propose a novel solution to overcome them. In terms of epidemic resurgence risk minimization, guaranteeing public health safety and quick return of cities to normalcy, a social as well as technological solution may be provided by incorporating the key features of DDEIS.

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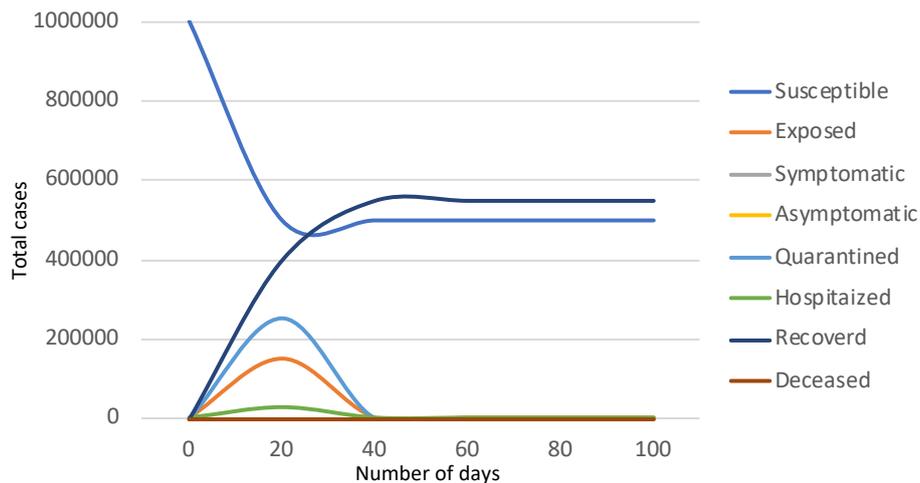
Fig. 3. Early detection scenario of the epidemic evolution

While considering the legal restrictions and cultural context, the response of the proposed model varies and can be tailored to adopt various strategies as required by the public authorities. The survey helps in deducing various strategies and their percentage of adhesion. Figure 4 provides the comparison of the proposed model along with early detection, surveillance, protection and combined techniques. The combination of these models helps in reducing the number of deceased individuals and the rate of hospitalization. A surveillance strategy may also be adopted on the global scale that provides beneficial towards the rate of reduction of the spread. When compared to the surveillance strategy, the protection strategy and early detection offers improved adhesion rate results. The traditional contact tracing and operative management features are overcome while easing the side-effects and preventing high-risk contacts using individual smartphones by means of automatic precaution mechanism distribution through protection strategy. The early detection strategy complies with the operating organizational infrastructure of public health with a high comparable degree of impact.

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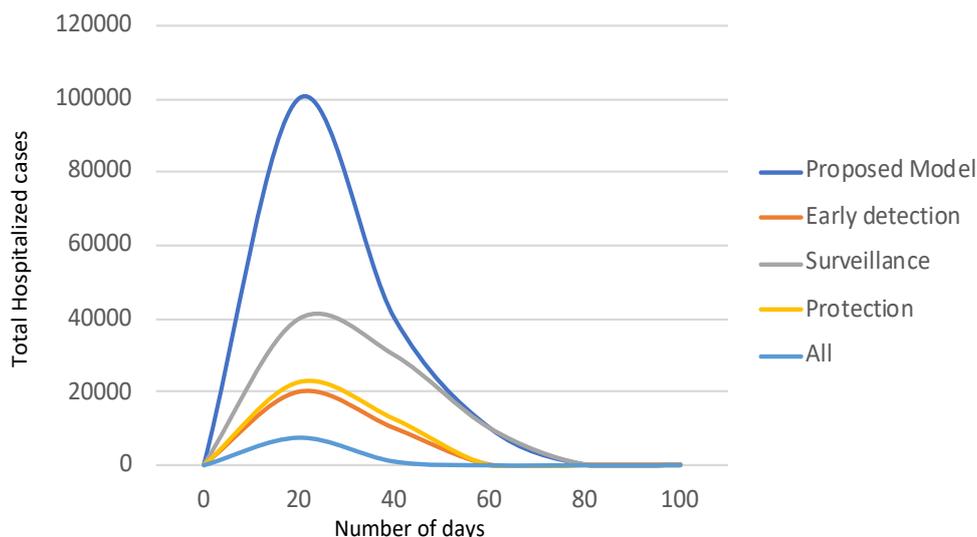
Fig. 4. Epidemic evolution based on the total hospitalized cases

5. Conclusion

Along with clinical research, assessment of mitigation strategies and their impacts are essential in epidemiological analysis and data collection. Several cities and countries adopted SPTTs for the control of epidemic. In order to avoid extreme lockdown measures and to reduce the impact of the pandemic on a global level, a data-driven strategy is adopted in this paper. Smartphone tracing is performed based on user preferences received as responses to an online survey and the parameters are fed to an epidemiological model. The policymakers make use of parameters such as peak occupancy of hospitals, death prediction and so on derived from non-linear differential equations. Evidence based decisions are used for speeding up the adherence of government and citizens towards reducing the disease spread using digital technology and model-driven strategies. The various strategies in use and their implications on different scenarios, society and its potential uses are compared and analyzed in this paper while overcoming their drawbacks and proposing an efficient model.

During initial comparison, the preliminary information obtained from the online survey regarding Covid-19 is used for establishing the epidemiological model. The implementation potentialities, simulation model, advantages, limitations, privacy and technological concerns of various models are analyzed. The paper supports the decision-makers in weighing the

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effects, prerequisites and several other aspects as well as their potential impacts through an extended comparison. As several variable factors are involved in decision making such as the preferences of citizens, national laws, government strategies, medical and infrastructural facilities. The proposed model is adaptable to the required context and local condition while reaching a mixed trade-off that is mindful and efficient against the spread. Developing a structured decision support tool while considering the effects of vaccination is considered as a future direction.

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