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Sustainability Measures for COVID-19 Pandemic

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Preface

The pandemic resulted from the novel coronavirus (COVID-19) has dramatically affected the society and individuals in many ways around the world. While emerging technologies have been widely used in the past, the appearance of the COVID-19 pandemic requires the use of these technologies across many sectors. Sustainable development is the buzz word now. It is the major research area across the disciplines of computer science and engineering, electrical engineering, and other engineering disciplines as well. It is a holistic approach that sustainable development is the means of improving the life of human beings. There is a strong need of monitoring and analysis of pandemic situation for sustainability like epidemic risk analysis by using pattern recognition or the mental health challenges during this outbreak. This book will focus on sustainability issues due to COVID outbreak and researcher's opinion to restrict the global spread of pandemic and also how to survive holistically in the environment. It will also discuss the economic impacts on the world due to the coronavirus outbreak. It has been organised into fourteen chapters.

Chapter "Internet of Things and Web Services for Handling Pandemic Challenges" provides promising solutions to combat the corona virus outbreak through advanced technologies. To monitor, track, and control the spread of viruses during the pandemic, IoT and similar sensor-based technologies have been employed which can handle remotely with support of cloud and artificial intelligence. The Hardware Meets Software establishes a secure remote monitoring system between patients and doctors, facilitating telehealth services to be rendered. Various Web services like RESTful APIs to track COVID-19 include CORD-19, deployed on Vespa Cloud, that enables search and navigation on Open Research Dataset, etc. Cloud-based services are employed to support remote work-from-home operations, e-commerce, retail, health care, and entertainment segments. Another sector is the energy and utility verticals, which uses IT service management (PaaS & SaaS) and infrastructure (IaaS) for digital transformation during this pandemic.

Chapter "Corona Thwack: Socio-Economic Impact of Covid-19 Pandemic in India", focuses that the disruptive corona pandemic caused India to witness a devastating crisis common to the whole world. Earth turned into a "global village" where each and every person of each and every community and locality strived towards a

common attack of the infectious disease COVID-19. This phenomenon came as a blow towards the social and economic impetus of India. COVID-19s colossal wreck paved towards lockdown of the entire nation which, in turn, rendered a severe loss worth billions of earnings of the government, along with, the impairment towards employment, production process, cultivation, social order, and many other national, economic, and societal issues. The present study is an attempt towards a discourse analysis of the socio-economic impact of the common corona culture caused by coronavirus on India.

Chapter "Mathematical Modeling on Double Quarantine Process in the Spread and Stability of COVID-19" formulates the transmission of COVID-19 and its stability. In the susceptible class, pre-quarantine technique is implemented for the individuals who have come from the disease-prone areas. Similarly, in the infected compartment post-quarantine technique is implemented. As per the principle of mathematical epidemiology, the rate of change of each compartment is expressed in the form of ordinary differential equations (ODEs). The differential equations are nonlinear in nature which are associated with the disease parameters, namely rate of natural death, death due to COVID-19, immigrant's influx, spread and recovery. Fourth-order Runge–Kutta numerical technique is used to solve ODEs. The global stability is explained on the basis of Lyapunov function. Routh–Hurwitz theorem is applied for the behaviour of eigen values to discuss the disease-free equilibrium. This investigation shows that the disease will be stable for a long run due to quarantine process.

Chapter "A Study and Novel AI/ML-Based Framework to Detect COVID-19 Virus Using Smartphone Embedded Sensors" presents a framework based on smart phones and artificial intelligence. The benefits are increased productivity, reliability, and availability of advanced infrastructure. There are various sensors embedded in the smart phones such as proximity sensor, light sensor, accelerometer, gyroscope, and fingerprint sensors which have very fast processors and memory space making it easy to read the sensors and scan the CT images, and the signal measurements in the sensors of the smart phones are read which scan the CT images for reliable diagnosis of the disease.

Chapter "Transmission Modelling on COVID-19 Pandemic and Its Challenges" focuses on a proper mathematical model with its associated parameters that leads better prediction to spread of COVID-19 virus and its future preparedness. The authors have mainly focused on hospitalized quarantine and proposed the mathematical model, justifying its positivity. Here, both the stability analysis like local as well as global are discussed, which depends upon the basic reproduction number. The numerical simulation and graphical analysis are analysed by the help of Raunge–Kutta methods. Finally, the outcomes of the model represent that person-to-person contact is the main cause of this pandemic COVID-19. Lastly, this model concludes that hospitalization is the best approach to reduce the infection and the fear of pandemic situations.

Chapter "Effect of COVID-19 Pandemic on Mental Health: An Under-Realized Sociological Enigma", discusses that the COVID-19 pandemic has vexed fundamental mental prosperity balance in 93% of countries worldwide while the interest

for emotional well-being is expanding as per the WHO overview. This brief review investigates down word's impact on psychological status in the COVID-19 pandemic worldwide, particularly with respect to India, based on the data published in various electronic media. The authors also discuss about the ramifications of social distancing rehearses and the financial downturn on psychological wellness, just as difficulties in getting too emotional well-being.

Chapter "Predicting the COVID-19 Outspread in Andhra Pradesh Using Hybrid Deep Learning" analyses that COVID-19 is one of the major healthcare challenges around the world today, but physical detection of the COVID-19 positive patients is time-consuming due to the limited data sources. Thus, the deep learning classifiers and the blood test parameters perform a significant part in the prediction of the disease and death of COVID-19. The parameters like age, gender, lactic dehydrogenase (LDH), lymphocyte count report the severity of COVID-19. The features lactic dehydrogenase (LDH), C-reactive protein (CRP), lymphocyte count predicts the mortality of the COVID-19 patients with accurate accuracy. Deep learning classifiers can detect nonlinear relationships and interactions between parameters and explain better performance.

Chapter "Mental Health Decline During Corona Virus Outbreak", highlights the fact that the onset of lockdown did have a significant psychological impact in India, with 62% of people experiencing moderate to severe stress. At a more granular level, individuals were found to have been essentially affected regarding their sentiments of nervousness, outrage/crabbiness, and dejection. It was discovered that the most significant reason for this effect was the vulnerability of how long the pandemic would last. This chapter focuses on emphasizing the stress levels experienced on all portions of respondents, may be understudies, business people, or working experts, ordinary lay people and children of all categories.

Chapter "Social Challenges and Consequences of COVID-19" presents that the epidemic of COVID-19 touches all fragments of the population and is especially harmful to participants of those social groups in the most disadvantaged circumstances and continues to have an emotional impact on the group of people, including those living in situations of poverty, the elderly, people with disabilities, young people, and indigenous people. If the community disaster is not adequately addressed by policy, inequality, exclusion, discrimination, and global unemployment will also increase over the medium and long term. When developed, robust, worldwide social safeguard programmes play an enduring role in protecting workers and dropping the pervasiveness of poverty by serving as automatic stabilizers. This is an issue of universal human unity. It is also important for the fight against the virus. Now is the time for the insecure to step up.

Chapter "Economic Impact and Measures of Corona Regime" presents that country-wide lockdown during COVID-19 resulted in unwanted disruption of global demand and supply chains eventually resulting in inevitable slump of the world economy. Several studies fear that the estimated loss to global economic growth in 2020 could be in range of −4.5% to −6.0% and possibilities of any revival can only be visible in the later part of 2021. However, the recent reappearance of contagious cases in some parts of Europe and the USA could further weaken or delay any chances

of early economic recovery. The report presents a summary of the financial impact caused because of the pandemic and steps taken by various governments to revive it through necessary fiscal measures to boost liquidity.

Chapter "Modeling the Impact of Various Treatment and Prevention Tact's on COVID-19 Worldwide" compares that various models like BHRP transmission model and SIR and SEIR models to develop the tactics of treatment and prevention for COVID-19 virus. Developing such tactics involves full understanding of how the virus is spreading all over the world. Various treatment and prevention methods have been started worldwide such as BCG vaccination, plasma therapy, antiviral drugs, immunoboosters, etc., to decrease the high death rate caused because of COVID-19 pandemic. With the study of these models, the authors have put-on focus on different control factors to understand the results of recovery from COVID-19 virus.

Chapter "Understanding Emotional Health Sustainability Amidst COVID-19 Imposed Lockdown" reports about the emotional health during the lockdown phases in India as a case study. This study's empirical findings are based upon eight emotions: Anger, Anticipation, Disgust, Fear, Joy, Sadness, Surprise, and Trust. The authors have described how every lockdown impacted the emotions among people in worst-hit Indian states towards COVID-19 cases by analysing how a particular lockdown comes to be associated with distress and relief and developed an automated tool to pictorially represent emotions, https://emotiontrackerindia.herokuapp.com/. Understanding the emotional and mental health of the masses makes the nations proactive and future-ready. Adoption of suitable sustainability measures at the right time mitigates such crisis-like situations. Thus, this chapter puts forth an emotion analysis mechanism using social media and recommendations for upcoming emergencies.

Chapter "Industry 4.0 Technologies and Their Applications in Fighting COVID-19" discusses the Industry 4.0 applications, methods, and case studies in various applications, which are essential to handle the sudden pandemic like COVID-19. Such situations demand the requirement of a medical facility in a nonlinear way which is hard to handle with traditional demand–supply strategy. This may lead to insufficient occupancy of services, etc. This insufficient occupancy leads to big losses in public health and lives. These scenarios can be handled by promoting the usage of advanced technology as a substitute for many services. In this pandemic situation, the manpower requirement can be replaced with automated devices and cyberphysical systems, which will assist and substitute humans in providing the various services like real-time assistance, observation, medication, sanitization, etc.

Chapter "Internet of Medical Things (IoMT)-Enabled TeleCOVID System for Diagnosis of COVID-19 Patients" presents a well-developed scheme of integrated computational tactics, digital, and mechanical machines capable of distributing data over a defined network without any human intervention at any stage. The authors have developed a TeleCOVID diagnostic system for monitoring COVID-19 patients with body temperature, oxygen saturation level, heart rate, throat, and patient's behaviour. A Web platform has been developed to monitor the patient's symptoms, and a smartphone application is also developed and used to detect the patient's activities. The accuracy of the activity detection system has reached 81.82% at 0.82 precision. The

overall system showed promising results for several test trials, and it is named as Internet of Medical-Enabled TeleCOVID System.

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https://scholar.google.com/citations?user=toYvcaoAAAAJ&hl=en

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Internet of Things and Web Services for Handling Pandemic Challenges

Duddela Sai Prashanth, Janardhana Swamy, and Shreyas Suresh Rao

Abstract Within the past few months, the COVID-19 pandemic has disrupted millions of lives and caused unforeseen economic damage, whose impact is both significant and far-reaching. There is an immediate need to utilize emerging technologies across various industries to fight the pandemic in this light. Internet of Things (IoT) and Web Services (Cloud services) are two such technologies that provide promising solutions to combat the virus outbreak. To monitor, track, and control the spread of viruses during the pandemic, IoT and similar sensor-based technologies have been employed. Innovative technologies that enable monitoring of health delivers live observation by using smart devices to monitor the health and can handle remotely with support of cloud and Artificial Intelligence. The HMS establishes a secure remote monitoring system between patients and doctors, facilitating telehealth services to be rendered. For tracking, the HMS uses a combination of personal health data and social data in real-time, enabled through technologies such as Machine Learning, distributed Cloud computing, and AI-based speech recognition. Because of lightweight Application Programming Interfaces (APIs) and edge computing capacity, the IoT-enabled HMS is now accessible through mobile apps and web-based applications. Web services are playing an integral role in Industry's response to fight the global pandemic. To access the data on the COVID-19 provided by World Health Organization a separate interface is provided over a web service. Some other RESTful APIs to track COVID-19 include: CORD-19, deployed on Vespa Cloud, that enables search and navigation on Open Research Dataset; CoronaTab that provides localized health information; COVID-19 India API sourced from the Ministry of Health and Family Welfare that retrieves case counts, testing statistics and hospital data from the Indian subcontinent. Cloud-based services are employed to support remote work-from-home operations, e-commerce, retail, healthcare, and entertainment segments, to name a few. Enterprises effectively use cloud services to build robust and disaster-averse networks worldwide to respond to a distributed workforce and protect data and business applications' integrity. Another sector is the energy and utility verticals, which uses IT service management (PaaS and SaaS) and infrastructure (IaaS) for digital transformation during this pandemic. This chapter

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discusses how IoT and Web services support handling global COVID-19 challenges, especially in Healthcare, retail, and social sectors.

Keywords IoT · Web services · COVID-19 · Digital transformation

1 Introduction

The Internet of Things (IoT) and Web Services are two emerging technologies that offer promising solutions to combat the COVID-19 pandemic. In this chapter, we discuss the solutions, from a literature perspective, regarding first IoT, then Web Services, for handling the pandemic challenges.

Many smart devices are connected over the internet and often exchange data that makes the networks more complex [1]. This helps to convert normal devices into innovative devices. Interaction with the devices is not required for these smart devices, they communicate with each other over the internet and accumulate data in the respective clouds [2]. The number of smart devices is increasing exponentially and IoT is contributing to the present digital era [3].

IoT has the ability to revolutionise a number of sectors, including health care [4], self-driven vehicles [5], home and robots for industry [6], industrial automation [7], energy storage [8] and more.

Global attention is gained to most of the new technologies in the form of IoT [9]. It becomes easily accessible to predict, prevent, and monitor the incipient infectious diseases [10]. Patterns are identified from the raw data collected from different sources like interconnected smart devices, sensors, and similar are often referred to as IoT. Health Monitoring System with State of the art included for observation over the wearable devices to monitor health. These devices are cloud-based that help to monitor health remotely, and AI is included for better services. These monitoring systems use digital platforms, survey records, and healthcare info, incorporating managed, unsupervised, and machine learning techniques. When technologies like AI and machine learning combine with the cloud for storing, blockchain for security and automation using system software with AI speech recognition, the health monitoring systems produce a consistent remote monitoring system. These IoT-enabled healthcare delivery systems provide features like digital triage, AI secure chat, and telecare. These technologies are now readily available via simple user interfaces on secure mobile apps and web-based applications, thanks to lightweight Application Program Interfaces (APIs) and edge computing capabilities.

Different technologies can communicate data through the network to anywhere around the World automatically where computing devices are included that are interconnected, electronics with digitalization, electrical, and medical devices [11]. IoT technologies have made the transmission of data an easier task [12]. The identification numbers or codes used for authentication or authentication are essential for all interconnected IoT platform devices. IoT currently provides a connection to multiple

approaches, quick analytics, machine learning, deep learning, and deep learning for every application that works [13].

Societies face various challenges in healthcare, training, construction, supply chain management, service delivery, travel, and tourism under present conditions and in a post-COVID-19 environment. Health care services are overloaded because of the exponential rise of COVID-19 cases, and it creates problems for regular patients who need medical assistance. The limited movements, which is a significant problem for the healthcare sector, lead to delay and increase the demand for resources. For tracing the people's contact, a practical and automated contact tracing application must regulate the spread. It is the responsibility of different sectors like engineering, healthcare workers, policymakers, research communities, and the public to join and provide a solution for such problems.

Digitalization and the use of telecommunications would be needed to protect and manage the post-COVID-19 environment. Artificial intelligence (AI), big data, 5G communications, cloud computing, and blockchain, among other emerging innovations, will play a crucial role in fostering the system's security and development for people and ecosystems. To incorporate these promising innovations and realise their advantages, technology and engineering managers will have to address major challenges and carry out complex managerial tasks in terms of cost, scope, performance, resource management, and risk management.

1.1 IoT Process to Combat the Covid-19 Pandemic

IoT is a useful technology platform in order to fight the COVID-19 pandemic, which will face significant challenges during the lockout scenario. This technology helps capture the infected patient's real-time information and other required information [14, 15]. Figure 1 illustrates the essential processes used for COVID-19 by IoT. IoT is used to collect health data in the first step of different infected patients' locations and use the virtual management system to handle all data [16, 17]. This technology allows the data to be monitored, and the report achieved to be followed.

Advantages by using IoT to combat COVID-19 are Reduced chance of mistakes, Lower expenses, Superior treatment, Lesser expenses, Effective control, and Enhanced diagnosis.

The rest of the sections are organized as follows. Section 2 describes the IoT applications used to combat the COVID-19 pandemic in medical Healthcare, smart home, and IT. This section also enlists some significant challenges faced for IoT implementation. Section 3 describes the various Web Services/Cloud Services used in the Industry/E-Governance sectors to fight COVID-19, and lastly, Sect. 4 concludes the chapter.

Fig. 1 IoT process for controlling Covid-19 pandemic

2 IoT for Handling the Pandemic Challenges

The IoT's important goals include developing a smart environment and self-aware autonomous devices, such as smart living, intelligent products, smart health, and smart cities, among others [2]. The following section addresses IoT implementations in the fields of Industry, medicine, and home automation.

2.1 Literature Survey

The author provided a methodology for effective utilization of 5 g for e-health use cases and its role as a facilitator of related online services [18]. Using wireless communications innovation, a low-cost IoT—based smart sensing system is built to assist, communicate, and reduce the covid-19 challenges [19].

To understand the human-technology relationship, providing a framework results in practical observations for controlling virus transmissions during pandemics [20]. The integration of 5 g IoT provides creative solutions for technological requirements and challenges in telemedicine, contact tracking, education, retail, production lines, e-government/remote office/information sharing, smart manufacturing and factory automation, e-tourism, and entertainment. It implies that IoT combined with 5G will make everyday life, work, and other aspects of human life simpler in the future [21].

The smart healthcare devices are implemented to identify the impact of COVID-19 and safeguard diabetic patients [22]. Gives an overview of the success of sensor-based E-health in the control of worldwide pandemics and how this pandemic situation has made rigorous development in the IoT network [23]. Made a significant contribution

to a deeper understanding of recent technical progress in IoT implementation areas, as well as the environmental consequences of increased IoT product adoption [24].

Implement IoT that discusses IoT's internal and external factors and deployment to detect possible challenges [25]. It is found that IoT enabled healthcare networks are useful to identify infected patients of COVID-19 and can provide better treatment for a speedy recovery of patients [26]. The smart IoT enabled wearable device is used to fight against COVID-19 pandemic challenges related to hygiene and disease prevention [27].

By using an integrated network, a healthcare system allowed by the Internet of Things (IoT) is useful for the proper check of patients with COVID-19. This technology boosts patient satisfaction while also lowering hospitalizations [12].

IoT offers the components needed to assist nations in reducing the effects of COVID-19. IoT has a broad variety of technology that can easily guarantee that almost all of the health officials' protection and precautionary recommendations are followed [12].

2.2 IoT in Personal Medical Devices

Medical care's primary goal is to guarantee the system's safety to keep patients safe from pernicious attacks. IoT has significant applications in medical fields during Covid-19, which are:

1. Internet-connected hospital: A fully integrated network inside hospital premises must introduce IoT to support a pandemic like COVID-19.
2. In the case of an emergency, alert the medical services involved: Where possible, this integral component would allow students and families to react better and quicker.
3. Transparent COVID-19 treatment: Patients should realize the profits without prejudice or advantage.
4. Standardized care process: Selecting therapeutic options becomes more effective and helps with case management.
5. Telehealth consultation: Using well-connected teleservices, this mainly makes healthcare accessible to those in need in rural parts.
6. Wireless healthcare network to classify patients with COVID-19: It is possible to mount different legitimate apps on smartphones, making the recognition process simpler and more fruitful.
7. Fast tracing of patients who have been infected: In the end, the impactful tracing of patients enhanced the treatment of cases more intelligently by service providers.
8. During the propagation of this virus, real-time information: Because the computers, sites, networks, etc. are well aware and linked, it is easy to exchange information on time and cases can be treated correctly.

9. Quick COVID-19 screening: As soon as the condition is received/discovered, smart linked treatment devices will be used to attempt a medical evaluation. As a result, the overall screening procedure becomes far more efficient.
10. Identify ground-breaking solutions: The most significant aim is to increase the general quality of supervision. It can be done by taking popular inventions to the bottom level.

They have their predefined targets at the stage where attackers target mobile phones. Typically, their point is to take the data, attack gadgets to use their properties, or shut down specific programs that check patients' conditions. There are various forms of attacks on medical devices that involve stealthy listening. The patient's protection is spilled, uprightness error in which the message is altered, and usability problems include depleting battery assaults. Some advanced security threats associated with the safety, security, and prosperity of patient remedial data are discussed as follows:

1. For any errand that uses battery power, PMDs are fundamental. Therefore, restricted encryption must support these gadgets. If the device is a component of different systems, there will be a high risk of confidentiality, accessibility, protection, and trustworthiness at that point.
2. Because PMDs have no remote correspondence validation instrument. So, the information put away in the gadget could be effectively assessed by unapproved individuals.
3. Besides, the absence of safe validation exposes the gadgets to various other security dangers contributing to vindictive assaults. An adversary can dispatch denial of Service (DoS) attacks.
4. Patient information is transmitted through the communication medium, which may be changed by unapproved parties, so a patient's protection may be unfortunate.

2.3 In Smart Home IoT

The IoT brilliant home administrations are expanding step by step [28]; advanced gadgets can adequately speak with one another using Internet Protocol (IP) addresses. In a keen home environment, all savvy home gadgets are associated with the web. Insidious attacks become more likely as the number of devices in the intelligent home province increases. When smart home systems are controlled independently, the number of instances of vengeful attacks reduces. Wherever and wherever keen home devices can be reached across the network. It generates the chances of malignant attacks on these gadgets in this way.

There are four parts of a vibrant home: administration level, brilliant gadgets, home door, and home system. Numerous devices are connected to an intelligent home and exchange knowledge using a home device cleverly. Therefore, a home portal governs the advancement of the data between the external system-related

gadgets. The administration process utilizes specialist co-op administrations that relay different administrations to the home system.

2.4 In IT Sector

The IoT has provided a fair opportunity to create powerful modern frameworks and applications [29]. The approved person will screen the current area and create a vehicle in an intelligent IoT transportation system. Likewise, the authorized person will predict his future location and street traffic. The word IoT was used in the previous process to differentiate one of a kind from RFID products. To date, specialists have correlated the term IoT with sensors, tools, mobile phones, and actuators of the Global Positioning System (GPS). Recognition and management of emerging IoT technologies are mainly focused on information protection and data security. The IoT provides various linked, monitored, and observed items, resulting in valuable data and private information. Security assurance is an increasingly fundamental problem in IoT conditions instead of conventional systems since the amount of IoT attacks is high.

2.5 Challenges of IoT in the Wake of COVID-19

Development of IoT for more comprehensive applications and devices is a challenging task for any organization. During development of applications of IoT, numerous hurdles are tangled that are mentioned.

Scalability Enforcing IoT to tackle the global pandemic of COVID-19 poses a significant challenge in terms of functionality. The Internet of Health Stuff (IoHT) necessitates a vast number of devices to reliably feel and relay patients' symptoms to the network. As of now, there are nearly 3.7 million active cases worldwide. Multiple sensors are required for each IoT system. Furthermore, because of scalability, energy requirements have increased.

Limited spectrum and bandwidth The need of data is more to communicate the data from different sensors to the cloud storage, this data is collected over numerous IoT devices. Currently, the majority of IoT devices depend on mobile operators' licenced spectrum. The bandwidth requirements have risen in parallel with the growth of these devices. The data is subjected to delay, which may result in incorrect data transmission. Operators use Wireless for specific IoT, that becomes unstable as the number of Devices in the service area increases. Many IoT devices currently rely on 4G/LTE infrastructure to complete their tasks. Many IoT devices would soon outgrow this restricted range of 3G/LTE/4G.

Security and privacy issues Conventional authentication methods are not areas comprising to enforce protection in IoT because of its adaptability and energy

constraints of IoT devices [30]. To provide end-to-end data protection, user privacy, and safe authentication, energy must be utilized optimally for security mechanisms, and techniques recognized to reliable the Iot system should have lower computational burden [31]. As a consequence, IoT authentication must be implemented using lightweight encryption methods. The security requirements of IoT enabled systems also increased significantly of the coronavirus pandemic.

The security concerns in implementing IoT concerning COVID-19 are:

(i) The information that was sent to the devices installed to the COVID-19 patent's body must be reliable,
(ii) The information should achieve its goals effectively,
(iii) The information must not be manipulated, and
(iv) The data must not be captured from the communication path, and
(v) The data stored in the IoT device's memory should not be accessible to everyone [32].

Big data centers Most information is recorded at data centers since each IoT system transfers information to the server through a pre-defined Application Interface (API). One of the most challenging aspects of adopting IoT to fight COVID-19 would be that it necessitates huge storage centers that can handle all of the necessary data without it being overburdened.

2.6 Uses of IoT for COVID-19 Pandemic

IoT is a modern technology that guarantees that patients infected with coronavirus need to quarantine for a defined time period to monitor the virus's spread to normal individuals [12]. During quarantine, careful monitoring is required to provide the appropriate precautions to save survival. By the use of Internet-based network systems such as IoT, COVID-19 patients are monitored very easily. Biometric technologies are now built into platforms for IoT and biometric measurements such as blood pressure, heartbeat, glucose level, breath analyzers, etc. The productivity of medical personnel and patient satisfaction is increased by combining medical measurement instruments and the Internet and computers, and the workload of medical staff with existing resources or equipment is also reduced. Health services are given to patients with minimum costs and higher patient satisfaction in the latest pandemic crisis of COVID-19 for the entire globe. Figure 2, the areas where IoT flourish because of the impact of COVID-19.

IoT devices and applications, including wearables, drones, robots, IoT buttons, and smartphone applications that are mainly utilized in the forefront of combating COVID-19 [33].

Wearables The mixture of technology and things that can wear, is known as Wearables in IoT. It is foreseen that healthcare workers will be spending twenty billion

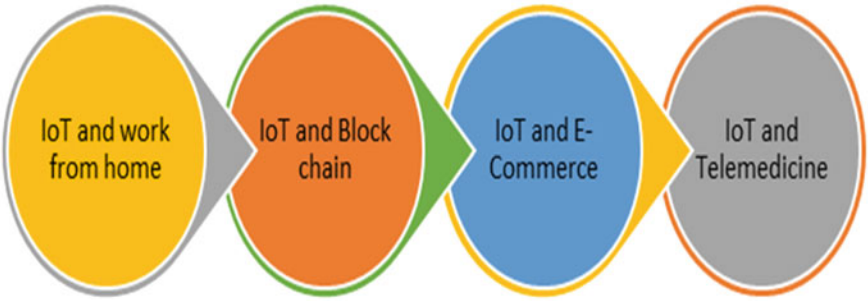

Fig. 2 Areas that flourish because of COVID-19 impact

dollars annually till further couple of years on wearable IoT devices. This helps to monitor more patients. IoT devices in health care make work easier to monitor temperature, and other health parameters using smart devices. It is not limited to health care but IoT becomes a part of day to day life.

Drones Drones are simply aircraft that are flown without any or minimal human operation by remote monitoring. Different types of IoT-based drones, including thermal imaging drones, disinfectant drones, medical drones, surveillance drones, announcement drones, and multipurpose drones, are used in the healthcare domain particularly, in the fight against COVID-19.

Robots A robot is defined as "a machine that resembles a living creature in being capable of moving independently".

IoT Button This type of IoT device is a small, programmable button connected to the cloud through wireless communication. The IoT button enables patients to complain if any hospital restrooms need cleaning by pressing a control only.

Smartphone Applications Many smartphone applications have been developed for the healthcare domain, and some of them have been used in response to COVID-19, namely nCapp, DetectaChem, Stop Corona, Social Monitoring, Selfie app, Civitas, StayHomeSafe, AarogyaSetu, TraceTogether, Hamagen, Coalition, BeAware Bahrain, Houska, and Whatsapp.

2.7 Practices Involved in IoT for Tracking COVID-19 Patients

IoT and related applications are termed as an innovative technology that acts as a platform for integrating different systems or processes. IoT is perfectly suitable and helpful in detecting real-time data from patients infected with the coronavirus.

Initially, the virtual management tool is created in the IoT database to collect information from different locations from infected COVID-19 patients and analyze the data obtained. Then IoT can be used to review the data and report received. IoT is a conceptual network created by joining more than one or more objects or sensors and systems to control the efficient flow of COVID-19 pandemic data through data exchange among cloud systems from anywhere [34, 35]. As stated earlier, monitoring of corona virus-infected patients can be achieved effectively by implementing IoT and allied techniques in the current COVID-19 pandemic, and suspected cases can be detected. Complete assurance can be provided to patients. In this situation, the monitoring of a cluster can be significantly developed by establishing a well-organized community of linked networks based on the Internet [36]. The COVID-19 community can be built on smartphones with the aid of IoT platforms so that patients or other needy people can benefit from it. It is essential to update the monitoring of COVID-19 symptoms in real-time and the recovery rate to the controller, such as physicians, doctors, healthcare staff, etc. Thus, significant measures can be taken to optimize the overall quarantine duration [35].

In combating a global virus pandemic, IoT technologies' implementation results in well-defined hardware, Software, and related policy ecosystem. This segment discusses the components of this particular healthcare environment based on results from the research surveyed. A niche collection of well-integrated components is developed by the sensibility of handling an outbreak with IoT-based technologies. As part of an ecosystem powered to combat and mitigate a virus's spread, these components work together. Many advantages with using IoT to fight a pandemic, such as COVID-19, involve improved patient treatment accuracy, reduced prices, more effective surveillance, quicker treatment, and better treatment choices [12].

2.8 Global Technological Advancements to Resolve COVID-19 Cases Rapidly

The Indian government has initiated e ArogyaSetu, a mobile application aimed at overcoming the COVID-19 pandemic and making people more aware of it. It aims to create a connection between the valuable player healthcare services and India's population. Similarly, China's civilians have access to a smartphone application called e Close Touch (English translation). This app notifies the app's owner of the proximity of a corona-positive user. To be capable of walking around with great care. The US government will finish its fiscal year in April 2020. Will soon be releasing a similar kind of smartphone application for its people.

After China, Taiwan was the most likely country to have more COVID-19 incidents. Nevertheless, Taiwan rapidly militarised and adopted unique methodologies to protect the population's health for any possible coronavirus case detection, containment, and resource provision. Taiwan provided and integrated its immigration department with its national health insurance database and took a catalog to instigate big

data for analytics; during a clinical visit, Taiwan developed real-time warnings based on the age of travel. Case detection is assisted by medical signs. They've also used cutting-edge technologies, such as QR code scanning, summary history monitoring, and so on, to identify sick individuals [37].

IoT technology has several characteristics. Here we can take into account those features because of which IoT applications are highly recommended in medical files supported by IoT applications/devices with seamless connectivity; medical staff can remotely track Covid-19 patients as well as self-quarantine individuals [38, 39]. Compared to the overall number of infected or suspected Covid-19 viruses, the number of medical employees is not accessible. Medical staff will collect the required criteria from these patients in one place with IoT applications' data protection and decide on further action [40]. IoT systems are simple to use so that patients can handle these applications on their own [41]. The IoT, Statistical techniques, Big Data based application offers an excellent level of accuracy with lower implementation costs. These techniques help in deciding the factors which are affecting during Covid-19 lockdown and suggesting precaution measures for the same [39, 42–45]. We can also save the lives of our medical personnel, laws, and policies by using such Software.

3 Web Services for Handling COVID-19 Pandemic Challenges

Web services are playing an integral role in Government and Industries' response to fight the global pandemic. Broadly, web services are used to access COVID-19 data, contact tracing, support Work-From-Home activities, and overcome challenges in the healthcare and retail sectors. Also, Industries are embracing Micro-services technology for developing resilience during pandemic times.

Each of the approaches above is explained in the subsequent paragraphs.

3.1 Accessing COVID-19 Data

Governments of different countries and private enterprises have developed web interfaces for COVID-19 data access. Notable ones include:

Athena API The World Health Organization (WHO) has released the Athena Web Service, which provides a RESTful interface to access WHO's data and statistics on the COVID-19 pandemic. Athena API supports CSV and JSON file formats for data interchange, allows querying against multiple WHO data sources simultaneously, and provides filter options for response download [46].

CORD-19 Deployed on Amazon Web Services Cloud, the service endpoint allows end-users to query the COVID-19 Open Research Dataset (CORD-19), using natural

language. The search results are processed using Amazon Comprehend Medical, which is updated regularly. The service answers Corona symptoms, infection rate, prevalent antibodies, vaccination options, their efficacies, clinical treatment, etc. The service responds to queries regarding virology, immunology, epidemiology, and genomics regarding the coronavirus [47].

Corona Tab This is deployed on the Programmable Web and provides localized COVID-19 data. The service offers a dashboard, REST API, and is localized in many languages. The endpoints are cached for one hour through Cloud flare [48].

COVID-19 India API Sourced from the Ministry of Health and Family Welfare retrieves case counts, testing statistics, and hospital data from the Indian subcontinent.

Postman COVID-19 API Resource Center provides critical real-time data as a service via the Postman REST APIs. This data can be consumed by front-line health care workers such as Doctors, Researchers, Government officials to access critical real-time data on COVID-19. The services are grouped into three categories of (a) Featured API Collections, (b) Twitter API Collection, and (c) Additional API Collections [49].

(a) **Featured API Collections:** This includes a set of four APIs. The first is the COVID Tracking Project API which collects SARS-Cov-2 testing data from 50 US states and 5 US territories. The second API is the Novel COVID API, which provides information on the current cases. This API refers to multiple data sources such as Worldometer, COVID-19 Time Series Summary, DATI COVID-19 Italia, Ministry of Health and Family Welfare for Government of India dataset, GOV.UK Coronavirus (COVID-19) in the UK dataset etc. The third API is COVID-19 Rich Data Services, which offers curated, high-quality data, and metadata from important Corona Virus datasets across the World. The fourth API is the Global Coronavirus API, which contains current and historical datasets for data scientists, researchers, and healthcare professionals to understand and provide timely interventions to the virus.

(b) **Twitter API Collections:** Twitter is an essential social medium for displaying vital information related to COVID and sharing the tweet accounts of important Government officials and healthcare workers whom the common public can contact during pandemic times. The Twitter API collection contains APIs for standard search COVID-19 search terms, tweet accounts of US State Government officials, US State Governors, and US State Health Departments.

(c) **Additional API Collections:** These are the other collections submitted by the community to fight the Corona Virus. Notable ones include DATA API, which provides the global statistics, country statistics, and timeline of the virus; Health API provides the global Corona statistics by country and state; Smartable.ai that provides the latest and historical news of the virus; Statistics API, which displays the public data collected by John Hopkins. The country-specific APIs also show country-based Coronavirus statistics for Japan, Canada, India, the US, the Philippines, etc.

3.2 Contact Tracing

Apple Inc. and Google released Exposure Notification API (also called Contact Tracing API) in April 2020 [17], which helps developers with public health authorities use Beacon technology to detect proximity among the people. The Apple-Google framework API uses Bluetooth and cryptography to see people's proximity and is deployed on Google Playstore. Once the end-users download this app from the Playstore, the app collects the user's necessary profile information. Furthermore, the person has to update his/her COVID-19 status on the app. Subsequently, the app shall use its API to notify the COVID status of the meeting person. However, one disadvantage of the Apple-Google framework API is that it cannot trace its location.

Governments in Europe, Asia, the United States of America, and other countries across the World mine the mobile phone location of users to detect symptomatic COVID-19 patients; this technique is called 'contact tracing.' Chinese use the 'Alipay Health Code' App, Indians use the 'Arogya Setu' app, Norwegians use the 'Smittestopp" app, Singaporeans use the 'TraceTogether' app for contact tracing. All these apps use Bluetooth signals between mobile phones to track the symptomatic and asymptomatic patients in a crowd. They use REST APIs for data collection and communication with the Government data sources (such as the Johns Hopkins Coronavirus Resource Center in the US).

3.3 Support Work from Home Activities

The Corona Virus pandemic has necessitated employees across the World to work from home (WFH) [50]. The success of WFH activity largely depends on the Cloud Computing platforms that support WFH. For example, employee meetings are conducted using Zoom, Google Meet, and Microsoft Teams platforms. Increased remote work is made possible through the Cloud Computing Environment (CCE), which consists of deployable Software as a Service (SaaS) cloud services that enable WFH. In the educational sector, Universiti Sains Malaysia (USM) has taken a lead role in allowing e-learning SaaS platforms for teachers and students to interact and conduct classes [51]. The same approach is followed by leading Universities of the World, such as Harvard University, Stanford University, and the University of Jordan.

In the IT environment, to facilitate better WFH facilities during the COVID-19 pandemic, IBM has announced two new services, namely CCE Migration Services and CCE Deployment services, that helps enterprises migrate their existing on-premise applications and data onto the IBM Cloud environment to assist in better WFH environment [52]. The CCE environment provides the WFH facilities at a lower cost, albeit with greater flexibility, security, and agility.

Blackboard Learning Management System [53] is revolutionizing the EdTech platform, used by over 100 million people, especially during the COVID-19 times.

The services are hosted on Amazon Web Services (AWS), which connects learners and educators worldwide to collaborate and create a meaningful online teaching experience.

3.4 Overcome Challenges in Critical Sectors

Here, we discuss the various challenges posed due to the COVID-19 pandemic on the Cloud Services sector, security-wise, and later in the healthcare domain.

Unexpectedly, the COVID-19 pandemic has given rise to a new terminology called "Home-to-X" [54]. Home-to-X services include Home-to-Business (H2B), Home-to-Consumer (H2C), and Home-to-Government (H2G). The virtual meetings, virtual classrooms, digital Healthcare (via telemedicine) poses a "security" risk to the Home-to-X establishment, as shown in Fig. 3. Healthcare data collected from the patients remotely, Virtual Private Networks data transmission vulnerabilities, can be classified under "data privacy." COVID-19 has turned into a digital transformation enabler since millions of people across the world use the Internet services provided by ISPs (Internet Service Providers). Netflix, Zoom, and Webex have compromised on the data security provided via the Internet due to an explosion in data usage [55].

Because of the Work-from-home imposition on several office workers due to the pandemic, large volumes of data (big data) is getting generated in most sectors [56]. The computation (cloud services) and storage of this big data pose an immense challenge since enterprises were not ready to support the vast volume, both infrastructure-wise and technology-wise. The big data presents the application issues of Home-to-X.

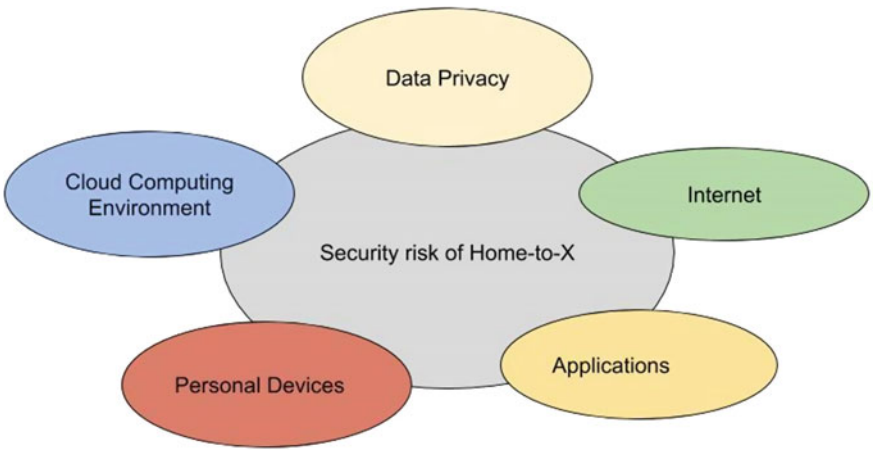

Fig. 3 The security risk of home-to-X

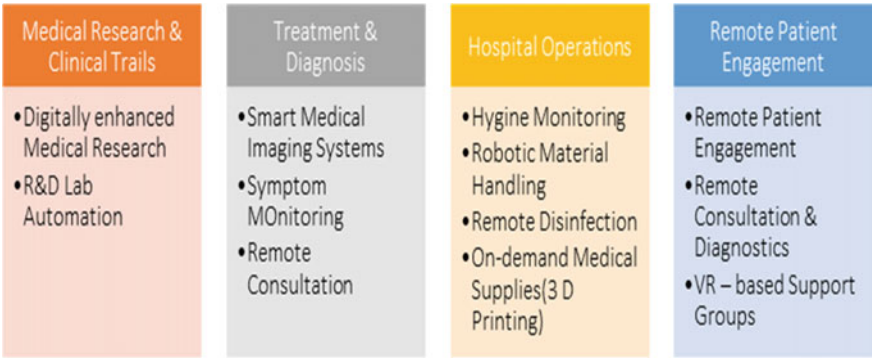

Fig. 4 IoT use cases across healthcare [57]

3.4.1 Healthcare

Diagnosis of COVID-19 through scrutinizing of X-Rays is a crucial element in preventive Healthcare. The paper [58] implements a free web service that classifies an input X-Ray image as COVID-19 or non-COVID. The classification algorithm is based on two deep learning models, wherein the first differentiate whether an input image is an X-Ray or not based on Mobile-Net architecture. In contrast, the second one identifies chest X-Ray images based on characteristics of COVID-19 based on DenseNet architecture. This web service can be used in telemedicine services by the health personnel or directly employed by the patient to self-detect COVID-19 based on chest X-Ray reports.

The availability of accurate epidemiology, laboratory, and clinical data is vital in fighting the COVID-19 pandemic. This data helps the Government to frame policies and guide public health decision-making. The epidemiological data provide a baseline for understanding the disease's transmissibility rate, identifying the risk factors of disease spread, and understanding the containment efforts. While the data is publicly available through google sheets and GitHub repository, a service is implemented to display the data in a user-friendly format. Figure 4 demonstrates the use case of IoT across Healthcare.

3.4.2 Retail

The COVID-19 pandemic has changed the way companies communicate with their customers. Organizations must reply with intensity, compassion, and kindness as customers demand virtual and touchless interactions that protect their wellbeing and inspire trust.

For the mobile app designers working on proximity-based technologies that use IoT, iBeacon technology is an excellent opportunity to design a resilient UX app.

Beacons are small, Bluetooth supportive wireless sensors that communicate with other smart devices or apps by broadcasting radio signals.

"Eggcellent," a restaurant in Tokyo specializing in egg cuisine, developed an egg-shaped porcelain beacon placed on dining tables. The porcelain beacon synchronizes with a beacon-enabled app that takes food orders and receives payments from customers. The app uses the REST Web Services API for communication. Organizations need to invest in building such resilient iBeacon apps that have use cases in the airline industry, home automation, service industry, retail, education, and entertainment.

From a design perspective, first, the beacon-enabled apps must grab user attention and provide useful content through a seamless, frictionless experience. Second, the app must engage the customers in meaningful dialogue, collect relevant data, and perform analytics, enhancing customer relationships. The analytics can be used to entice potential customers with relevant offers, thereby generating more revenue.

3.5 Adoption of Microservices Technology

To develop resilience during the COVID-19 times, enterprises need to adopt the "Microservices" architecture and thereby move from Cloud Virtualization to Containerization.

Unlike traditional virtualization, where hypervisors virtualize the physical hardware, containers virtualize the Operating System to contain the application along with dependent libraries. One can use container orchestration systems such as Kubernetes or Docker Swarm to automate container management, scale, and route.

Containerization enables the adoption of "Microservice" architecture, where the application is designed as a collection of loosely coupled services. Adoption of microservice architecture to App creation will increase resiliency and minimise time-to-market. Microservices are computer and platform agnostic. Offer consistent user experience across mobile, web, wearable environments.

As one of the first successful cases, Walmart Canada handled a transaction of 6 million page views per minute by adopting the microservice architecture. This success is replicated by several multinational companies such as Amazon, NetFlix, PayPal, Twitter, and eBay using microservices. DevOps practices of continuous integration and delivery is an enabler for microservice deployments.

As evident from Fig. 5, over 63% of enterprises are either transitioning or have fully microservice-based applications, while 21% are actively considering adopting the technology. Unforeseen circumstances such as the COVID-19 pandemic necessitates enterprises to embrace the microservice-based delivery model to build IT resilience proactively since microservices improve fault isolation and eliminate vendor and technology lock-in, favors continuous deployment using the DevOps model, and is scalable.

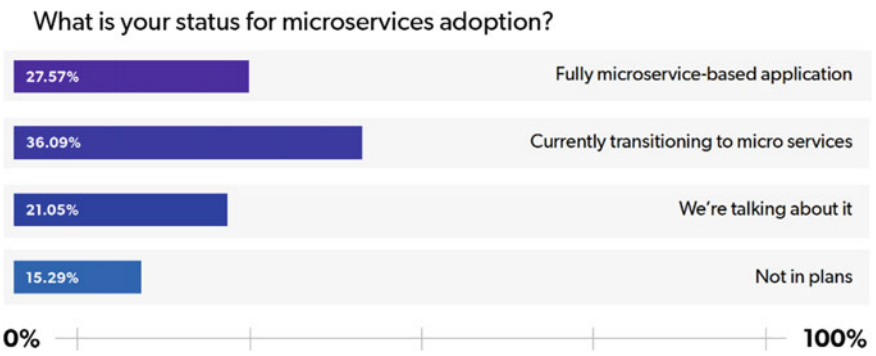

Fig. 5 Microservices adoption in enterprises (*Source* JRebel Java Microservices report, 2020)

4 Conclusion

IoT and Web services are emerging technologies that play an integral role in Government and Industries' response to fight the global COVID-19 pandemic. This chapter describes how the IoT applications are used to combat the COVID-19 pandemic in medical Healthcare, smart home, and IT. Further, the chapter throws light on some IoT implementation challenges. Web/Cloud services are used to access COVID-19 data, contact tracing, support Work-From-Home activities, and overcome challenges in the healthcare and retail sectors. By transitioning from Cloud Virtualization to Containerization, the adoption of Microservices technology builds resilience in the IT enterprises and helps overcome the COVID-19 challenges.

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Corona Thwack: Socio-Economic Impact of Covid-19 Pandemic in India

Anuradha Bhattacharjee

Abstract The disruptive corona pandemic caused India to witness a devastating crisis common to the whole world. Earth turned into a "global village" (McLuhan in Understanding Media—The Extensions of Man, McGraw Hill, New York, 1964) where each and every person of each and every community and locality strived towards a common attack of the infectious disease Covid-19. It has been haunting India since January 2020 and its turbulent tremors led to a massive acquisition of the virus with lakhs of people becoming contagion to it and thousands dying. This phenomenon came as a blow towards the social and economic impetus of India. Covid-19s colossal wreck paved towards lockdown of the entire nation which, in turn, rendered a severe loss worth billions of earnings of the government, along with, the impairment towards employment, production process, cultivation, social order and many other national, economic and societal issues. The present study is an attempt towards a discourse analysis of the socio-economic impact of the common corona culture caused by coronavirus on India.

Keywords Corona culture · Impact · Socio-economic

1 Introduction

Corona is on earth. The new corona culture has engulfed the entire world, and, even, India could not restrict itself from its claw. The vibration of this infectious disease has made itself felt throughout the masses irrespective of sex, caste, creed, race and community. Coronavirus has forced people to be locked indoors and a new stigma has been set up amidst society.

In today's 'mechanical age', there is the extension of the methods of knowing of the human beings. This process has led to the diminishing of space and time, and the extension of technology has increased the vibes of the sense of responsibility towards humans of the whole world [1]. In such an advanced electric age, it is hard to grasp

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as to how a virus has created such a pandemic throughout, where an anti-corona environment can be in the extended hands of humans.

The acceleration of the novel coronavirus reportedly originated from the Wuhan city of China which spread like a wildfire and the World Health Organisation considered the situation and declared it as a global pandemic. SARS-COV-2, a type of virus, is the cause of this disease, which has infected around 2,164,111 people and caused the death of 146,198 people of around two hundred nations of the world [2]. Some have claimed the bats to be responsible in spreading the virus through human consumption of it. This pandemic has put the entire humanity to danger and even the big economies are suffering a great loss of their resources [3]. This paper is a discursive look at the social and economic impact brought about by this pandemic in India.

1.1 Coronavirus: A Bird's Eye View

'Corona' is a Latin term which means 'crown' coined by the researchers Almeida and Tyrell and which has the imagery look of a solar corona [4]. The coronavirus is the largest RNA genome which can cause respiratory disease to mammals, birds and humans. SARS, COVID-19 are its harmful forms. Dr. Tedros Adhanom Ghebreyesus, the Director-General of WHO, termed this epidemic as Covid-19 and called it to be a global health emergency as it is highly contagious [5].

1.2 Covid-19 Acquisition

Covid-19 can cause acute respiratory disorder leading to respiratory failure. It is highly transmissible and the toddler, elderly and people originally afflicted with co-morbid disorder are more prone to get infected. This virus can hover up in the environment and onto surfaces for long. The virus can transmit through eyes, nose, mouth, ears or even by getting in contact with the contaminated surface.

1.3 Covid-19 Complications

Infected persons can be, both, symptomatic and asymptomatic. Incubation can range from two days to fourteen days, and the patient gradually develops the effects of the deadly virus (Table 1).

Table 1 Different ranges of complications of covid-19

Mild symptoms	Severe symptoms	Critical
Fever	Migraine	Myocardial infarction
Cough	Shortness of breath	Multiple organ failure
Cold	Pneumonia	
Sore throat	Lung damage	
Weakness		
Diarrhoea		

1.4 Safety Measures

It is said that prevention is better than cure and as such social distancing and isolation is the only way out. Wearing of masks in public places, avoiding crowds, washing hands frequently with soaps and keeping a sanitiser along while going out may help to prevent the acquisition of Covid-19. Sanitising even the food packets, mobile phones or keeping them under the heat of the sun is also, in a way, an attempt to safeguard the virus from entering the bodies. It has also been suggested to have ginger tea, green tea, turmeric milk, items rich in vitamin C like lemons, mangoes, oranges to raise the body's immunity level. Afterall, the stronger the immunity the lesser is the risk of Covid contamination.

2 Pathogenic Diagnosis

Investigative diagnosis of the presence of the extra parasite in human body is done through different testing of respiratory infections like viral infections—RSV, para influenza, metapneumovirus, non Covid virus, adenovirus, bacterial infections and atypical organisms like mycoplasma and chlamydia [6]. Molecular tests or swab tests play vital role in determining the presence of Covid-19. The C-reactive proteins also called CRP show rising signs when tested. The white blood cell (WBC) shows a decreased count, liver enzymes, LDH shows an increase in count while, lymphocyte shows a decreased count. Serologic diagnosis samples collected from naso-oropharyngeal tract or from faecal matter or blood are also done. Chest PA view, radiography, ultra-sonography, tomo-graphy of the chest and lung areas can also be done to examine if there is any abnormal formation.

3 Corona Cure

The appropriate cure for the Covid-19 virus has not exactly been developed, but, different symptomatic treatments are given to the patients to survive the virus. The patients are shifted to isolated wards in hospitals so that the droplets of virus do not fall out and do not contaminate, further.

Zhai et al. maintained in their paper about the different forms of treatment of the patients which include giving anti-viral agents, treatment through the medicines chloroquine and hydroxychloroquine, providing antibodies, giving doses of corticosteroids, plasma transfer and the usage of vaccine, which is, however, under the process of the stages of development [7].

3.1 Treatment

The basic Covid-19 treatment includes the kind of treatment meted out for SARS or MERS. Anti-viral agent Lopinavir (LPV) for SARS and remdesivir for Ebola virus are used as novice. Lopinavir and ritonavir are to be given twice a day to the patients. Even, arbidol, ribavirin, interferon, alpha-1b are also effective. Tocilizumab, recognisable for diseases like rheumatoid, juvenile and giant cell arthritis, has also proved itself in Italy as an effective therapy [5].

Sanders et al. talk about chloroquine and hydroxychloroquine as valuable medicines which can cure chronic diseases of inflammation and malaria by the process of restricting the entry of the virus into the cells [8].

Even, corticosteroids are helpful to control inflammation of lungs which can cause acute respiratory distress syndrome (ARDS) [8]. They are used only in severe cases. Shen et al. conducted a test on five number of patients who were at a critical stage of Covid-19 infection. The patients ranging between thirty-six and sixty-five years of age were on ventilation. They were given plasma transfusion treatment. Very soon, the body temperature decreased among four patients and the 'viral load' results became negative, and, gradually, the patients became normal [9].

3.2 Vaccine: The Ray of Hope

Vaccines are liable to mark a control on the infectious virus. Bharat Biotech is in the process of developing a safe vaccine candidate, Covaxin, which will create antibodies and increase human immunity [10]. Perappan and Koshy noted that trials are conducted to see if the vaccines produce any side effect and if not the vaccine might reach the public in the next year [10]. Nevertheless, Oxford has developed a new vaccine candidate to give "double protection" for Covid-19, which is to be manufactured by Serum Institute of India and Astrazeneca [11].

4 Covid-19 Pandemic in India

4.1 Cataclysm

The Covid-19 predicament in India has given rise to an upsurge of around 45,720 cases per day as per 23rd July, 2020 report and 49,931 cases as per 27th July, 2020 report (Fig. 1).

Table 2 and the diagrammatic representation are showing the data of the number of cases of 13th July in India. 13th July marked the total number of Covid-19 inflicted patients to be 878,254; where, active cases were 301,610; 553,470 of them got cured and 23,174 casualties have happened (Fig. 1).

Table 3 and the diagrammatic representation are showing the data of the number of Covid-19 inflicted people of the data of 23rd July in India. There were total 1,238,635 positive cases among whom 426,167 them were active patients; 782,606 became well, whereas, 29,861 deaths happened (Fig. 2).

Table 4 and diagrammatic representation reveals the data of Covid-19 cases available as of 27th July, in India. There is a total of 1,435,453 cases, where, 485,114 of them were active patients. 917,568 of them got discharged. 32,771 of them have died (Fig. 3).

As of now, India is in the third position in regard to the number of active Covid-19 cases in the world. The topmost country is U.S., the second one is Brazil. Table 5 will be worth explainable (Fig. 4).

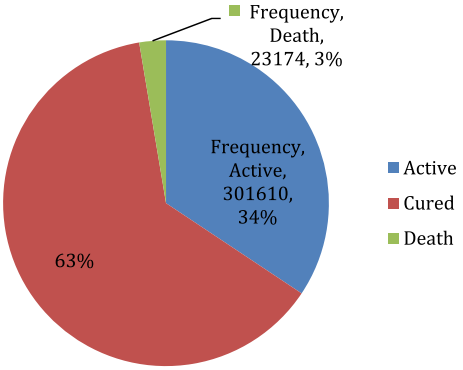

Fig. 1 Covid-19 cases as per 13th July, 2020 report (*Source* www.mohfw.gov.in) [12]

Table 2 Covid-19 cases as per 13th July, 2020 report

Cases	Number	Percentage
Active	301,610	34.34
Cured	553,470	63.02
Death	23,174	2.64
Total	878,254	100

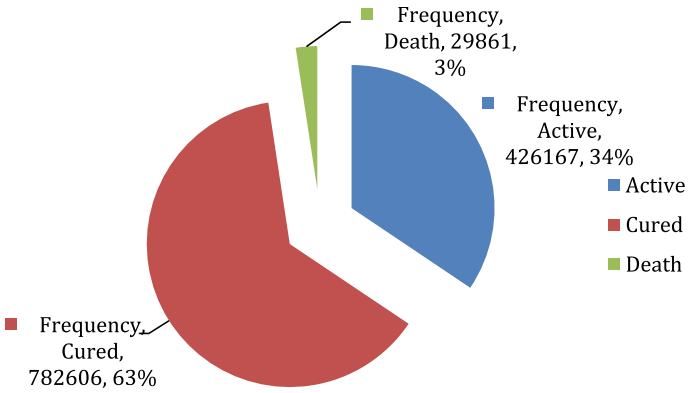

Fig. 2 Covid-19 cases as per 23rd July, 2020 report (*Source* Health Ministry Data) [12]

Table 3 Covid-19 cases as per 23rd July, 2020 report

Cases	Number	Percentage
Active	426,167	34.41
Cured	782,606	63.18
Death	29,861	2.41
Total	1,238,635	100

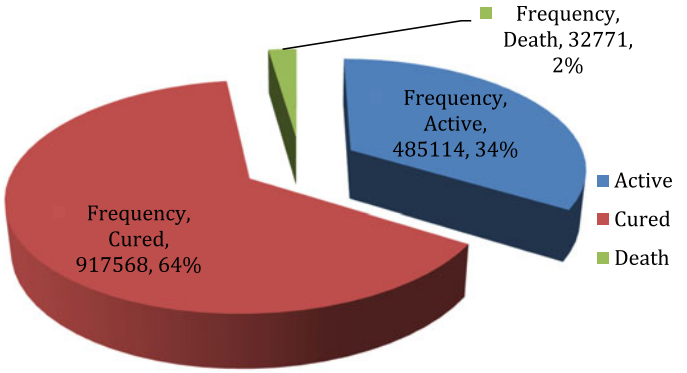

Fig. 3 Covid-19 cases as per 27th July, 2020 report (*Source* The Quint, https://www.thgequint.com) [13]

Table 4 Covid-19 cases as per 27th July, 2020 report

Cases	Number	Percentage
Active	485,114	33.8
Cured	917,568	63.92
Death	32,771	2.28
Total	1,435,453	100

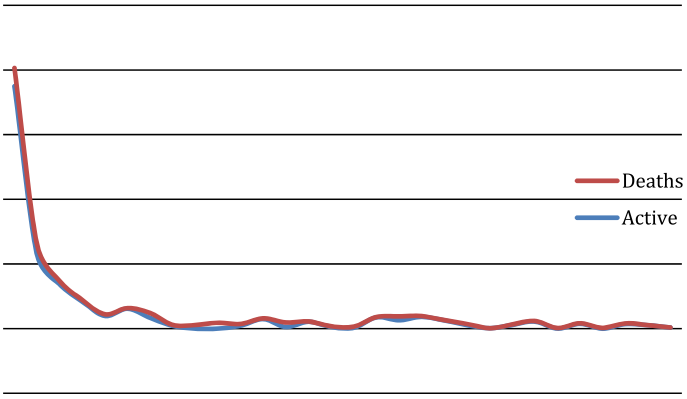

Fig. 4 Worldwide ranking of covid-19 infected countries (*Source* World data: worldometers.info: India data mohfw.gov.in; retrieved from https://www.cnbctv18.com) [12]

The table and the diagrams mentioned the serial list of the countries in accordance to their total cases of Covid-19 cases. USA has the highest number of cases with 3,695,025 total cases. Brazil is in the second with 2,014,738 cases, India, the third, with 1,003,832 cases, Russia has 752,797 cases, Peru has 341,586 cases, South Africa has 324,221 cases, Mexico has 324,041 cases, Chile has 323,698 cases, Spain has 305,935 cases, UK has 292,552 cases, Iran has 267,061 cases, Pakistan has 257,914 cases, Italy has 243,736 cases, Saudi Arabia has 243,238 cases, Turkey has 216,873 cases, Germany has 201,836 cases, Bangladesh has 196,323 cases, France has 173,838 cases, Colombia has 173,206 cases, Argentina has 114,783 cases, Canada has 109,264 cases, Qatar has 105,477 cases, Iraq has 86,148 cases, Egypt has 85,771 cases, China has 83,622 cases, Indonesia has 81,668 cases, Sweden has 76,877 cases, Ecuador has 71,365 cases, Kazakhstan has 66,895 cases and Belarus has 65,623 cases (Fig. 4).

This data is in accordance to 17th July of 2020

It is worth mentioning that at present (July, 2020) India is witnessing an increase in community transmission of the coronavirus in many parts of the country. Many places are undergoing a rapid spread of the infection among people without showing any signs of travel history. India is, however, facing the tally with a fighting spirit (Table 6).

The above information is in accordance to the data as per 17th July, 2020. It is revealed that Maharashtra has the highest number of Covid-19 cases with 284,281 persons infected [12].

Table 5 World-wide ranking in covid-19 cases as per 17th July, 2020 report

Country	Active	Deaths	Total
USA	1,874,274	141,118	3,695,025
Brazil	571,141	76,822	2,014,738
India	342,473	25,602	1,003,832
Russia	209,168	11,937	752,797
Peru	97,977	12,615	341,586
South Africa	153,961	4669	324,221
Mexico	83,003	37,574	324,041
Chile	21,107	7290	323,698
Spain	NA	28,416	305,935
UK	NA	45,119	292,552
Iran	22,845	13,608	267,061
Pakistan	73,751	5426	257,914
Italy	12,473	35,017	243,736
Saudi Arabia	53,246	2370	243,238
Turkey	12,613	5440	216,873
Germany	6279	9157	201,836
Bangladesh	86,864	2496	196,323
France	64,664	30,138	173,838
Colombia	91,013	6029	173,206
Argentina	63,551	2112	114,783
Canada	27,601	8827	109,264
Qatar	3157	152	105,477
Iraq	28,310	3522	86,148
Egypt	54,960	4120	85,771
China	251	4634	83,622
Indonesia	37,450	3873	81,668
Sweden	NA	5593	76,877
Ecuador	34,898	5207	71,365
Kazakhstan	26,264	375	66,895
Belarus	8223	485	65,623

Source World data: worldometers.info; India data mohfw.gov.in; retrieved from https://www.cnbctv18.com

4.2 History

India's beginning of Covid-19 pandemic journey can be traced back to 30th January, 2020. The first patient was detected in Kerala and then, some cases were among the tourists who came to visit India. The Sikh festival and the Tablighi Jamaat were

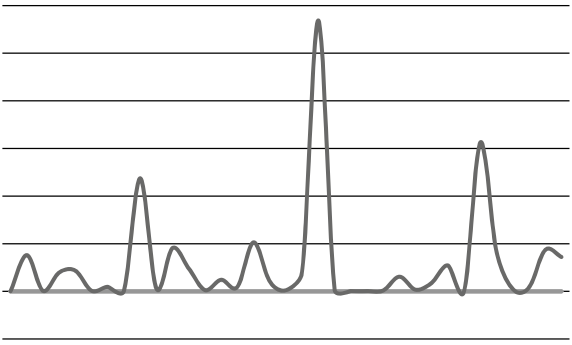

Fig. 5 State-wise total covid-19 cases [12]

regarded as the milestone for this pandemic journey in India. The virus began to spread in the Metropolitan cities. Dharavi, the largest slum area became the centre point of virus infected Mumbai. Celebrity Kanika Kapoor with her travel history, further, spread the virus because of her negligence. Gradually, the virus spread rapidly in the whole of India.

4.3 Initiatives

Narendra Modi, the Prime Minister of India, came in live telecasts and delivered speeches on different issues of the pandemic.

The Government announced Janata Curfew for a day to make the people accustomed to the pandemic issue.

The Government announced complete lockdown in India to limit the spread of the virus. Later, the unlock 1.0 phase began where the country was divided into three zones—red, orange and green, depending on the severity of the Covid-19 cases. The Covid-19 suspected areas are kept as containment zones. Aarogya Setu app can now be downloaded in android phones which show the Covid-19 cases of our nearby place. Helpline numbers of medical team can be dialed anytime if any susceptible symptom of Covid-19 is felt in one's body.

4.4 Creating History

India has created history even during this national crisis. Narendra Modi requested the citizens to bang bells or thaalis at 5 pm without violating social distancing rules. Even on his urge, the whole of India lighted diyas and torches together at a particular time to unite together during this crisis.

Table 6 State-wise alphabetical covid-19 cases as per 17th July, 2020 report

States and union territories	Active	Cured	Deaths	Total
Andaman and Nicobar Island	47	133	0	180
Andhra Pradesh	18,159	19,393	492	38,044
Arunachal Pradesh	387	153	3	543
Assam	6818	12,888	48	19,754
Bihar	7549	14,018	197	21,764
Chandigarh	164	476	11	651
Chattisgarh	1260	3451	21	4732
Dadra and Nagar Haveli	179	371	2	552
Delhi	17,407	97,693	3545	118,645
Goa	1272	1817	19	3108
Gujarat	11,289	32,103	2089	45,481
Haryana	5495	18,185	322	24,002
Himachal Pradesh	382	984	11	1377
Jammu and Kashmir	5488	6446	222	12,156
Jharkhand	2069	2513	42	4624
Karnataka	30,661	19,729	1032	51,422
Kerala	5376	4862	37	10,275
Ladakh	176	970	1	1147
Madhya Pradesh	5562	14,127	689	20,378
Maharashtra	114,947	158,140	11,194	284,281
Manipur	635	1129	0	1764
Meghalaya	309	66	2	377
Mizoram	112	160	0	272
Nagaland	525	391	0	916
Odisha	4436	10,877	79	15,392
Puducherry	774	947	22	1743
Punjab	2587	6277	230	9094
Rajasthan	6666	19,970	538	27,174
Sikkim	155	88	0	243
Tamil Nadu	46,717	107,416	2236	156,369
Telangana	13,327	27,295	396	41,018
Tripura	676	1604	3	2283
Uttarakhand	937	2995	50	3982
Uttar Pradesh	15,720	26,675	1046	43,441
West Bengal	13,679	21,415	1023	36,117

Source Ministry of health and family welfare, Govt. of India; retrieved from https://www.cnbctv18.com

5 Socio-Economic Impact of Covid-19 in India

According to Merriam-Webster Dictionary, impact means the impression exerted on something by some other thing [14]. In a nutshell, impact means the effect caused by any means or any situation which can be both, positive or negative.

The Covid-19 crisis has also exerted a kind of impact in India in, both, social and economic arena.

5.1 Social Impact

The lockdown has increased the usage of internet; especially the social media sites have gained immense usage during the pandemic time. Twitter and facebook are used throughout with people tweeting on different issues and posting memes or write-outs in facebook. People are fighting together virtually for the controversial Sushant Singh Rajput suicide case through Hashtag Justice for Sushant Singh Rajput, to acquire permission for CBI probe into the incident. Even, in facebook app people are spending their lockdown times either talking about burning issues, playing ludos or posting about the making of Dalgona coffee at home or accepting different online challenges like the Saree Challenge. This sharing made Korea's Dalgona coffee famous allover India. Even, the social media sites proved helpful in spreading awareness among people about the Covid-19; its precaution or about the active cases of the locality. Excessive dependence on social media during the free time increased contacts with different people. It helped in making new friends and recovering contacts with the old ones.

People got a free outlet for the dormant passion that they had in their hearts. Some began playing guitars, some began music, some dancing; while, some put their hands in painting. Extra-curricular activities increased with the family members playing indoor games sitting together. The bonding of family grew stronger which was, however, somehow lost in our busy cosmopolitan life.

The pandemic time proved to be a boon for the researchers to stay at home and conduct their research with active participation. The reading habit of students, also, increased to an extent. Even, the online classes taken for the students encouraged digital learning. But, the education of students is hampered a lot. Without going to schools, colleges and universities, the disciplined life and education is suffering to a great level.

Due to social isolation, the geriatric and the children are suffering mental hardships. They cannot come out of their home as they are more prone to the virus and they are showing mood swings for that. Lovers cannot meet or get intimate to each other. Even, people of younger of middle generations have acquired depression and co-morbid disorders. Roy et al. conducted an online survey on 662 respondents to study as to how much people are suffering from anxiety. Their study showed that approximately eighty percent of the respondents should be given clinical sessions

as majority of them has acquired insomnia in the fear of getting infected by Covid-19 [15]. Sood wrote about the psychological impact that can inflict the psyche of the people and cause trauma, panic attacks or change in behaviour which can be minimised by giving counseling to the tensed people by suggesting them to meditate [16].

A new kind of 'corona phobia' has engulfed the minds of people. People look at every individual with suspecting eyes. This is becoming like an 'obsessive compulsive disorder'. The fear of corona has made the neighbours turn indifferent. Javadekar and Kannur in their article talked about how the neighbours do not let doctors or other medical professionals to come to their own homes in the fear of getting contaminated [17]. This shows the savage attitude, which is the result of 'corona phobia'.

Constant staying at home has caused obesity in some. Even, some people with illness other than Covid-19 are finding it difficult to go to doctors or hospitals for treatment. Suicide cases have, also, risen out of financial problems or because of depression and loneliness. The controversial Sushant Singh Rajput suicide case, the tiktok star Siya Kakkar's suicide or suicide caused by one of Sushant's fan or other students; or businessmen who have fallen in debt because of financial loss. Even, some corona patients are also found to make suicide attempts because of the 'corona phobia'.

Religious festivals and other celebrations have come to a halt due to the decorum of social distancing. The celebration of Eid and the celebration of the entire 'Ramzan month' was done in a simple manner. Even, the pious Ratha Yatra of Jagannath temple, Puri was kept low profile. The Ambubachi celebration of Kamakhya temple, where thousands of people flock to get special power and blessings from Goddess Kamakhya was restricted. Even, marriage parties, birthday celebrations, get-togethers, night-outs are totally stopped. Although, now, the parents can get their daughters married off at a low budget.

The ozone layer depletion has diminished and the Ganga and the Yamuna rivers are now experiencing much purity. This is a positive aspect for the society as water and environment is a society's basic exponent.

Death can come anytime. But, the last rites of the dead receive less people to take part in the mourning in fear of the virus culmination. Even, the dead bodies of the Covid-19 patients are not given to their families because this can spread the virus. This is leaving some sort of repentance or regret for not being able to perform the last rites; and this emotional turbulence might last throughout a person's life.

Films are not released in theatres. Television soaps have stopped their shooting. Thus, the channels broadcast old serials for the viewers. *Ramayana* and *Mahabharata* have special place in the heart of people and to watch these serials, again, made the audience nostalgic. Religion indulged deep in the hearts of the people. People are also been heard discussing Indian mythologies and their own view-points over telephonic conversations. Thus, religious feeling has hiked.

Agarwal and Sharma discussed the social impact from the gender perspective. They noted that women are vulnerable to higher risk of domestic violence, abuse, and exploitation with the increase in their work-load [18]. Even, women tend to suffer from the virus because of lack of self-care. They discussed about how the increase

in the selling of pregnancy kits, condoms, contraceptives can point out the sexual atrocities on women during the social isolation [18]. Rise in alcoholism in men is curbing the physical and mental decorum of the women [18].

5.2 Economic Impact

Whenever a country faces any kind of national crisis, the first and foremost impact of the same, falls upon the economic condition of the country. The Covid-19 pandemic led India towards a lockdown of the nation for a long time. This lockdown resulted towards a heavy loss of capital. It has also negative impact on the GDP growth. However, in terms of sensex, India has shown a huge rise since a decade. The three offspring of GDP viz. "consumption, investment and external trade" is vulnerable to the impact of the Covid-19 crisis in the economic sector [19].

The economic slowdown led the banks to curb their loan interests of different schemes. Companies like Aditya Birla Group, Tata restricted their works. There has occurred a toll in the revenue income of the government. The revenues earned through alcohol, travel, tourism, pan masala encountered a huge loss [20]. Due to the virus scare, there arose a decline in the selling of alcohol. Travel and tourism are considered as an important source of earning revenue by the government of India. Many tourists visit India to enjoy the scenic beauty. People visit monumental places like The Taj Mahal, The Hawa Mahal, The Golden Temple and many other places. But, due to the restrictions imposed on international and national travels, India has to incur a great loss [21].

Regarding e-commerce, companies began to focus on the selling of essential ingredients. Their service, however, extended, as people feel it better to buy goods online than to go out themselves.

Supply chain has been restricted. This has harmed the farmers and the daily wage earners. Even, the domestic helps, vendor sellers have lost their source of income. People do not keep the domestic helps anymore, and do their household chores themselves in fear of becoming Covid-19 positive. As such, the domestic workers are losing their source of income. People no longer eat fast foods or bur things from vendor stalls. Even, people have restricted their visit to parlours, salons, gyms. This has inflicted the income of a certain group of people. Unemployment has increased. The employed ones are losing their jobs with no fresh recruitments.

There is a price hike in petrol, diesel, vegetables like potatoes, carrots, fruits. People are finding it hard to maintain a healthy diet by buying costly food stuff.

Bollywood, Tollywood, the producers and directors of Television serials are facing a lot of downfall in their economic earning because of the pandemic. Bollywood has to release different big budget films on Netflix or Amazon Prime. Even, the Television serials are unable to shoot on the daily basis. Many Television stars have, even, talked of being unpaid in this time of crisis.

India's relation with China has soared. India has stopped China's different apps to function in India, and also, the export import business has declined leading to disrupt

in the economic activity of India. India is highly dependent on China's electronic imports, machinery, organic chemicals, indigo medicines and mainly the mobile phone [19] and as a result, it will certainly have an effect on Indian economy.

Indian government is spending huge on the treatment of the virus patients including the cost of ventilators, sanitisers, kit, gloves, medicines. Even, the government of India has announced the "Atmanirbhar Abhiyan" in which there will be a package of twenty lakh crores to enhance the poor mass to become self-dependent. The country has even made ration (rice, dal, sugar) available to the people below poverty line at free of cost.

6 Conclusion

The dire strait of Covid-19 pandemic has endangered the normal life of India. The corona disaster has not only stirred the lifestyle of the people, but, it has also wrecked the social and economic growth of India. This extremity can be swiped out only with the successful arrival of anti-viral vaccine and the necessary distribution of the same among every Indian. Apart from following social distancing and taking other precautionary measures; maintaining patience, unity and solidarity can help us to stand strong against the crisis with positive vibes.

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Mathematical Modeling on Double Quarantine Process in the Spread and Stability of COVID-19

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Abstract The transmission of COVID-19 and its stability are formulated in this chapter. In the susceptible class, pre-quarantine technique is implemented for the individuals who have come from the disease prone areas. Similarly, in the infected compartment post-quarantine technique is implemented. As per the principle of mathematical epidemiology, the rate of change of each compartment is expressed in the form of ordinary differential equations (ODEs). The differential equations are nonlinear in nature which are associated with the disease parameters, namely rate of natural death, death due to COVID-19, immigrant's influx, spread, and recovery. The basic reproduction number is found mathematically which is useful to address the local and global stability. Fourth-order Runge–Kutta numerical technique is used to solve the ODEs. The trend of spread and stability of disease are visualized in the graphs with the help of MATLAB software. The stability analysis at disease-free state and endemic state is discussed. The global stability is explained on the basis of Lyapunov function. Routh–Hurwitz theorem is applied for the behavior of eigenvalues to discuss the disease-free equilibrium. Our investigation shows that the disease will be stable for a long run due to the quarantine process.

Keywords Eigenvalues · Endemic · Equilibrium · Quarantine · Stability · Virus

Mathematics Subject Classification (2010) 92D25 · 92D30 · 93D20 · 93D05

Nomenclature

A	Rate of immigrants and newborn.
S	Susceptible population.

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I	Infected population.
Q_{H}	Home isolation population, i.e., pre-quarantine class.
Q_1	Quarantine populations in hospitals, i.e., post-quarantine class.
R	Recovered population.
β	Rate of infection from infective class to susceptible class.
θ	Rate at which the susceptible population goes to home isolation.
ω	Probability at which the home isolation population becomes susceptible.
p	Probability at which the infected population goes to hospital quarantine for treatment.
γ	Rate at which the population becomes recovered after hospitalities.
d_1	Natural death rate.
d_2	Rate of death due to COVID-19.
d_3	Rate of death due to preexisting diseases that are vulnerable to COVID-19.
R_0	Basic reproduction number of pre-quarantine class.
R_{0H}	Basic reproduction number after hospitalities.

1 Introduction

The infectious diseases due to different viruses are more harmful, quickly spread, and uncontrolled than the infectious diseases due to other microorganisms. Human being has been mostly affected by these diseases. The information from different sources witnessed that these diseases were originated from birds, animals, men, and changing climates, etc. Most of these diseases are seasonal in the remote areas, hilly areas, and unhygienic environment in the underdeveloped countries of the African continent but in December 2019, the present pandemic disease COVID-19 was detected in China (Wuhan city). The disease spread all over the world by the end of March 2020 and severely affected many developed countries like USA, Italy, France, Spain, England, Germany, and Belgium. As per WHO's (WORLD HEALTH ORGANIZATION) [1] report from December 31th, 2019, to May 7th, 2020, the disease has spread over 212 countries and 2 international conveyances with number of confirmed cases is more than 38 lakhs, at least 2.6 lakhs death and more than 13 lakhs recovered persons have been reported around the world. The disease shows the sign of enhancing body temperature, sneezing, itching of throat, and difficulty in breathing in most of the cases; also in some cases, headache and diarrhea are reported. COVID-19 spreads due to social contact, sneezing openly, and cough of infected individuals. On average of 5–6 days is the latency period; however, it can take up to 14 days. The time period of recovery from the COVID-19 is nearly about 2 weeks in case of mild cases, but it takes up to 3–6 weeks in case of critical patients. COVID-19 affects the people of different age groups; however, the older people and people with preexisting diseases like asthma, heart problem, kidney disease, and hypertension are appeared to be more vulnerable. Presently, the disease is not resistant to any vaccine or medicine. Based on the patient's clinical conditions, some prescribed antibiotics are given to the patients

and ICU or ventilator is used for treatment as per the guideline of WHO. Many persons are cured or recovered from the disease. The disease can be stabilized through home quarantine, washing hands with soap several times about 20 s, sanitization, not touching the face, eyes, ear, and wearing mask. So, it is a big challenge for researchers of different fields including the mathematicians to investigate, analyze, and interpret the available data including the model parameters to ascertain the cause, effect, and control of the disease. Mathematical models embedded with the rate of transmission, recovery rate, rate of quarantine, and death rate with stability analysis will be helpful for the researchers of other fields to investigate in a realistic way. Before beginning the study of a new problem, it is required to acquaint with the background of other infectious disease and research development of current pandemic disease COVID-19. Therefore, after reviewing, analyzing, and interpreting many past and present research articles on the epidemiology, we have cited the following limited numbers of research articles in this paper due to the paucity of article length.

Trawicki [2] has discussed the vaccination of newborn, temporary immunity, vital dynamics having unequal rate of birth, and death with help of SEIRS epidemic modeling. Also both local and global stability analyses are performed. The model has not included the quarantine class. Lu et al. [3] have explained predator–prey model using nonlinear perturbation method to investigate the SIS and SIQR epidemic models. Lyapunov function is established for stability analysis using an ergodic stationary point. Analysis of stability in biological system using differential equations is presented by Bastin [4]. Bin et al. [5] had modeled the disease that demonstrates the intervention of post-lockdown which mitigates COVID-19. Xu et al. [6] have explained the evolution of the disease in China and obtained the risk of human transmission by modeling its spike protein. Pederson et al. [7] have explained how the undetected patients quantify the number of infected cases and effort of containment to control the disease in Italy. Li et al. [8] have proposed COVID-19 mathematical model on the transmission of the disease and suggested the controlling measure that can die out the disease. Xia et al. [9] have proved the local stability using the delayed SEIQ epidemic model. Juhen et al. [10] examined the transmission of the disease from December 2019 to January 2020 in Wuhan and suggested the effective measures to stabilize the disease. Rothe et al. [11] have shown how the asymptomatic contact individuals of Germany have transmitted the disease and impact of severity on infection. Zhang et al. [12] have studied the SEIQR mathematical model and explained the stability analysis. Zhang et al. [13] have studied the different mathematical models of influenza viruses and discussed their stability analysis using vaccination. Lan et al. [14] studied the SIQR model with stochastic persistence of diseases using Markov semigroup theory. Erdem et al. [15] have observed the oscillatory behavior of SIQR model with imperfect quarantine that resembles the stability of the disease in South Korea and China. Ma et al. [16] have used the comparison principle to discuss the global stability of SIR model. Rao et al. [17] explored the individual mobility of the disease using the SEIVR model. They have explained that the disease is transmitted indirectly through the environment. Their numerical simulation exhibits global stability and equilibrium. Malik et al. [18] have proposed a fractional-order system of the disease for finding parameters using numerical method. They found that the

result agrees with real data. Zhang et al. [19] have searched hidden parameters that impact the resurgence of SARS-COV-2 pandemic due to the removal of lockdown and other social measures. Baba et al. [20] have presented a model for the stability of disease outbreaks using optimal control function. They established the Lyapunov function for global stability which shows the disease reduces drastically. Oliveria et al. [21] have conducted the study of disease in the city of TeraSanya, Brazil. They used descriptive bibliometric process to ascertain the scientific production through bibliometric analysis on new COVID-19. Savas et al. [22] have compared the estimated and real cases of COVID-19. They also calculated death cases for 45 days in Turkey. Their mathematical model suggested that the estimation accuracy was 90% and 66% for 30 days and 45 days of COVID-19 death, respectively. Gracia et al. [23] have studied the dynamics of coronavirus in the advanced and emerging country to forecast economic growth. They found the economic growth is expected to recover for the long term. Rauta et al. [24] have investigated the SIQRS model to study the transmission of disease and the impact of isolation. They found the disease can be controlled for a long run due to quarantine. Paul et al. [25] have investigated COVID-19 using simple population dynamics based on incidence–fitness relationships. They found the corona case peaked to the top using the concept of geometry. Murray [26] has forecasted the effect of death during the transmission of the disease in the first phase in USA and European economic areas in hospitals. He interpreted that the load on the health system in the USA was beyond the current capacity. He claimed that to mitigate the overload in hospital system and to prevent the death, it is required to enhance the medical facilities.

The literature survey reveals that mathematical modeling of the transmission of COVID-19 due to coronavirus is inadequate and has many limitations. Many researchers have investigated different epidemic models on COVID-19 but ignored some important parameters. So the research done till date is insufficient for this emerging pandemic disease. A few studies have been reported about the double quarantine effect using limited parameters but the stability analysis is hardly discussed. Therefore, the model developed in this research paper to investigate the pre- and post-quarantine effect on the transmission and stability of COVID-19 is new. The novelty of the proposed model in this chapter is original, and the discussion of both local and global stabilities will explore the new dimensions in the study of COVID-19.

2 Mathematical Model

Let $S(t), I(t), Q_{\mathrm{h}}(t), Q_1(t)$, and $R(t)$ are five disjoint classes whose union is total population N over the time t. The rate at which the average number of sufficient contacts by a single infected person per day from infected compartment (I) to susceptible compartment (S) is β. So the mean number of susceptible those who got infected by an infected individual is βS. Thus, the whole infected class is βSI which is called incidence (mass action law). The immigrants, newborn, and suspected individuals having travel history are kept in home quarantine class Q_{h} at rate 'θ' for 14 days.

Therefore, the mean rate of home quarantine class is $\frac{1}{\theta}$. The probability of recovery due to Q_{h} is taken as 'ω' that enters into susceptible class, and probability of showing symptoms of COVID-19 in Q_{h} is $(1-\omega)$ that enters into infected compartment. Again, the probability of infected showing mild symptoms to be kept in government quarantine Q_1 for another 14 days during the treatment is taken as 'p' and the probability of recovered as $(1-p)$. Let 'γ' is the recovery rate from post-quarantine class to recovery class. The natural mortality rate in each class is given by d_1 with an average life time is $\frac{1}{d_1}$. The disease-induced death rate in infected class I and post-quarantine class Q_1 are taken at the rate d_2 and d_3, respectively. Thus, the rate of mortality due to disease induced and natural reason in infected compartment is (d_1+d_2) with average mortality rate is $\frac{1}{d_1+d_2}$. Similarly, the average mortality rate of post-quarantine class Q_1 is $\frac{1}{d_1+d_3}$. It is assumed that everyone has equal chance of infection. Every compartment is dynamic in nature with respect to time. Based on these assumptions, the flow diagram and modeling of COVID-19 are given in Fig. 1.

The net flow of quantity that enters into each compartment is taken as positive and exit from each compartment is taken as negative. Thus, as per Kermack–McKendrick model [27–29] the size of each class can be expressed in terms of the following differential equations

$$\begin{aligned}
\frac{\mathrm{d}S}{\mathrm{d}t} &= A+\omega Q_{\mathrm{H}}-(\beta SI+d_1S+\theta S)\\
\frac{\mathrm{d}Q_{\mathrm{H}}}{\mathrm{d}t} &= \theta S-(1-\omega+\omega+d_1)Q_{\mathrm{H}}=\theta S-(1+d_1)Q_{\mathrm{H}}\\
\frac{\mathrm{d}I}{\mathrm{d}t} &= \beta SI+(1-\omega)Q_{\mathrm{H}}-(p+d_1+d_2+(1-p))I\\
&= \beta SI+(1-\omega)Q_{\mathrm{H}}-(d_1+d_2+1)I\\
\frac{\mathrm{d}Q_1}{\mathrm{d}t} &= pI-(d_1+d_3+\gamma)Q_1
\end{aligned}$$

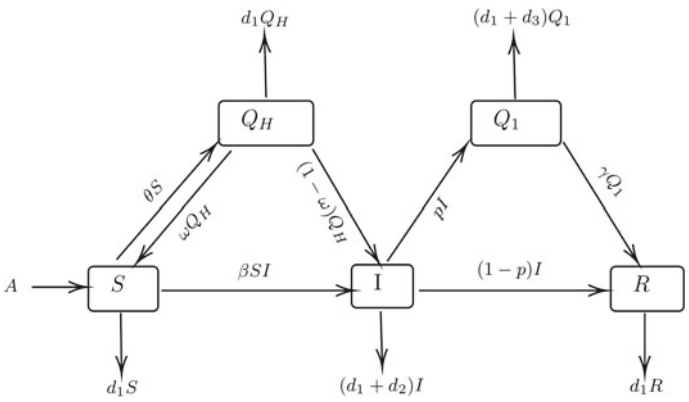

Fig. 1 Schematic diagram of the model

$$\frac{\mathrm{d}R}{\mathrm{d}t} = (1-p)I + \gamma Q_1 - d_1 R \tag{1}$$

With initial conditions $S(0) > 0$, $Q_H(0) > 0$, $I(0) > 0$, $Q_1(0) > 0$, $R(0) > 0$. Since these systems of nonlinear differential equations are not in standard forms to solve analytically, so fourth-order Runge–Kutta numerical method is used for solving them with help of MATLAB software. Simulated results are interpreted graphically with detailed discussions.

2.1 Model Analysis

In epidemiology, the basic reproduction number (R_o) is an important indicator that denotes the contagiousness of infectious agents. It is the average number of maximum contacts by an infected individual to the whole susceptible class during the infection period. Therefore, R_o = number of new cases arising per day from one infective × average days of infection. It is a threshold quantity. When a number of infectious is entered into a population, then the number of infected individuals in population will either decrease to zero or increase to a peak. These threshold conditions are characterized by the basic reproductive number in epidemiology. With initial infective is small and initial susceptible is large so that $\beta S > 1$, then I increase to a peak and S decrease eventually. In this case, $R_o > 1$, i.e., the disease spread for longer time leads to epidemic and the system is said to be unstable. When $R_o < 1$, i.e., infected replaces itself with less than one new infective, then the disease will extinct and the system is said to be stable. If $R_o = 1$, then an infected person produces only one new case of the diseases, so disease will not grow significantly but the disease persists. It is the critical value of the threshold quantity. So, the analysis and interpretation of R_0 are important for the study of COVID-19 and due to adoption of two quarantine process (pre- and post-quarantine) in this paper, we derived two basic reproduction numbers from the model.

The region in which solutions for the model are uniformly bounded is defined as $\Omega \in R_+^5 = \{(S, Q_H, I, Q_1, R) \in R_+^5, S \geq 0, Q_H \geq 0, I \geq 0, Q_1 \geq 0, R \geq 0$. The interactive functions of system (1) are continuously differentiable, so the solution of the system (1) exist and unique. The uniform boundedness of solutions for the system (1) having nonnegative initial conditions is discussed using different theorems.

Theorem 1 *Solutions of the system* (1) *which are defined in* R_+^5 *are uniformly bounded.*

Proof Let $S(t)$, $Q_{\mathrm{H}}(t)$, $I(t)$, $Q_1(t)$, and $R(t)$ be any solution of system (1) having nonnegative initial condition $S(0)$, $Q_{\mathrm{H}}(0)$, $I(0)$, $Q_1(0)$ and $R(0)$.

Therefore, $N(t) = S(t) + Q_{\mathrm{H}}(t) + I(t) + Q_1(t) + R(t)$.
Then, $\frac{\mathrm{d}N}{\mathrm{d}t} = \frac{\mathrm{d}S}{\mathrm{d}t} + \frac{\mathrm{d}Q_{\mathrm{H}}}{\mathrm{d}t} + \frac{\mathrm{d}I}{\mathrm{d}t} + \frac{\mathrm{d}Q_1}{\mathrm{d}t} + \frac{\mathrm{d}R}{\mathrm{d}t}$ so, $\frac{\mathrm{d}N}{\mathrm{d}t} = A - d_1 N - d_2 I - d_3 Q_1$.

In the dearth of any infection, N becomes $\frac{A}{d_1}$, i.e., as $t \to \infty$, then $N \to \frac{A}{d_1}$. Hence, the solution of the system (1) is well posed and confined in the region $\Omega = \left\{(S, Q_{\mathrm{H}}, I, Q_1, R) \in R_+^5 : N \leq \frac{A}{d_1}\right\}$.

2.2 Calculation of R_0 from SIQ_1R Model

The SIQ_1R compartmental equations are

$$\begin{aligned}
\frac{\mathrm{d}S}{\mathrm{d}t} &= A + \omega Q_{\mathrm{H}} - (\beta SI + d_1 S + \theta S) \\
\frac{\mathrm{d}I}{\mathrm{d}t} &= \beta SI + (1-\omega) Q_{\mathrm{H}} - (d_1 + d_2 + 1) \\
\frac{\mathrm{d}Q_1}{\mathrm{d}t} &= PI - (d_1 + d_3 + \gamma) Q_1 \\
\frac{\mathrm{d}R}{\mathrm{d}t} &= (1-P)I + \gamma Q_1 - d_1 R
\end{aligned} \tag{2}$$

This model is also positive and closed invariant.

R_0 = the largest positive eigenvalue of the matrix FV^{-1}, where F is called infection matrix and V is called transformation matrix between the compartments.

Linearization of Eq. (2) by taking two classes I and Q_1, we have

$$R_0 = \frac{\beta S_0}{(d_1 + d_2 + 1)}$$

2.3 Stability Analysis for SIQ_1R Model

For steady state of Eq. (2), we take

$$\begin{aligned}
A + \omega Q_{\mathrm{H}} - (\beta SI + d_1 S + \theta S) &= 0 \\
\beta SI + (1-\omega) Q_{\mathrm{H}} - (d_1 + d_2 + 1) I &= 0 \\
PI - (d_1 + d_3 + \gamma) Q_1 &= 0 \\
(1-P)I + \gamma Q_1 - d_1 R &= 0
\end{aligned} \tag{3}$$

There are two equilibrium points, which can be obtained from Eq. (3).

Equilibrium point for disease-free state = $(S_0, 0, 0, 0)$.

Equilibrium point for endemic state = $\left(\mathrm{S}^*, I^*, Q_1^*, R^*\right)$.

Theorem 2 *If $R_0 < 1$, then the system at disease-free equilibrium of (3)is stable; otherwise, it is unstable when $R_0 > 1$.*

Proof Linearization of model at equilibrium point for disease-free state in (3),

$$J_{\mathrm{DFE}}(S_0, 0, 0, 0) = \begin{pmatrix} -(d_1+\theta) & -\beta S_0 & 0 & 0 \\ 0 & \beta S_0 - (d_1+d_2+1) & 0 & 0 \\ 0 & P & -(d_1+d_3+\gamma) & 0 \\ 0 & (1-P) & \gamma & -d_1 \end{pmatrix}$$

By calculating the eigenvalues, we have

$$\begin{aligned} \lambda_1 &= -(d_1+\theta) \\ \lambda_2 &= -(d_1+d_3+\gamma) \\ \lambda_3 &= -d_1 \\ \lambda_4 &= \beta S_0 - (d_1+d_2+1) \end{aligned}$$

For $\frac{\beta S_0}{d_1+d_2+1} < 1$, i.e., $R_0 < 1$ so the eigenvalues are negative.

Hence, the equilibrium is asymptotically stable locally for the disease-free state as per Routh–Hurwitz principle of stability.

Theorem 3 *The system at endemic equilibrium point $\left(S^*, I^*, Q_1^*, R^*\right)$of (3) is locally stable when $R_0 > 1$.*

Proof At the endemic equilibrium point

$$J_{EE}\left(S^*, I^*, Q_1^*, R^*\right) = \begin{pmatrix} -\left(\beta I^* + d_1 + \theta\right) & -\beta S^* & 0 & 0 \\ \beta I^* & \beta S^* - (d_1+d_2+1) & 0 & 0 \\ 0 & P & -(d_1+d_3+\gamma) & 0 \\ 0 & (1-P) & \gamma & -d_1 \end{pmatrix}$$

The eigenvalues are

$$\begin{aligned} \lambda_1 &= -(d_1+d_3+\gamma) \\ \lambda_2 &= -d_1 \end{aligned}$$

Remaining eigenvalues can be derived from the equation $a\lambda^2 + b\lambda + c = 0$, where

$$\begin{aligned} a &= \left(\beta I^* + 2d_1 + d_2 + 1 + \theta - \beta S^*\right) > 0 \\ b &= \left(d_1 + d_2 + 1 - \beta S^*\right)\left(\beta I^* + d_1 + \theta\right) > 0 \end{aligned}$$

Since $a > 0, b > 0$, we have $ab > 0$ Hence, by Routh–Hurwitz condition the system is stable.

Theorem 4 *The diseases-free equilibrium $E_0 = \left(\frac{A}{\mu}, 0, 0\right)$of (3) is globally asymptotically stable if $R_0 < 1$.*

Proof Consider a Lyapunov function.

$$\begin{aligned} Z &= I \\ \frac{\mathrm{d}Z}{\mathrm{d}t} &= \frac{\mathrm{d}I}{\mathrm{d}t} \\ &= \beta SI - (d_1 + d_2 + 1) \\ &= -(1 + d_1 + d_2)I\left(1 - \frac{\beta S}{1 + d_1 + d_2}\right) \\ &= -(1 + d_1 + d_2)I(1 - R_0) \end{aligned}$$

If $R_0 < 1$ then $\frac{\mathrm{d}Z}{\mathrm{d}t_1} < 1$. It is observed that $\frac{\mathrm{d}Z}{\mathrm{d}t_1} = 0$ if $I = 0$.

Therefore, equilibrium of disease-free state is asymptotically stable globally for $R_0 < 1$ as per LaSalle Lyapunov theory.

2.4 Calculation of Basic Reproduction Number from $SQ_{\mathrm{H}}IQ_1R$ Model

$R_{0\mathrm{H}}$ for $SQ_{\mathrm{H}}IQ_1R$ is calculated as;

$$R_{0\mathrm{H}} = \frac{\beta S_0(1 - \omega)}{(\omega + d_1)(d_1 + d_2 + 1)} = \frac{R_0(1 - \omega)}{(\omega + d_1)}$$

Success or failure of COVID-19 virus attack depends on basic reproduction number $R_{0\mathrm{H}}$. If $R_{0\mathrm{H}} \geq 1$ the COVID-19-based epidemic will carry on, i.e., the disease becomes endemic, but, if $R_{0\mathrm{H}} < 1$, then COVID-19-based epidemic will die out; i.e., the infected population will slowly become zero.

2.5 Stability Analysis for $SQ_{\mathrm{H}}IQ_1R$ Model

The disease-free equilibrium point of systems of Eq. (1) is $(S_0, 0, 0, 0)$, and the equilibrium for endemic state is as follows:

$$\begin{aligned} S^* &= \frac{(1 - \omega)A + \omega(1 - R_0)I^*}{(1 - \omega)(d_1 + \beta I^* + \theta)} \\ Q_{\mathrm{H}}^* &= \frac{(1 - R_0)I^*}{(1 - \omega)} \\ Q_1^* &= \frac{PI^*}{(d_1 + d_3 + \gamma)} \end{aligned}$$

$$R^* = \frac{\left[(1-P)(d_1+d_3+\gamma)+\gamma P\right]I^*}{(d_1+d_3+\gamma)}$$

Theorem 5 *The system is locally stable if* $R_{0\mathrm{H}} < 1$*, and it is unstable if* $R_{0\mathrm{H}} > 1$*at diseases-free equilibrium point* $(S_0, 0, 0, 0)$*of the system of* Eq. (1).

Proof Linearization of the system of differential Eq. (1) and the characteristic equation is

$$J_{\mathrm{DFE}} = (S_0, 0, 0, 0) = \begin{pmatrix} -(d_1+\theta) & \omega & -\beta S_0 & 0 \\ \theta & -(1+d_1) & 0 & 0 \\ 0 & (1-\omega) & \beta S_0 - (d_1+d_2+1) & 0 \\ 0 & 0 & P & -(d_1+d_3+\gamma) \end{pmatrix}$$

One of the roots of the characteristic equation is $\lambda_1 = -(d_1+d_3+\gamma)$.
Other three roots are obtained from the equation $\lambda^3 + A\lambda^2 + B\lambda + C = 0$ where

$$\begin{aligned} A &= 3d_1 + d_2 + \gamma + \theta + 1 \\ B &= (d_1+\theta)(d_1+1) + (\gamma+d_3+d_1)(\theta+d_1) \\ &\quad + (\gamma+d_3+d_1)(1+d_1+d_2)(1-R_0) - \omega\theta \\ C &= (1+d_1)(d_1+d_3+\gamma)(d_1+\theta) \\ &\quad - \omega P\beta S_0 - \omega\theta(d_1+d_3+\gamma) \end{aligned}$$

Since $AB > C$, so by Routh–Hurwitz condition for stability, it is locally stable.

Theorem 6 *At the endemic equilibrium point* $\Omega^*\left(S^*, Q_{\mathrm{H}}^*, I^*, Q_1^*, R^*\right)$*,the system is locally stable when* $R_{0\mathrm{H}} > 1$.

Proof At the endemic equilibrium, $\Omega^*\left(S^*, Q_{\mathrm{H}}^*, I^*, Q_1^*, R^*\right)$, the Jacobian matrix is

$$\begin{aligned} J_{\mathrm{EE}} &= \left(S^*, Q_H^*, I^*, Q_1^*, R^*\right) \\ &= \begin{pmatrix} -\left(\beta I^* + d_1 + \theta\right) & \omega & -\beta S^* & 0 & 0 \\ \theta & -(1+d_1) & 0 & 0 & 0 \\ \beta I^* & (1-\omega) & \beta S^* - (d_1+d_2+1) & 0 & 0 \\ 0 & 0 & P & -(d_1+d_3+\gamma) & 0 \\ 0 & 0 & (1-P) & \gamma & -d_1 \end{pmatrix} \end{aligned}$$

Here the two eigenvalues are

$$\begin{aligned} \lambda_1 &= -d_1 \\ \lambda_2 &= -(d_1+d_3+\gamma) \end{aligned}$$

And other three eigenvalues are determined from the equations $\lambda^3 + a_1\lambda^2 + a_2\lambda + a_3 = 0$, where

$$a_1 = 3d_1 + d_2 + \gamma + \theta + 1 + \beta I^*$$

$$a_2 = \big(d_1 + \beta I^* + \theta\big)\big(d_1 + d_2 + 1 - \beta S^*\big) + \big(d_1 + \beta I^* + \theta\big)(1 + d_1) + (1 + d_1)\big(d_1 + d_2 + 1 - \beta S^*\big) + \beta^2 S^* I^* - \omega\theta$$

$$a_3 = \omega\theta(1 + d_1 + d_2)(R_0 - 1) + \big(d_1 + \beta I^* + \theta\big)\big(1 + d_1 + d_2 - \beta S^*\big)(d_1 + 1) - (1 + d_1)\beta^2 S^* I^* + \beta S^*(1 - \omega)$$

Since $a_1 a_2 - a_3 > 0$, hence by Routh–Hurwitz condition, the system is locally stable for endemic equilibrium.

2.6 Analysis of Global Stability at Endemic Equilibrium

Endemic equilibrium points with death due to infection satisfy the system (1) for $SQ_{\mathrm{H}}IQ_1R$ model. The analysis for global stability can be dealt through geometric approaches. According to the approach, if the differential equation $\frac{\mathrm{dx}}{\mathrm{d}t} = f(x)$, $x(t) = x_0$ for the mapping $f: \phi \subset R^n \to R^n$, where φ is an open connected set, then the equilibrium point $\overline{x} \in \phi$ which agree the following conditions.

1. ϕ is simply connected.
2. $\exists$ is a compact absorbing subset $K \in \phi$.
3. $\overline{x}$ is the only equilibrium point in ϕ that is globally stable if it satisfies the Bendixson criteria $\overline{q}_2 = \limsup_{n\to\infty} \sup_{x_0 \in K} q < 0$, where $q = \int_0^t \psi(Z(x(s, x_0)))\mathrm{d}s$ and $Z = M_f M^{-1} + M\frac{\partial J}{\partial x}M^{-1}$,$M$ is matrix-valued function which satisfy the condition $Z = M_f M^{-1} + M\frac{\partial J}{\partial x}M^{-1} \le 0$ on K. Further, the fourth-order second compounded Jacobian matrix is $J^{[2]} = \frac{\partial f^{[2]}}{\partial x}$.

Theorem 7 *The system is globally stable at unique endemic equilibrium points* $\Omega^*\big(S^*, I^*, Q_{\mathrm{H}}^*, Q_1^*\big)$ *in the interior of* Ω^*, *when* $R_0 > 1$.

Proof From the system of Eq. (1), the Jacobian matrix, leaving the recovered population is

$$J = \begin{pmatrix} -(d_1 + \beta I + \theta) & -\beta S & \omega & 0 \\ \beta I & \beta S - (d_1 + d_2 + 1) & (1 - \omega) & 0 \\ \theta & 0 & -(1 + d_1) & 0 \\ 0 & P & 0 & -(d_1 + d_3 + \gamma) \end{pmatrix}$$

Again,

$$J^{[2]} = \begin{pmatrix} \beta S - (2d_1 + d_2 + 1 + \theta + \beta I) & (1 - \omega) & 0 \\ 0 & -(2d_1 + \beta I + \theta + 1) & 0 \\ P & 0 & -(d_1 + \beta I + \theta + d_2 + d_3 + \gamma) \\ -\theta & \beta I & 0 \\ 0 & 0 & \beta I \\ 0 & 0 & \theta \end{pmatrix}$$

$$\begin{pmatrix}
-\omega & 0 & 0 \\
-\beta S & 0 & 0 \\
0 & \omega & \\
\beta S-(2d_1+d_2+2) & -\beta S & 0 \\
P & \beta S-(2d_1+d_2+1+\gamma+d_3) & (1-\omega) \\
-P & 0 & -(d_1+d_2+d_3+\gamma+1)
\end{pmatrix}$$

where $J^{[2]}$ is the second compound additive Jacobian matrix.

To get the matrix Z in Bendixson criteria, the diagonal matrix M is defined as. $M = \text{diag}\left(1, \frac{I}{Q_\text{H}}, \frac{I}{Q_\text{H}}, \frac{I}{Q_\text{H}}, \frac{I}{Q_\text{H}}, \frac{I}{Q_\text{H}}\right)$ and vector field f of the system is defined as

$$M_f M^{-1} = \text{diag}\left(0, \left(\frac{I}{Q_\text{H}}\right)_f \frac{I}{Q_\text{H}}, \left(\frac{I}{Q_\text{H}}\right)_f \frac{I}{Q_\text{H}}, \left(\frac{I}{Q_\text{H}}\right)_f \frac{I}{Q_\text{H}}, \left(\frac{I}{Q_\text{H}}\right)_f \frac{I}{Q_\text{H}}, \left(\frac{I}{Q_\text{H}}\right)_f \frac{I}{Q_\text{H}}\right)$$

Hence, we obtain the block matrix $Z = M_f M^{-1} + M J^{[2]} M = \begin{pmatrix} Z_{11} Z_{12} \\ Z_{21} Z_{22} \end{pmatrix}$ where

$$Z_{11} = \beta S - (2d_1 + d_2 + 1 + \theta + \beta I)$$

$$Z_{12} = \begin{pmatrix} (1-\omega)\frac{Q_\text{H}}{I} & 0 & -\omega\frac{Q_\text{H}}{I} & 0 & 0 \end{pmatrix}$$

$$Z_{21} = \begin{pmatrix} 0 \\ P\frac{I}{Q_\text{H}} \\ -\theta\frac{I}{Q_\text{H}} \\ 0 \\ 0 \end{pmatrix}$$

$$Z_{22} = \begin{pmatrix}
(-(2d_1+\beta I+\theta+1)+X) & 0 & -\beta S \\
0 & (-(d_1+\beta I+\theta+d_2+d_3+\gamma)+X) & 0 \\
\beta I & 0 & (\beta S-(2d_1+d_2+2)+X) \\
0 & \beta I & P \\
0 & \theta & -P
\end{pmatrix}$$

$$\begin{pmatrix}
0 & 0 \\
-\beta S & \omega \\
0 & 0 \\
(\beta S-(2d_1+d_2+d_3+1+\gamma)+X) & (1-\omega) \\
0 & (-(d_1+d_2+\gamma+d_3+1)+X)
\end{pmatrix}$$

where $X = \frac{I'}{I} - \frac{Q'_\text{H}}{Q_\text{H}}$.

The Lozinski measure of matrix Z is estimated as $\psi(Z) \leq \sup\{g_1, g_2\}$, where g_1, g_2 are defined as

$$g_1 = \psi(Z_{11}) + |Z_{12}| = \beta S - (2d_1 + d_2 + 1 + \theta + \beta I) + (1-\omega)\frac{Q_\text{H}}{I} \leq \frac{I'}{I}$$

$$g_2 = \psi(Z_{22}) + |Z_{21}| = (\beta S - (2d_1 + d_2 + 2) + X) + P\frac{I}{Q_\text{H}} \leq \frac{I'}{I} - d_1$$

So, $\psi(Z) \leq \sup\{g_1, g_2\} \leq \frac{I'}{I} - d_1$. Hence, $\int_0^t \psi(Z)\text{d}t < \log I(t) - d_1 t$.

Finally, we have $\overline{q}_2 = \frac{\int_0^t \psi(Z)\mathrm{d}t}{t} < \frac{\log I(t)}{t} - d_1 < 0$, for all absorbing set Ω is bounded. Thus as per Li and Muldowney [30], Bendixson criteria is satisfied at endemic equilibrium for global stability.

3 Discussion of the Result

Our model is based on two unique approaches: Firstly, it is based on pre-quarantine of suspected immigrants and individuals having travel history. Secondly, the approach is based on post-quarantine of infected individuals. Two basic reproduction numbers R_0 and $R_{0\mathrm{H}}$ are derived. These two basic reproduction numbers collectively give the overall disease outbreak. The numerical simulation of the available data relevant to COVID-19 obtained from different sources is validated with analytical results with the help of MATLAB. The nonlinear ODEs are solved with the help of Runge–Kutta fourth-order numerical method. Graphical interpretation of numerical results is thoroughly discussed using different parameters. It is found that the interpretation of data agrees with the current phenomena of COVID-19 and results of existing literature. As per the relevant data of COVID-19 available from different sources (Govt. Websites of different countries, Media, WHO, etc.), we have assumed the whole population as one unit and the initial conditions are set as $S(0) = 0.82$, $Q_{\mathrm{H}}(0) = 0.03$, $I(0) = 0.12$, $Q_1(0) = 0.02$, $R(0) = 0.01$. The graphs are plotted by taking the appropriate values of different parameters associated with the model that are indicated in each figure.

Figures 2 and 3 represent the behavior of all compartments for $R_0 < 1$ and $R_0 > 1$, respectively when $A = 0$. Figure 2 indicates the disease-free equilibrium because susceptible class does not tend to zero level. Figure 3 indicates endemic equilibrium because the susceptible class tends to zero level. Due to the adoption of pre- and post-quarantine processes, the infection decreases that indicates the decline of infected line in both diagrams. Prior to the whole population being infected, the disease dies out that indicates the recovered line is higher but not approaches to zero. As infected individuals are isolated through quarantine, the disease does not spread.

Figures 4 and 5 interpret the effect of influx of newborn and immigrants (i.e. $A \neq 0$) on all compartments for $R_0 < 1$ and $R_0 > 1$, respectively. Because of the continuous influx of immigrants and newborns in susceptible class and due to double quarantine effect, the infective class approaches to zero level. So, the disease is stable after some days.

The phase diagram of susceptible verses infective is shown in Figs. 6 and 7 for $A = 0$ and $A \neq 0$, respectively. When S increased, infection reached to a peak but then decreased because of double quarantine effect and proper health care. The declined trend of infective graph indicates that the disease is toward the stable condition due to the enhanced recovery rate.

Figures 8 and 9 exhibit the phase portrait graph of infective verses recovery class. Due to pre-quarantine of susceptible class, entry of immigrants, newborn cases,

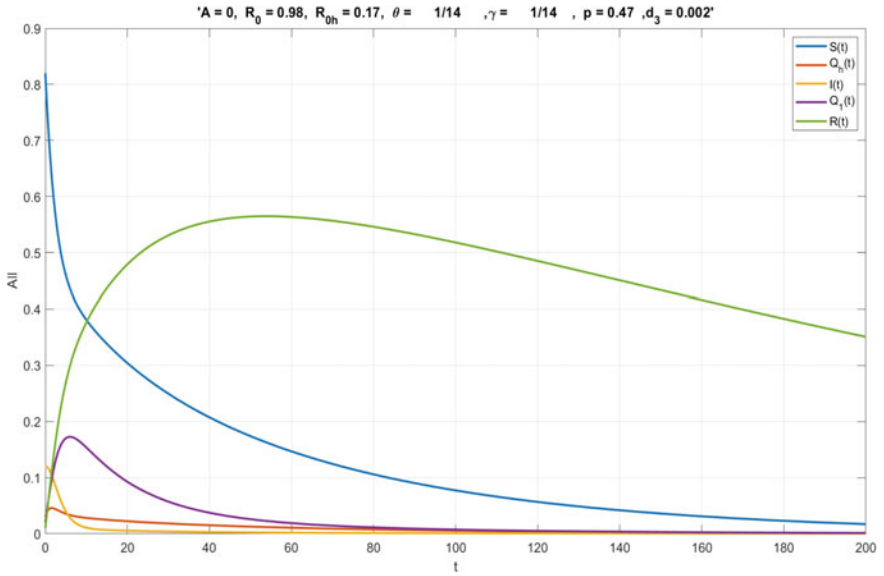

Fig. 2 $A = 0$, $R_0 = 0.98$, $R_{0\mathrm{h}} = 0.17$, $\theta = \frac{1}{14}$, $\gamma = \frac{1}{14}$, $p = 0.47$, $d_3 = 0.002$

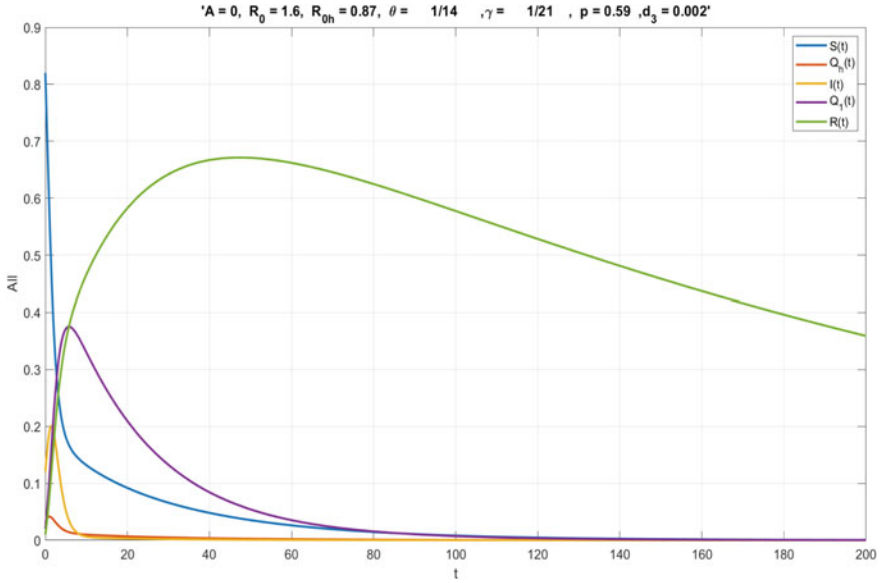

Fig. 3 $A = 0$, $R_0 = 1.6$, $R_{0\mathrm{h}} = 0.87$, $\theta = \frac{1}{14}$, $\gamma = \frac{1}{21}$, $p = 0.59$, $d_3 = 0.002$

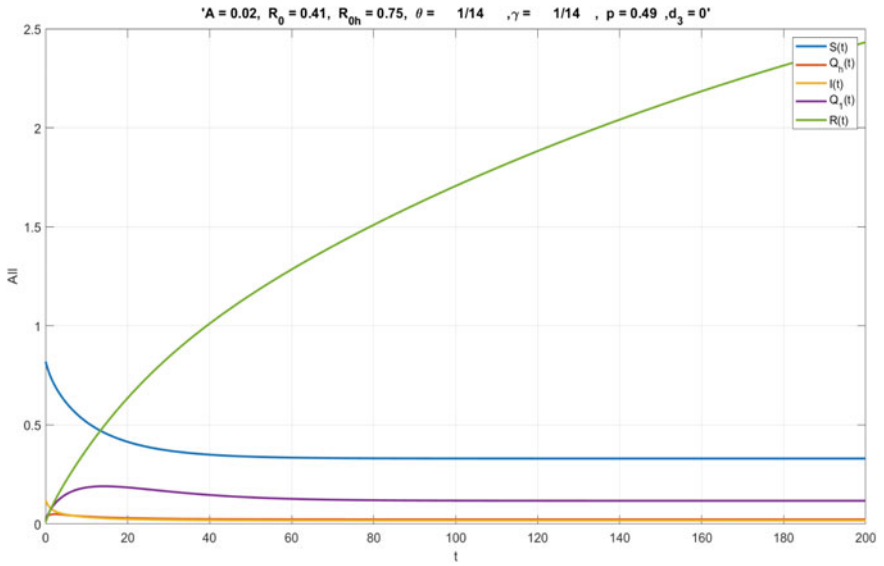

Fig. 4 $A = 0.02$, $R_0 = 0.41$, $R_{0\mathrm{h}} = 0.75$, $\theta = \frac{1}{14}$, $\gamma = \frac{1}{14}$, $p = 0.49$, $d_3 = 0$

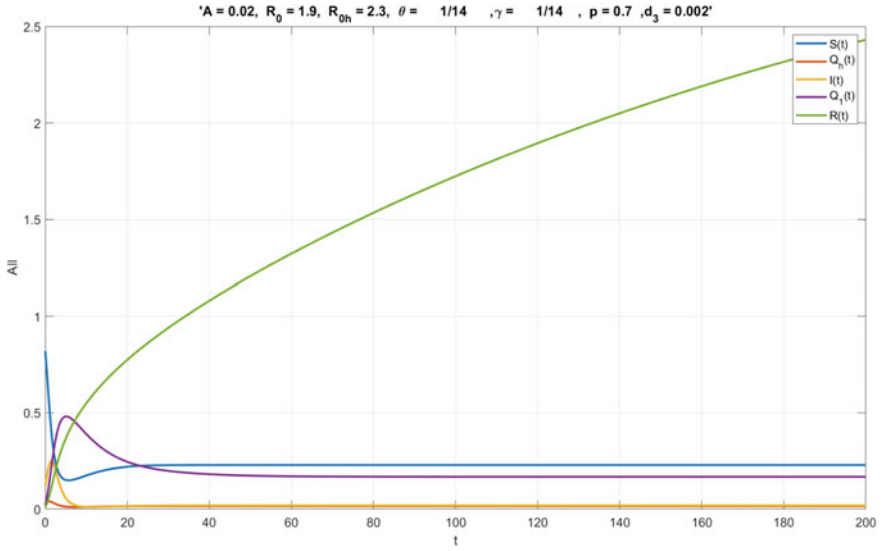

Fig. 5 $A = 0.02$, $R_0 = 1.9$, $R_{0\mathrm{h}} = 2.3$, $\theta = \frac{1}{14}$, $\gamma = \frac{1}{14}$, $p = 0.7$, $d_3 = 0.002$

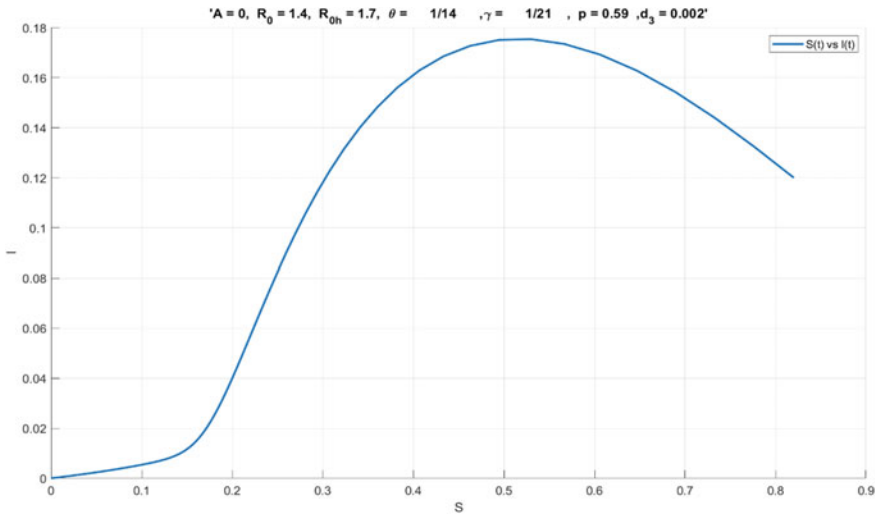

Fig. 6 $A = 0$, $R_0 = 1.4$, $R_{0\text{h}} = 1.7$, $\theta = \frac{1}{14}$, $\gamma = \frac{1}{21}$, $p = 0.59$, $d_3 = 0.002$

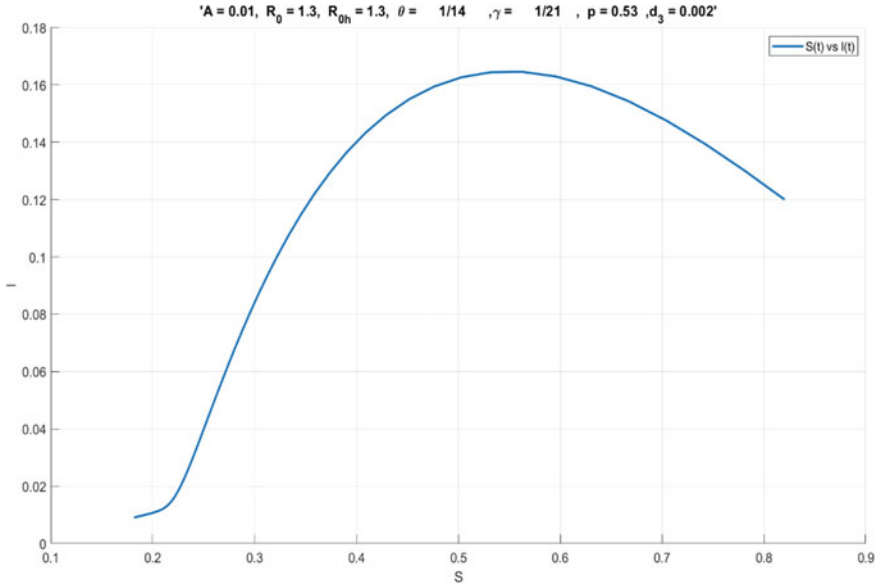

Fig. 7 $A = 0.01$, $R_0 = 1.3$, $R_{0\text{h}} = 1.3$, $\theta = \frac{1}{14}$, $\gamma = \frac{1}{21}$, $p = 0.53$, $d_3 = 0.002$

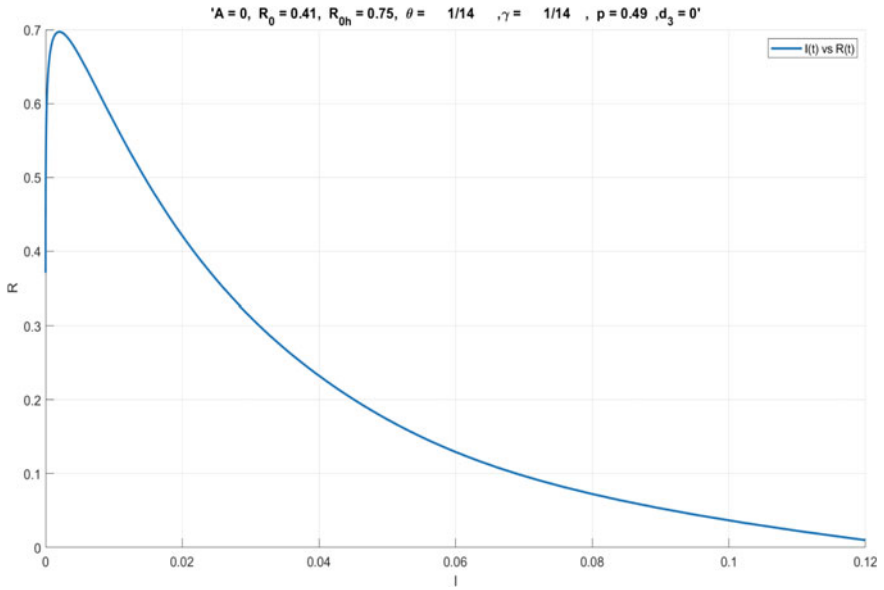

Fig. 8 $A = 0$, $R_0 = 0.41$, $R_{0\text{h}} = 0.75$, $\theta = \frac{1}{14}$, $\gamma = \frac{1}{14}$, $p = 0.49$, $d_3 = 0$

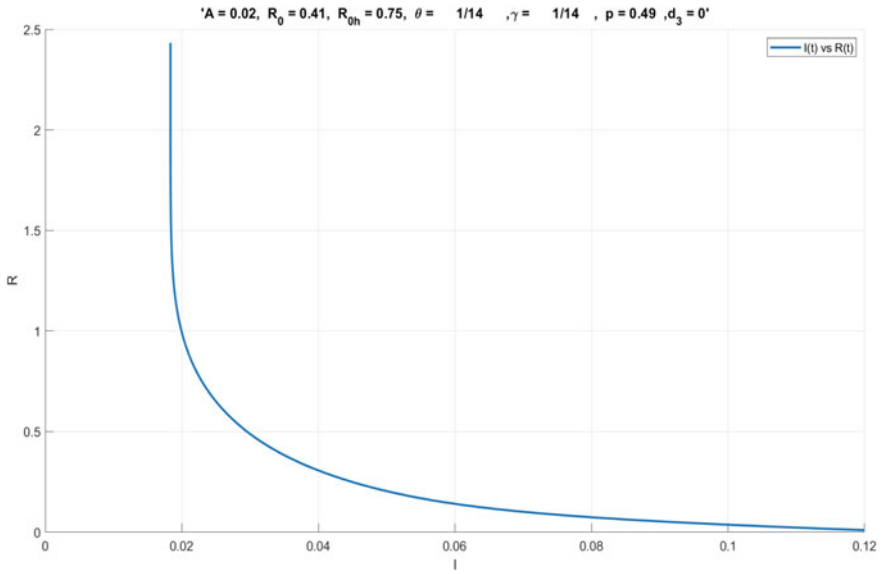

Fig. 9 $A = 0.02$, $R_0 = 0.41$, $R_{0\text{h}} = 0.75$, $\theta = \frac{1}{14}$, $\gamma = \frac{1}{14}$, $p = 0.49$, $d_3 = 0$

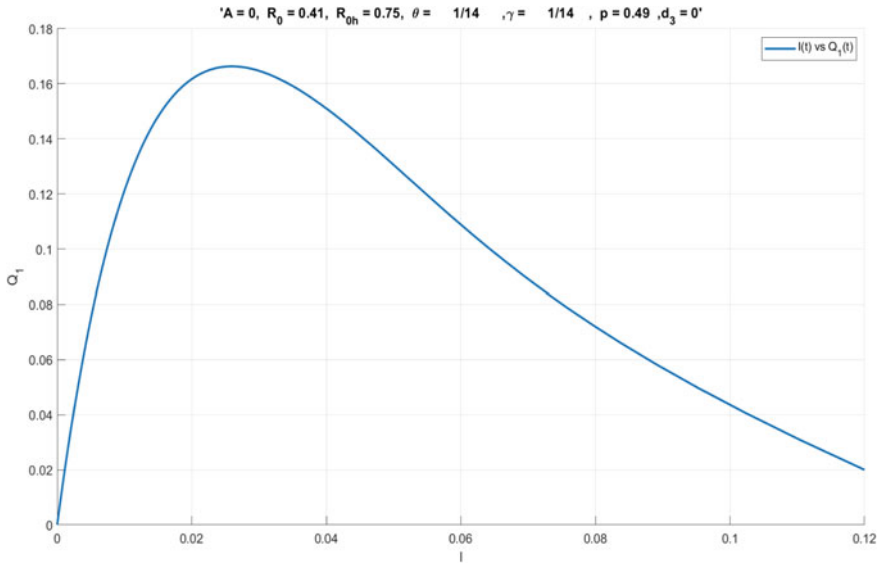

Fig. 10 $A = 0, R_0 = 0.41, R_{0\text{h}} = 0.75, \theta = \frac{1}{14}, \gamma = \frac{1}{14}, p = 0.49, d_3 = 0$

and post-quarantine of infective class, the recovered population enhanced first but decreased after certain period of time. So the growing number of invectives leads to an endemic in the absence of quarantine.

The phase diagram of quarantine verses infective is shown in Figs. 10 and 11 for $R_0 < 1$ when $A = 0$ and $A \neq 0$, respectively. With the increase of invectives in the quarantine class, the post-quarantine class increased initially and then decreased due to either the stability of disease or recovery of maximum number of individuals.

4 Conclusion

The research designed in this chapter is based on the formulation of the spread and control of the coronavirus disease-19. Here, a model is developed to investigate the effects of double quarantine process on the stability analysis. We conducted a detailed analysis of this model, devised the methodology, reviewed, analyzed, and discussed the result both analytically and numerically. Eigenvalues are derived from Jacobian matrix and equilibrium points (disease-free and endemic) are obtained. Analysis for both local and global stabilities is carried out with the help of existing theorems. The analytical and numerical results are well in agreement that validates the data. The graphical interpretation explores the real findings of the investigation. The finding of the investigation done in this paper indicates that the disease will be stable locally asymptotically for $R_0 < 1$. The finding of our research supports the speculations of the disease that would persist in human world for long term. Moreover, if the double

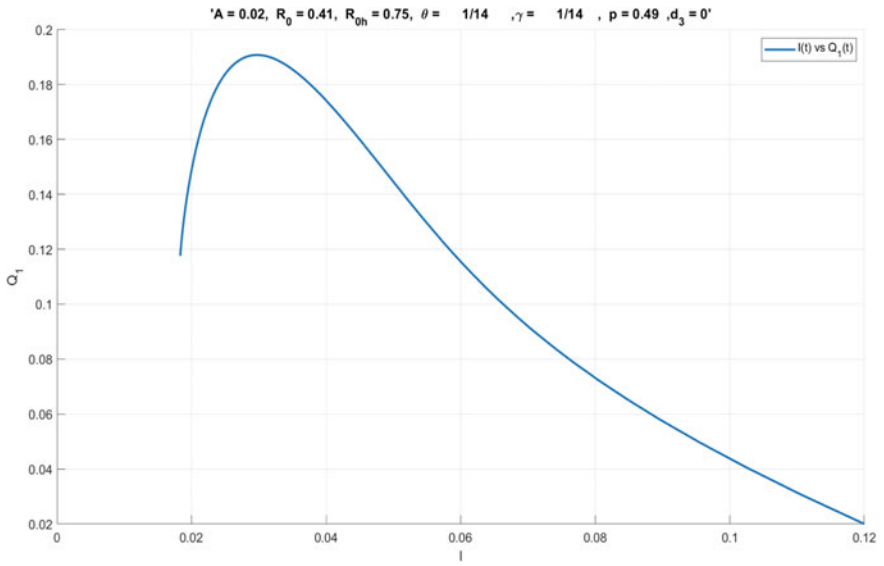

Fig. 11 $A = 0.02$, $R_0 = 0.41$, $R_{0h} = 0.75$, $\theta = \frac{1}{14}$, $\gamma = \frac{1}{14}$, $p = 0.49$, $d_3 = 0$

quarantine process at both susceptible and infected levels is effectively implemented and social distancing is strictly maintained with lockdown or containment, then the disease will be globally stable in a long term for $R_0 > 1$. More realistic models with detailed data or parameters like immunity, age structure, saturated incidence, and exposed compartment may be employed in future investigation to explore the analysis of COVID-19 outbreak.

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A Study and Novel AI/ML-Based Framework to Detect COVID-19 Virus Using Smartphone Embedded Sensors

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Abstract SARS-CoV-2 also known as COVID-19 is a novel corona virus which originated from China. Corona virus disease COVID-19 is the official name given by WHO is caused by SARS (Severe Acute Respiratory Syndrome) which have very mild symptoms in the beginning but slowly progress to failure of multiple organs followed by death. The emergency committee of WHO declared COVID-19 as a pandemic. The disease is spread from person-to-person and the spread is very fast making serious impacts on the lives of the people. CT scan and PCR (Polymerase Chain Reaction) are the tests for the diagnosis of COVID-19 virus in the human body. The symptoms of this disease are very common which include fever, breath shortness, dry cough and pain in the muscles. The solutions which are available currently have less accuracy, take longer time and are costly. In this paper, a framework is proposed based on smart phones and artificial intelligence. The benefits are increased productivity, reliability and availability of advanced infrastructure. There are various sensors embedded in the smart phones such as proximity sensor, light sensor, accelerometer, gyroscope and fingerprint sensors which have very fast processors and memory space making it easy to read the sensors and scan the CT images, the signal measurements in the sensors of the smart phones are read which scan the CT images for reliable diagnosis of the disease. The proposed framework is based on artificial intelligence, cloud network and machine learning.

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Keywords COVID-19 · Corona virus · Deep learning · Smartphones · Detection · Sensors

1 Introduction

An infectious and communicable disease named COVID-19 is a novel corona virus which originated from China. The virus is known as severe acute respiratory syndrome corona virus 2 abbreviated as SARS-CoV-2 and generally known as corona virus disease COVID-19. Its epicenter is in the Wuhan city of China. Many respiratory diseases are caused from this virus as confirmed by the World health Organization in December 2019. The symptoms include high fever, dry cough, sore throat and difficulty in breathing as this virus directly attacks lungs. This virus has now become pandemic and has already affected many parts of the world. On 11th March World Health organization (WHO) declared COVID-19 as a pandemic in their emergency committee. The disease is spread from person-to-person and the spread is very fast making serious impacts on the lives of the people. The old-aged humans are most vulnerable to COVID-19 as they have comparatively less immunity than the younger population [1]. The recovery chances therefore becomes somewhat less in the elderly population of the world. Many species of animals are also affected by COVID-19, but in humans it has spread to a larger extent making it as an emergency situation in the health sector. Firstly, the disease spread from animal-to-person in Wuhan city of China which is the epicenter of this disease [2]. The people of Wuhan ate sea food which was infected from COVID-19, thus spreading it from animal-to-person. Now, the virus is continuously spreading from person-to-person in a fast manner. Therefore, the persons having no contact with live animals also became the victim of COVID-19 due to person-to-person spread [3]. Corona virus disease (COVID-19 is the official name given by WHO) is caused by SARS (Severe Acute Respiratory Syndrome) which have very mild symptoms in the beginning but slowly progress to failure of multiple organs followed by death. The symptoms of this disease are very common which include fever, breath shortness, dry cough and pain in the muscles [4]. But there are many people out there in the population which do not show any kind of symptoms and thus the fatality rate is overestimated. All these symptoms slowly progress to other health problems [5]. The person-to-person spread of the virus is caused through the respiratory droplets when the person coughs or sneezes. The patients showing these symptoms need to treat urgently so that there is low chances of the community spread. The life of the virus on the contaminated surfaces is about 72 h. The symptoms start to reveal within average 5 day. CT scan and PCR (Polymerase Chain Reaction) are the tests for the diagnosis of COVID-19 virus in the human body [6]. The physical distance needs to be maintained to prevent the infection. The main organ affected by the COVID-19 virus is the lungs as the host cells accessed by the virus through zyme ACE2 are found abundantly in the lung cells. The gastrointestinal organs are also affected by this virus. People having MERS (Middle East Respiratory Syndrome) and SARS are mostly affected by this virus. NAT (Nucleic Acid Test) is also one of the

techniques to diagnose COVID-19 disease. The sequence of nucleic acid that may be present in the form of a virus causing infections in the blood. The most effective way to diagnose COVID-19 is CT scan as it detects the serious inflammation in the lungs despite other detection kits and techniques [7]. the medical system gets overloaded due to multiple CT scans as the number of patients and the suspected cases are increasing exponentially everyday which also causes frustration in the people. The other patients get cross infected due to all these problems and therefore the risk factor increases. The physicians and medical systems are thus overloaded due to increasing number of patients for the CT scan which is the main functional test for COVID-19 disease. The radiologists and the medical staff is far less than the patients [8]. Due to this, the detection of the disease is late causing serious health problems in the patients. The suspected persons are advised to go into the quarantine so that they do not contact other people and therefore cross spreading could be prevented to some extent. In Italy, only the serious cases are being treated due to shortage of ventilators and hospital beds and that too when Italy has the best medical health care properties in the world [9]. Since, the pandemic COVID-19 is showcasing the nightmares, the expectations from scientists and academicians from all over the world is increasing for their efficient and intelligent response for detection methods. Many smart and intelligent techniques for CT scan are being revealed and studied by the scientists taking in account the accuracy and speed with which the detection is being done. The most perfect diagnosis for COVID-19 is not yet discovered as both CT scan PCR test are individually not enough to detect the virus accurately in the lungs. The perfect lies in the combination of numerous methods of diagnosis. The medical kits for the diagnosis of the virus are quite costly and requires installation. The research for the quick detection kit is continuous all over the world by several scientists and the companies. After the disease has been declared pandemic by the WHO there is an urgent need to treat the symptomatic patients who show the probable symptoms of COVID-19 disease just to lessen the community spread through these careers. Since asymptotic patients cannot be treated and their numbers have been increasing, so the treatment of the disease play a vital role. The old drugs are being repositioned for the antiviral treatment of COVID-19. This is because there are certain factors to be taken care of such as the side effects if mixing drugs and the drug interactions since the proper vaccine is still under testing. An anti malarial drug called chloroquine has a very significant inhibitor effect on SARS-CoV-2 virus. The outcome of the drug clinically has given an effective result and clearance of virus through this drug has also been observed in many patients in China. The patients showing very mild symptoms such as cough and mild cold could be treated with 500 mg dose of chloroquine twice a day for about 10 days. This drug was not recommended for the patients showing symptoms of pneumonia [10].

The computational capabilities of the smart phones which are used in modern times is very powerful. They contain embedded sensors which enhance the capabilities of the smart phone. The information regarding daily activities can be easily sensed using smart phones. They even have the capability to capture the visual data with the help of several sensors embedded on the smart phones. The data from the suspected COVID-19 patients can be easily captured, collected and stored in the

smart phones. The CT images of the suspected patients could be easily scanned in the smart phones for the purpose of further research and analysis. The comparative analysis of the CT scan images fed in the smart phones can also be done leading to better detection of the virus. In this way the inflammation and the infection in the lungs can be monitored and analyzed with the help of CT scan images fed into the smart phones of the suspected COVID-19 patients [11]. The diagnosis of the corona virus disease officially called COVID-19 with the help of smart phone sensors and artificial intelligence (AI) is demonstrated in this paper. The framework presented in the paper provides a solution of low cost for dedicated smart phones used by the radiologists for the detection purpose. The people themselves can regularly monitor the infection in their lungs through the progressive CT scan images stored in their smart phones leading to early diagnosis of the disease. There are various sensors embedded in the smart phones such as proximity sensor, light sensor, accelerometer, gyroscope and fingerprint sensors which have very fast processors and memory space making it easy to read the sensors and scan the CT images, the signal measurements in the sensors of the smart phones are read which scan the CT images for reliable diagnosis of the disease. In this way the virus of the COVID-19 would be detected in a very short time as compared to the time taken by the radiologists to detect the virus. The development of the disease COVID-19 can be easily tracked and evaluated for treatment using this framework.

2 Smart Phones to Detect COVID-19

The pandemics or the infectious diseases which spread very quickly should be identified rapidly so that there is a proper and effective treatment to such diseases. But this process is very lengthy and complicated and large professional labs are needed to carry out the diagnosis of such pandemics. A diagnosis is received in hours and even days. More is the diagnosis time; more will be the delay in the treatment of patients since large time would spend in determining the virus. Therefore, a diagnostic system is being tested using the smart phone technology by various researchers all over the world. Smart phones integrate the cloud network with the chip device present in them [12]. This can help in detection of the disease in the initial stage even in the remote areas. The applications in the smart phones helps in the process of diagnosing and testing of the patients in a progressive manner. The sample of the patient is extracted using electromechanical sensors present in smart phones through a disposable cartridge. The temperature regulation of the device is done after loading the cartridge into the portable device so that there is proper amplification of the sample to the extent that the DNA can be identified and the whole process is about 30 min long. The microcontroller present in the smart phone transfers all the data of the patient to the smart phone app through Bluetooth. In case the result is positive a report detection along with the relevant data and location is sent to the cloud network which is then further displayed online. Figure 1 shows the samples of the patient tested o the cartridge. The results are then shown at the cloud network when the

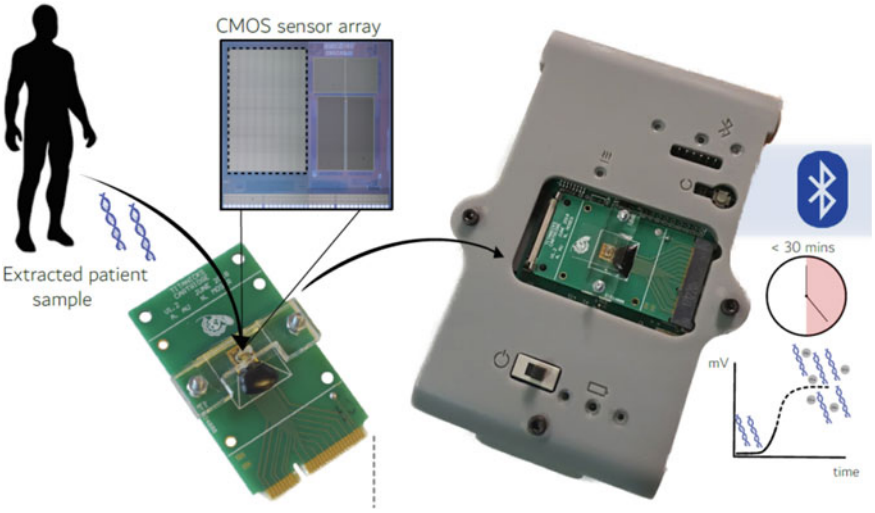

Fig. 1 Test results in cloud network through smart phone

smart phones receive the test via Bluetooth [13]. The device was successfully used for the detection of dengue virus in 2018 in Taiwan where the clinical samples which were stored were used for detection. The same was also used to detect the malaria causing parasite in 2019 in Kenya. Many researches have been done by the scholars in various countries to use smart phones as a medium to screen the patients infected from any virus, parasites or bacteria.

Talking about the virus which causes the infectious disease COVID-19 CoV-2 SARS the cartridge for storing the clinical samples can be developed once the sequence of the genetics is available publically. These could be then used to provide the tests very fast at an affordable price which can prove quite significant in detecting and monitoring the outbreak of this disease. Figure 2 shows the geo-tagged test results which are tracked on the cloud network.

3 Combating Covid-19 with Artificial Intelligence/Machine Learning

There has been a lot of development in the field of automation and artificial intelligence in the medical sector and has set revolution in this workspace. Half of the activities carried out have the ability to get automated and there is impact on all the other fields as well. Artificial Intelligence in health sector means that the patients who require care are diagnosed and treated using automated machines and process. Since it seems like the diagnosis and treatment are quite simple steps there are so many unseen background factors to be taken care of to properly treat the

Fig. 2 Cloud server displaying the geo-tagged test results

patient [14]. These unseen factors include: data collection through various modes such as calls and interviews; results are processed and analyzed; accurate and proper diagnosis id done using multiple sources of the data; the treatment methods which seem accurate are determined; the treatment method to be chosen is prepared and administered; continuous monitoring of the patient and the aftercare which includes follow-up appointments [15]. The time taken in the data entry by the workers was consuming a lot of time which could be rather engaged with patients. Therefore, the automation in the health care and medical fields should not go excessive but should go in a progressive manner so that the doctor–patient bond is still alive and strong. There is a need of sensible and deliberate identification of the areas where the time and effort of the workers is relaxed using automation [16]. The proper and effective balance should be maintained with the technology and artificial intelligence as well as with the trained judgments and strengths of the humans in medical professionals. The technology and automation play an incredible role in the field of medicines already such as digitization of medical records, scheduling online appointments, using of smartphones by the user for the nearest healthcare clinic and many more [17]. There are many examples of artificial intelligence which are already being used and deployed in the field of medicines. These include decision support system: this system gives the list of diagnosis possible for the given symptoms, information system for laboratories: the infections of the patients being hospitalized are detected, tracked and investigated in this system, robotic surgical systems: this system allows the doctors for precise surgeries with the help of magnetized vision and robotic arms which is

difficult using manual approach, therapy: artificial intelligence therapy is the online course for dealing with social anxiety, reduction in human error: the appointments could be booked by the patients through online apps present in the smart phones [18]. This also includes online consultation with the doctors for monitoring the routine and day to day health and provide test kits accordingly. Artificial intelligence in a way helps the medical sector to move towards better solutions, diagnosis and treatment in a precise manner. There is an increase in the productivity and efficiency other than reducing manual errors by incorporating artificial intelligence. Since artificial intelligence has come a long way in the medical field in combating the viruses it can surely be employed to combat the major pandemic of COVID-19 disease. Figure 3 shows the concept of incorporating artificial intelligence in the medical health care sectors.

The biomedical sensors on the patients imply that the smart phones carried by the patients progressively record and store the symptoms of the patient in the form of data. This data is then transferred to the cloud network through Bluetooth with the help of sensors present in the smart phone. The concerned healthcare community is also connected to the same cloud network. The data from the sensors present in smart phones and the mobile healthcare community is recorded on the cloud network. The clinical information system sends the information about the diagnosis and treatment of the disease to the clinical decision support system which is connected to the cloud network directly. This sends the data containing information about the possible diagnosis and treatment to the cloud. The doctors are also connected to the clinical decision support system to provide the accurate and efficient treatment to the patients. In this way the artificial intelligence plays a vital and significant role in the medical health care sector by reducing the efforts and time manually.

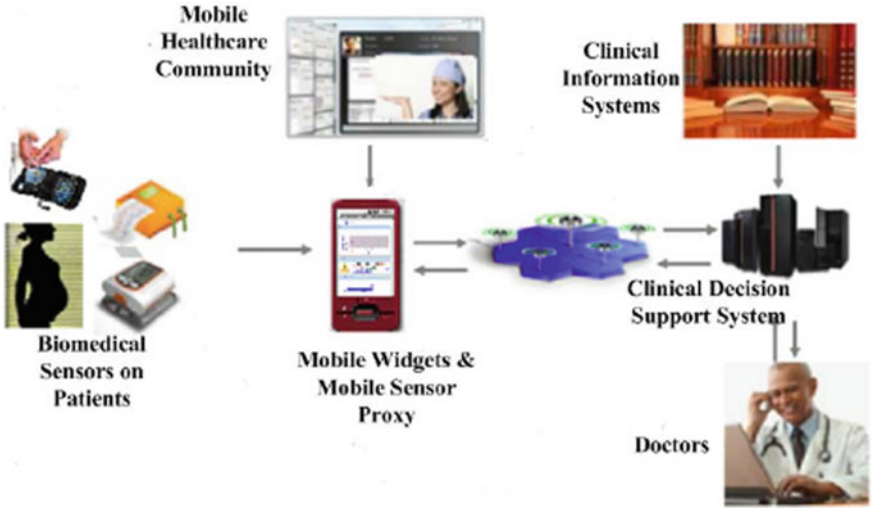

Fig. 3 Concept of artificial intelligence in medical sector

The critical thinking and intelligent behavior is simulated using with the use of computers which is comparable to a human resource. There are many kinds of artificial intelligent techniques which are employed in the health care sectors such as fuzzy expert systems, artificial neural networks, Bayesian networks and a lot more [19]. Since 2016 healthcare sectors have experienced biggest contribution of artificial intelligence research as compared to any other sectors. Artificial Intelligence in medicines has two types which are virtual and the other one is physical. The electronic systems for recording and the guidance in treatment based on the neural network systems come under the subtype of virtual category. The robots helping in surgeries come under the physical subtype. The basic idea is to correlate the clinical insights with the patterns already available in the information stored at the database [20]. Statistical methods are employed to establish the associations and patterns. Flowcharts and algorithms are being made by computers for database approach in the treatment and diagnosis of the patient. The flowchart includes the questionnaire by the physician to take a medical history record of the patient for providing a suitable diagnosis based on the complex systems presented by the patient. The cloud network which is machine-based stores and feeds large chunks of data which is considered later for the routine practice and treatment of the patient. But there are some limitations such as some symptoms are not identified by the machine which can be done physically by a doctor. The deep learning principle is utilized in the database approach in which there are repetitive algorithms for identifying certain symptoms and radiological images [21]. To combat the COVID-19 disease, artificial intelligence will play an essential role since it has already been utilized in many public health sectors and have created a large impact in every sector of medical field. This will help to diagnose the CoV-2 SARS virus in a short span of time so that the patient is quarantined timely and the community spread is reduced [22]. Figure 4 shows the flow diagram of employing artificial intelligence in the form of sensors in our medical departments.

4 Proposed Smartphone Based Framework

The detailed design is presented based on the proposed approach. A framework based on the smart phones is elaborated. The embedded sensors, algorithms and flowcharts are discussed in the proposed framework; the sensors embedded in the smart phones are used to associate the algorithms in order to diagnose COVID-19 corona virus disease [23]. Though many techniques and tests have been available as discussed in the previous section to diagnose COVID-19 but the method described in the given proposal is user friendly, cheap and readily available. Radiologists can use the solutions anywhere and anytime in their smart phones in case of emergency situations. Firstly, the symptoms of the suspected COVID-19 patient should be detected correctly [24]. The symptoms of this disease are very common which include fever, breath shortness, dry cough and pain in the muscles. Each symptom can be differentiated as these are the same symptoms for common cold and flu. The sensors available in smart

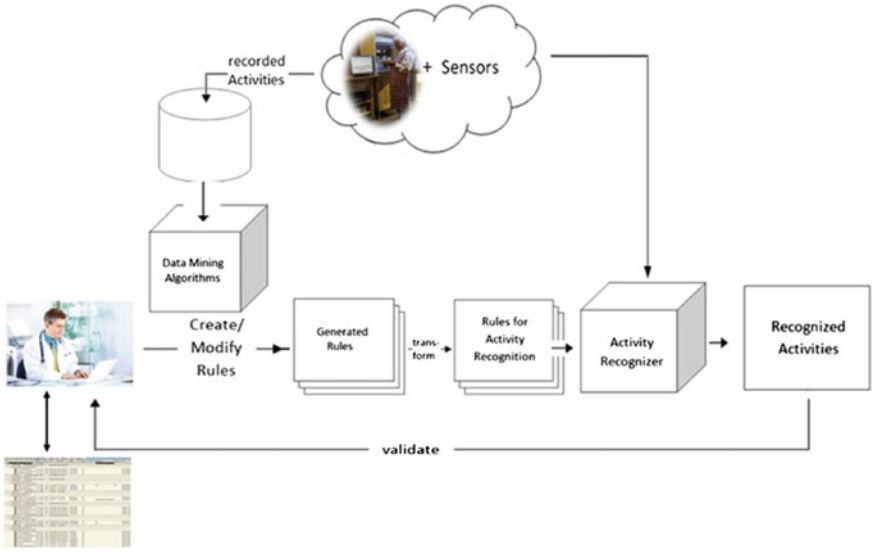

Fig. 4 Flow chart to identify the virus

phones today are able to take the input and can be made to measure the level of all symptoms in the proposed framework. The smart phones are embedded with many technology sensors such as temperature control, heart rate sensor, proximity sensor and microphones [25, 26]. The symptoms of the corona virus disease should be easily sensed by these technologies. Each sensor reading has the application of different algorithm owing to the different symptoms of the disease. For example fever can be detected with the help of fingerprint temperature sensor present at the rear side of the smart phone [27]. The human fatigue can be detected using the features of camera such as images and videos. The accelerometer sensors can also be used to detect the fatigue in the patient. Person is asked to take sit-ups for 30 s and total sit-ups can be counted using image processing and the activity can be monitored. The observations made in the video of the smart phone can be used to predict the level of nausea. The neck posture and the headache level can be predicted using the camera and inertial sensors embedded on the smart phones. Also samples of Lung CT scan and X-ray of chest can be uploaded. The microphone sensor can be used to identify the cough type whether it is dry cough or not. Heartbeat of person can be recorded through heart rate sensor available on smart phone. The above-mentioned algorithms and sensors are used in the proposed framework. After gathering the results and predictions of the symptoms using the sensors, the data is collected and stored as a record [28]. After collecting the records and data from various patients, they are used as inputs to the various techniques of machine learning. The techniques of machine learning in the medical field includes neural networks and *k*-nearest neighbor. There are various deep learning methods in the machine learning techniques which are quite accurate and comes under the family of neural networks. CNN and RNN are the

two main algorithms for deep learning which are used for the purpose of recognition and classification [29]. Here, CNN stands for convolution neural network and RNN implies recursive neural network. The neural method which is feed forward is called CNN and is mostly used for recognizing the images whereas there is a different concept for RNN. In RNN, the next layer input will be the output of previous layer being saved. The measurement of signals and test is mostly done by RNN. CNN is used for spatial data whereas RNN is used for saving the temporal data [30]. Figure 5 shows the proposed framework which contains different set of layers. These layers are reading layer, configuration layer, symptoms prediction layer and COVID-19 prediction layer.

The function of the first layer is to read the data stored in the sensors. For example, the CT scan of lungs, X-ray of chest, videos captured in the smart phone (camera sensor), and measurements from inertial and accelerometer sensors by sit-stand, measurements recorded through microphone sensor to identify the cough, heart rate can be recorded using heart rate sensor and the fingerprint sensor to measure the degree of temperature. All the readings of the sensor are identified in the first layer itself. The sensors present in the smart phone are configured in the second layer of the framework. This includes the intervals during the readings, size of the image, time resolution and so on [31]. The applications in the smart phones run the algorithm input to which are these configurations and readings in the first two steps. The level of the symptoms such as abnormal sub-image shapes, nausea level, fatigue level, cough

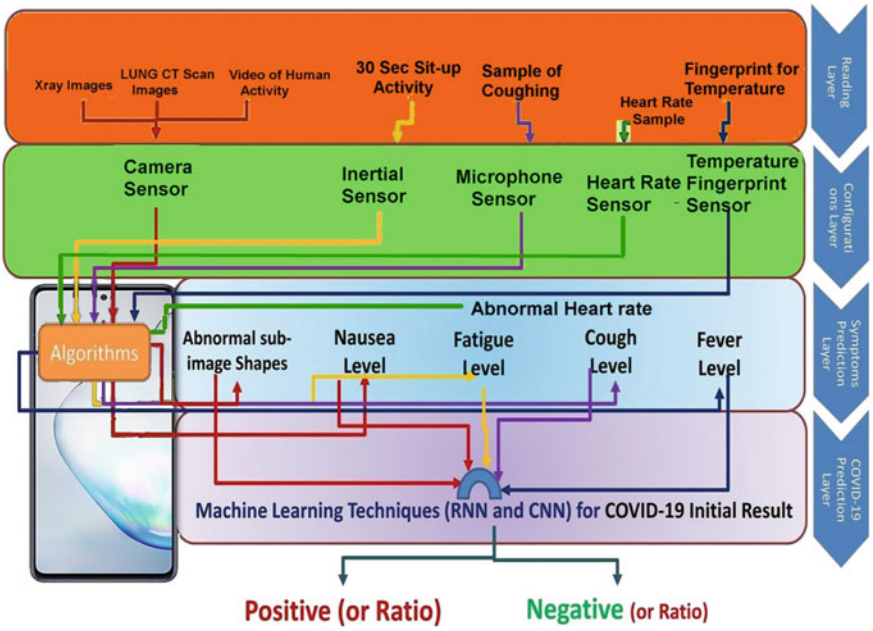

Fig. 5 Proposed framework to predict COVID-19

level and fever level are calculated in the third layer of the proposed framework. The symptoms are recorded separately and are stored for the input in the upcoming layer. The techniques of the machine learning are applied in the last layer of the framework which is used for the prediction of COVID-19 corona virus disease. For example, if the CT scan images are not normal then the CNN is used [32]. The last layer predicts the initial result for COVID-19 using CNN and RNN techniques of machine learning. The progressive CT scan images of the lungs is shown in Fig. 6. The key technique for detecting the COVID-19 disease is the CT scan. The increase in the volume and density of CT scan images is the evidence for confirmed COVID-19 case. The proposed framework allows the radiologists to efficiently decide the suspected cases which would otherwise take longer time if done manually by the radiologists.

Using deep learning the COVID-19 can be predicted using X-ray images. The epithelial cells of respiratory systems are affected by presence of COVID-19. So, X-rays can be used to analyze the presence. The dataset of X-rays of normal people and X-rays of COVID-19 people can be used to train the model and with the use of CNN and deep learning, the model will be able to detect the presence of COVID-19 virus in X-ray [33]. Figure 7 shows the X-ray dataset of normal and COVID-19 positive people and Fig. 8 shows detection of COVID-19 using algorithm.

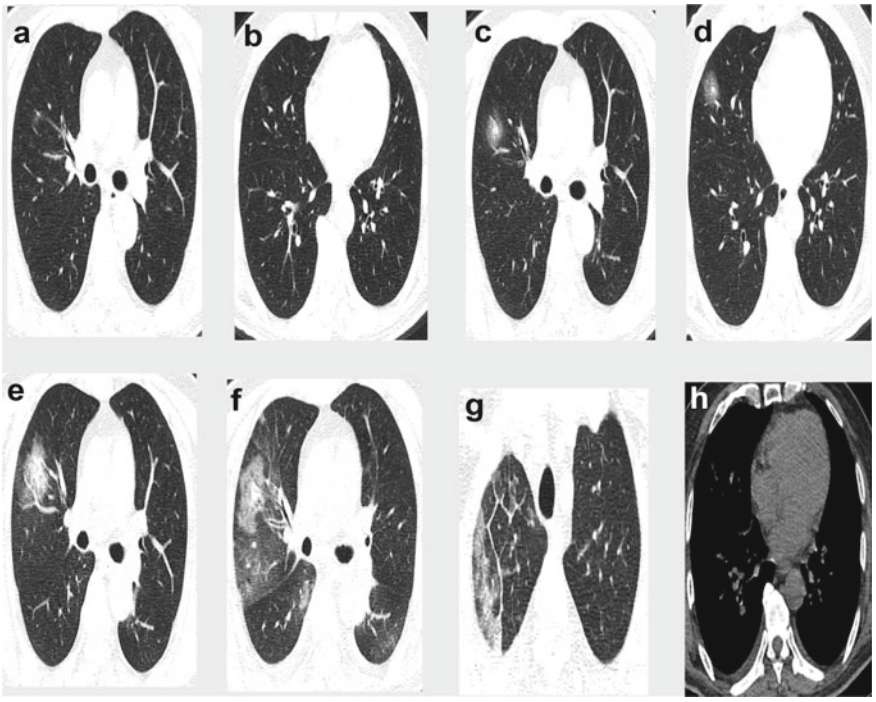

Fig. 6 CT scan images of a suspected COVID-19 case

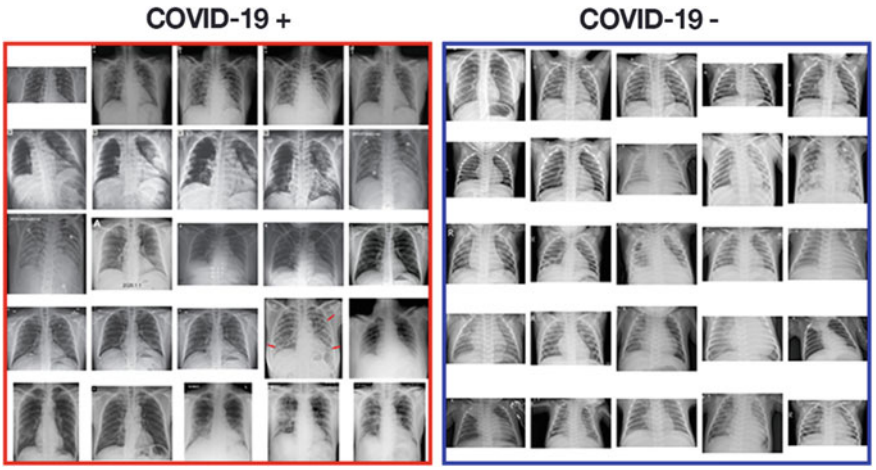

Fig. 7 Dataset of normal and COVID 19 people

Fig. 8 Detection of presence of COVID-19

The merging of artificial intelligence with cloud computing has manifested great results in the health sector. The models of the machine learning are generated to apply huge data to the algorithms and in order to store the data, cloud network is required. Variety of data obtained make different patterns which are identified by the models used in the machine learning. The accuracy and prediction of the framework is improved if more data is provided to the model. To identify the presence of virus in the lungs through CT scan images and in X-ray of chest many [34–36] reports of radiology should be trained in order to get a better diagnosis. The industries can use this pattern of images and records which are obtained as inputs in different forms like unstructured data and raw data. Since the computational techniques have become

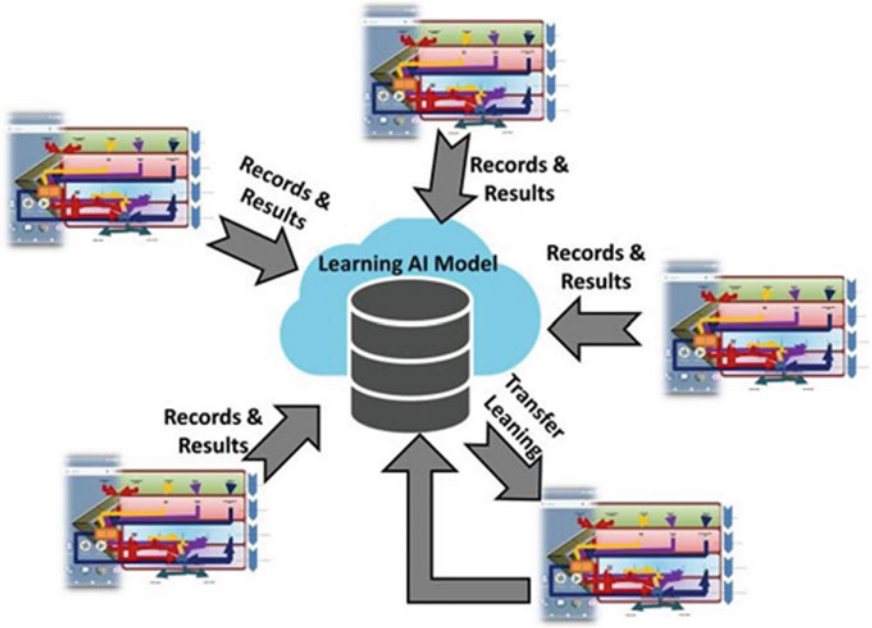

Fig. 9 Cloud network for the proposed framework

very advanced, CPUs and GPUs are required which are provided by the cloud in the form of virtual machines [37].

The automation of various tasks of machine learning is done with the help of various services such as server less computing, batch processing. The predictive analytics are also handled quite effectively through the automation. There are many benefits of combining artificial intelligence with cloud network through smart phones. These benefits are increased productivity, reliability and availability of advanced infrastructure [38–43]. Figure 9 shows the learning AI model in which different records and results from various patients are stored. To have a quick access to all the records, the merging of artificial intelligence with cloud computing plays a major role. The data from the AI models is also transferred for further progress through the cloud network. This type of framework can effectively use to combat the pandemic disease COVID-19.

5 Conclusion

In this paper, the detailed discussion about COVID-19 corona virus disease and the techniques to combat it. The symptoms, cause and the tests are broadly discussed and elaborated. Various radiology techniques, CT scan imaging, medical kits and modern

technologies are discussed. CT scan and PCR (Polymerase Chain Reaction) which are the tests for the diagnosis of COVID-19 virus in the human body are discussed. An anti malarial drug called has a very significant inhibitor effect on SARS-CoV-2 virus. This drug was not recommended for the patients showing symptoms of pneumonia. The solutions which are available currently have less accuracy, takes longer time and are costly. Artificial intelligence in a way helps the medical sector to move towards better solutions, diagnosis and treatment in a precise manner. There is an increase in the productivity and efficiency other than reducing manual errors by incorporating artificial intelligence. Since artificial intelligence has come a long way in the medical field in combating the viruses it can surely be employed to combat the major pandemic of COVID-19 disease in this paper, a framework is proposed based on smart phones and artificial intelligence which do not have the above mentioned issues. This framework can prove to be quite reliable as it is solely based on the measurements done by the sensors embedded in the smart phones. The radiologists and doctors can easily use these measurements anywhere and anytime on their smart phones. The proposed framework can also run in the applications of smart phones since no additional sensors are required which makes this framework more accurate and reliable. There are four different layers in the proposed framework which are reading layer, configuration layer, symptoms prediction layer and COVID-19 prediction layer. There are multiple readings in the sensors of the framework which refer to the various symptoms making this framework more reliable.

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Transmission Modelling on COVID-19 Pandemic and Its Challenges

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Abstract Presently, the whole world is facing the global imbalance and challenges caused by the pandemic COVID-19. So all are eager to discover the protective method for this pandemic. It is a great opportunity for researchers to analyse the high rate of spreading of virus and also about the increase in the number of deaths due to this hazard. In order to understand that we think of a proper mathematical model with its associated parameters that lead to better prediction of spread of virus and its future preparedness. Here a dynamic epidemic model is developed to study the dynamic behaviour and control technique of COVID-19. We have mainly focused on hospitalized quarantine. In this chapter, first we propose the mathematical model and justifying its positivity. Here both the stability analyses like local and global are discussed, which depends upon the basic reproduction number. The numerical simulation and graphical analysis are analysed with the help of Runge–Kutta methods of said model. Finally, the outcomes of the model represent that person-to-person contact is the main cause of this pandemic COVID-19. Lastly, this model concludes that hospitalization is the best approach to reduce the infection and fearness of pandemic situations.

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Keywords COVID-19 · Stability · Basic reproduction number · Lyapunov function hospitalization quarantine

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1 Introduction

The current epidemic of coronavirus disease-2019 (COVID-19) gives rise to a substantial quantity of mental alarms and fitness complications; consequently, these continuously have twisted towards drastic tragedy to civilization and ecosystem. World Health Organization has reported that in excess of 220 countries, areas or territories with overall established diseased numbers of 56,623,643 and 1,355,963 numbers of death owed to coronavirus as on 20 November 2020. In the present scenario, COVID-19 characterized as both an epidemic and pandemic; however, people are generally named the phenomenon an outbreak. The word endemic denotes towards the continuous existence along with the traditional occurrence of a disease or infective agent in a resident in the interior of a topographical space. Pandemic denotes the epidemic that has spread across nation state and mainland—the worldwide spread of the new infection, the epidemic happens globally so it is called as pandemic or else in excess of a very widespread zone, inter-sectioning the international boundaries which usually disturb an enormous number of individuals. But an outbreak is an "abrupt breaking out or incident" or "outburst". As soon as denoting a contagious disease, an outbreak is explicitly a rapid increase in numbers, particularly when it is solitary or up to now disturbing a comparatively confined to a small area. The pandemic is an epidemic and an infection that has blown out over a massive range, that is, its "widespread all over the whole country, landmass, or the whole flora and fauna". It was established that COVID-19 triggered by SARS-CoV-2 known as severe acute respiratory syndrome coronavirus 2, which was first recognized in the last part of the year 2019 in country China at Wuhan, but it was affirmed as pandemic by WHO in 2020 [1, 2].

Right now, there are forty different names of coronaviruses approved by the international committee of the world. But out of forty coronaviruses, the current COVID-19 placed at number seventh position including other known coronaviruses. Mostly the animals are affected by the viruses. Out of these seven known coronaviruses, only four are obtained by the public and spread through inhabitant continuously for an era. Consequently, the mortality rate was increasing very high due to the recent outbreak of SARS-CoV-2, MERS-CoV, SARS-CoV. Siddique R et al. [3] reported that all the above viruses as well as H1N1 2009 and H5N1 influenza A cause the severe acute respiratory and lungs injury, which leads to pulmonary failure and ultimately death. Bats were the starting sources of COVID-19, whereas how the virus is transmitted through the human being is not yet recognized. According to the research report, the human beings are affected from the air and by touching the infected objects. On copper, aerosols, cardboard and stainless steel/plastics, the virus is staying for up to four hours, within three hours, up to one day and within two/three days, respectively [4].

The common cold appears in the human being because of infections in respiratory tract by COVID-19. This will transmit to other host due to high rate of infection, mutations and recombination of these viruses. At the new round of adoptions, harshness of the disease is considerably apex between the fresh host and virus. Different

persons are affected by COVID-19 in different ways. Many of the infected human being grows the mild to severe symptoms due to respiratory diseases arises from COVID-19 and recover without need of special treatment. The symptoms of these disease include fever, tiredness, respiratory illness, cough and pneumonia. The other symptoms of this viruses are shortness of breath, headaches, pain in throat, diarrhoea and vomiting [5]. In order to protect our body from COVID-19 and considering public health perspective, we use different scientific masks, maintain social distancing and self-quarantine. The respiratory droplet coming from coughing and sneezing of infected people can infect this virus. More than 95% of all particles can be eliminated by using different scientific masks. In fact these mask can do the filtering every particle for showing the virus free. Therefore, different masks likely protect against several modes of viral transmission.

As per the report of WHO, COVID-19 case was identified on 31st December 2019 from the seafood market of Wuhan City, ROC. The virus was supposed to propagate mainly from living things to human beings. However, successive cases were not related to this mechanism. So, later it was established that people-to-people transmission could be possible by this virus the symptomatic people are the main source of COVID-19 spread. Transmission by asymptomatic people appears to be occasional but it cannot be expelled because these people could transform the disease slowly to other individuals. In [6], it suggests that loneliness is the greatest weapon for controlling epidemic disease. Depending upon the survey and investigation organized by the health organization of the Chinese Government, the incubation time period of coronavirus could be normally 3–7 days and remains up to two weeks. The highest time period from infections to the indication of virus present in the body was 12.5 days to 18 (95% confidence interval) [7]. This information too showed that about in a week the epidemic was doubled, whereas the basic reproduction number (R_0) is 2.2. That is on an average each individual infected person spread the infections approximately to 2.2 individuals. Earlier, in the year 2002–2003 the basic reproduction numbers were calculated for the SARS-CoV approximately 3 [8].

As reported earlier, the source of the respiratory infection was SARS-CoV-2. In Johns Hopkins, a new analysis was conducted in the School of Public Health (SPH) and was supervised in the same organization by different scientists and investigators at Bloomberg. The analysis was based on the publicly obtainable statistics and information on contaminations from the SARS-CoV-2. Finally, it was established that SARS-CoV-2 was responsible for COVID-19 and was created in the median infection incubation time approximately of about 5.1 days [9]. Considering this augmented median time, 14-days should be the quarantine time for infected people. In the USA, CDCP popularly known as Centers for Disease Control and preclusion executed 14-days as the quarantine time for persons who are expected to come in contact with the coronavirus. The exploration also endorses that approximately 97.5% of individuals having matured with the indications of SARS-CoV-2 contamination will organize subsequently within 11.5 days of contact. Social distancing strategies are required from a community health point of view but social distancing can have adverse effects on financial condition.

The human being who are under some severe medical treatments for critical diseases and above sixty years old people have a jeopardy of developing critical diseases infected by coronavirus are dying at the last. All the governments of different countries along with health organizations and WHO are implementing probable attempts seriously to combat COVID-19. Since there is no definite treatment for the control or cure of COVID-19, the researcher and scientists have been initiating different proposed medical treatments to reduce or control the death rate due to COVID-19 [10]. Keeping in the above situations, different therapeutic measures such as hydroxychloroquin, azithromycin, rapamycin, doxycycline anti-ageing drug, acetazolamide, plasma therapy and vitamins-like zinc supplements are suggested to the patients with virus COVID-19 over a duration of approximately 4 months to develop antibodies and fight against COVID-19 [10]. In this research paper, the authors Shinde et al. [11] have discussed the forecasting model for COVID-19. This study explains fighting against the coronavirus by using data science/machine learning techniques and mathematical models related to stochastic theory of probability. Mathematical modelling is an important devices to study the propagation of this disease. The valuable control technique can be considered and to calculated through the numerical simulation and mathematical analysis. The compartmental model for the COVID-19 was described by Tang et al. [12]. They were adopted the sensitivity analysis and to show that transmission risk could reduce in connection with quarantine and isolations. In this paper, Anirudha [13] discussed the outcomes and challenges of different epidemiological models of SIR, SEIR, SEIRU, SIRD, SLIAR, ARIMA, SIDARTHE, etc., which predicts of spreading, peak and decreasing rate of COVID-19 cases. Annas et al. [14] formulated a mathematical model SEIR by assuming isolation and vaccination factors as parameters. Here the author studied the pandemic situation of the country Indonesia. Finally, the authors discussed that if there is no vaccine, then Indonesia is endemic and the spread of COVID-19 reduces for the case of maximum isolation [15]. Zeb et al. [16] have formulated the SEIQR model and discussed for COVID-19 infection dynamically by taking quarantine compartments. This model describes the isolation of the infected class as main measures to reduce the coronavirus from person to person contact. The authors Biswas et al. [17] have discussed a particular case of COVID-19 in the continent of Asia (India) mathematically. They compared two basic reproduction numbers for the outbreak of COVID-19. According to the Indian Council of Medical Research report, he studied the actual reproduction number from the data and compared it with the calculated basic reproduction number. Predictions are given to control the disease under some preventive measures. Khosla et al. [18] have discussed that telemedicine is better for mitigation of COVID-19 during the lockdown period. The authors Linton et al. [19] have presented the statistical analysis of COVID-19 on the basis of available data and investigated the incubation period with other time intervals of epidemiological behaviour of COVID-19. In the research article [20] the authors proposed a adapted compartmental epidemic model to explain the transmission of COVID-19. Here they derive the relationship between control coefficient and basic reproduction number. On a priority basis, home isolation plays a vital role for controlling the spread of coronavirus. Therefore, it is concluded that the transmission of this disease

occurs by direct or indirect contact with people, contact with surface objects used by the infected people. Chawla et al. [21] have mainly focused on coronavirus how it happened and spread. They are suggesting the social distancing, and lockdown system is main solution of the pandemic situation of COVID-19.

Mishra et al. [22] have discussed three quarantine model for different stages of COVID-19 stage of coronavirus [23] in this chapter the authors mainly focus on the isolation of the migrants to mitigate the COVID-19 diseases. The authors [24] have used the GLM for the study of COVID-19 pandemic in Asia. They mainly focus on social distancing which is the key measure for controlling COVID-19. There is a lot of work has been done mathematically as well as numerically for the outbreak of COVID-19. So far the absence of any vaccinations and proper treatment of the outbreak of these pandemic diseases. Most of the existing work on coronavirus did not consider the role of control measures in the spread of COVID-19 as highlighted above. In this present work, we present the role of hospitalization quarantine for severe and mild case infected populations to organize and calculate for the susceptible individuals. We formulated a mathematical model of mild and severe transmission to study the dynamic behaviour of the COVID-19 outbreaks.

According to the WHO data as shown in Fig. 1, initially the number of infected and death rate increased exponentially. So all the government adopted the lockdown system nationwide to control and manage the spread of epidemics. Since the large number of infected cases increases but due to the limited number of hospital facilities like beds and supporting medical staff results in failure of the treatment of the patient, which increases the severe infected persons and deaths. Thus, it is very difficult to manage the pandemic situations in all aspects. Hence, medical resources like ventilator, PPE kit and nebulizer are essential factors which can determine the capacity of the hub epidemic regions to afford proper treatments to patients. So improving and building a huge number of hospital beds along with nationwide lockdown improved

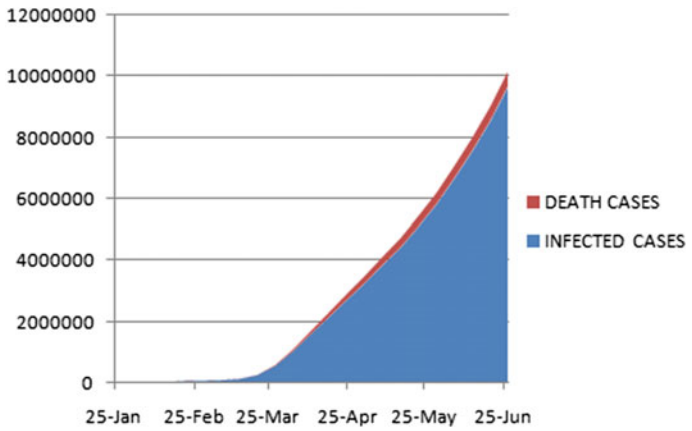

Fig. 1 Movements in COVID-19 development from 25 January 2020 to 25 June 2020 across the globe number of infected cases and death cases

cure percentage and decreased mortality rates. Overall, the patients who are cured in hospitals effectively control the spread of the epidemic. The epidemic can be controlled in a more effective way by the early implementation of city lockdown as well as hospitalization of the patient.

This chapter is organized as follows: In Sect. 2, we have prepared a mathematical model for the COVID-19 and to verify the boundedness and positivity of the solution of the system of Eq. (1). In Sect. 3, we have derived the basic reproduction number. In Sect. 4, it emphasizes the stability analysis for corona-free and endemic equilibrium points for local and global stability. In Sect. 5, some numerical simulations and conclusions are discussed.

So proper medical treatment or hospitalizations of patients with COVID-19 will reduce the catastrophic effects of COVID-19.

1.1 Nomenclature

Symbols/parameters	Descriptions of the parameters
S	Susceptible populations
I_S	Severer infected populations
I_M	Mild infected populations
Q_H	Hospitalized quarantined populations
R	Recovered populations
A	Recruitment population to susceptible from newborn/ Immigrants
β_1	Contact rate at the severe populations
β_2	Contact rate at the mild populations
γ_1	Rate of hospitalized from the severe population
γ_2	Rate of hospitalized from the mild populations
η_1	Rate of recovered after hospitalized populations
η_2	Rate of recovered after treatment of mild populations
μ_1	Natural death rate of coranavirus diseases
μ_2	Death rate other than coranavirus diseases
N	Total number of population under considerations

2 Model Formations and Basic Assumptions

The world has focused its attention to outbreak of the COVID-19. Till date there is no proper vaccination and treatment for cure of these diseases propagations. This study is significant as humanity will always entertain contributions for prevention, control and even the eradication of the COVID-19 pandemic. The research will be appreciated in the medical world; policy-makers can also use the acquired knowledge from this research on the need to always quarantine suspected cases of COVID-19. So according to the current situations of the pandemic and treatment of the disease, we are inspired by all these the work, and we have formulated an epidemic model

COVID-19 of severer and mild transmission of these disease. This model includes new births, immigrations inflows of the susceptible populations. Here we can assume all the populations die naturally at the rate μ_1 and also death due to other diseases can be considered in the model. The infected populations can be taken into two accounts like severer and mild. These are contacted with infected from the migrants or other travel history. The lack of immunity power of body, the people having high blood pressure, suffers from diabetes, and other respiratory diseases are contacted with COVID patients who are treated as a severe infected population in this model. Again the mild infected population are considered as the people who are contacted with the COVID patients but the symptoms are only shown. Some of these people recover naturally after making self-isolations take light fever medicines. Rest of the mild infected and severer populations go to hospital and are treated with medical supervision, get recovered. Though the rate is assumed to be minimal, this model is based on compartmental structures. So by considering the total number of populations is divided into five sub-populations, i.e. susceptible, severe infected–mild infected, hospitalized quarantined and recovered population. As susceptible populations are contacted with infected populations, I_S and I_M states with different contact rates were getting infected with some probability. An infected population both mild and severe went through the hospital quarantine for treatment. Some mild infected patients will get the recovery use of isolation and take some minor medicine independently for some days. But infected patients who are not treated properly for the certain period might get death. The hospital quarantine patients are treated with proper treatment within the period getting recovery. So every individual taken treatment recovers at a high rate, that is to say the treatment is considered to be effective on a made under consideration. The movement of the individuals is shown in Fig. 2 and formulated by the system of nonlinear ordinary differential equations.

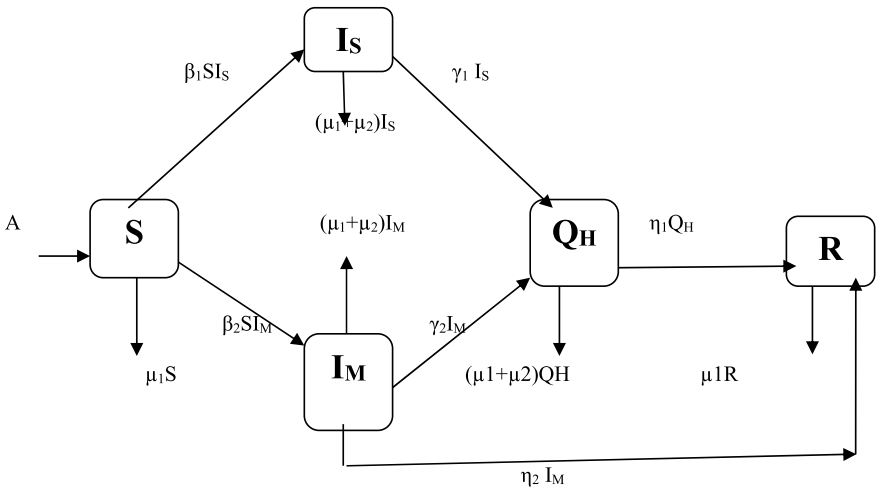

Fig. 2 Schematic diagram transmission of the COVID-19

2.1 Mathematical Model

The model for transmission of coronavirus diseases is formulated by a system of nonlinear ordinary system of differential equations.

$$\begin{aligned}
\frac{\mathrm{d}S}{\mathrm{d}t} &= A - (\beta_2 I_{\mathrm{M}} + \beta_1 I_{\mathrm{S}} + \mu_1)S \\
\frac{\mathrm{d}I_S}{\mathrm{d}t} &= \beta_1 I_{\mathrm{S}} S - (\mu_1 + \mu_2 + \gamma_1) I_{\mathrm{S}} \\
\frac{\mathrm{d}I_M}{\mathrm{d}t} &= \beta_2 I_{\mathrm{M}} S - (\mu_1 + \mu_2 + \gamma_2 + \eta_2) I_{\mathrm{M}} \\
\frac{\mathrm{d}Q_H}{\mathrm{d}t} &= \gamma_1 I_{\mathrm{S}} + \gamma_2 I_{\mathrm{M}} - (\mu_1 + \mu_2 + \eta_1) Q_{\mathrm{H}} \\
\frac{\mathrm{d}R}{\mathrm{d}t} &= \eta_1 Q_{\mathrm{H}} + \eta_2 I_{\mathrm{M}} - \mu_1 R
\end{aligned} \tag{1}$$

2.2 Boundedness and Positivity of the Model

It is necessary to show the solution of the system (1) is positive and boundedness in all time $t > 0$. Here we want to add all the pupations size

$$\begin{aligned}
N &= S + I_{\mathrm{S}} + I_{\mathrm{M}} + Q_{\mathrm{H}} + R \\
\text{i.e.} \frac{\mathrm{d}N}{\mathrm{d}t} &= \frac{\mathrm{d}S}{\mathrm{d}t} + \frac{\mathrm{d}I_{\mathrm{S}}}{\mathrm{d}t} + \frac{\mathrm{d}I_{\mathrm{M}}}{\mathrm{d}t} + \frac{\mathrm{d}Q_{\mathrm{H}}}{\mathrm{d}t} + \frac{\mathrm{d}R}{\mathrm{d}t} \\
&\Rightarrow \frac{\mathrm{d}N}{\mathrm{d}t} = A - \mu_1 N - \mu_2 (I_{\mathrm{S}} + I_{\mathrm{M}} + Q_{\mathrm{H}})
\end{aligned}$$

In the absence of the any coranavirus, i.e. $(I_{\mathrm{S}} = I_{\mathrm{M}} = Q_{\mathrm{H}} = 0)$.

Then $\frac{\mathrm{d}N}{\mathrm{d}t} = A - \mu_1 N$.

Which shows that the total populations N approaches to $\frac{A}{\mu_1}$ as $t \to \infty$. It follows the explanation of (1) is exist in the region Γ. This is defined by

$$\Gamma = \left\{ (S, I_{\mathrm{S}}, I_{\mathrm{M}}, Q_{\mathrm{H}}, R) \in R_+^5 : S > 0, I_{\mathrm{S}} > 0, I_{\mathrm{M}} > 0, Q_{\mathrm{H}} > 0, R > 0; S + I_{\mathrm{S}} + I_{\mathrm{M}} + Q_{\mathrm{H}} + R \leq \frac{A}{\mu_1} \right\}$$

By the maximal interval $[0, \infty)$ principle, the initial value problem is well-defined, bounded as well as positive invariant under the region Γ.

3 Stability Analysis and Calculation of the Basic Reproduction Number

At the steady state for equilibrium points of the system, (1) becomes

$$\begin{aligned} A - (\beta_2 I_{\mathrm{M}} + \beta_1 I_{\mathrm{S}} + \mu_1)S &= 0 \\ \beta_1 I_{\mathrm{S}} S - (\mu_1 + \mu_2 + \gamma_1) I_{\mathrm{S}} &= 0 \\ \beta_2 I_{\mathrm{M}} S - (\mu_1 + \mu_2 + \gamma_2 + \eta_2) I_{\mathrm{M}} &= 0 \\ \gamma_1 I_S + \gamma_2 I_{\mathrm{M}} - (\mu_1 + \mu_2 + \eta_1) Q_{\mathrm{H}} &= 0 \\ \eta_1 Q_{\mathrm{H}} + \eta_2 I_{\mathrm{M}} - \mu_1 R &= 0 \end{aligned} \tag{2}$$

3.1 Calculation of Basic Reproduction Number

Basic reproduction number is acting a significant role in the coranavirus diseases. These numbers determine whether the infection will transmit or die out through the populations. It can be calculated by using next-generation matrix method. It can be obtained by calculating V and F. The F be the new infections while V be the transfers of infections from one populations to another populations. Hence for calculating the basic reproduction number for COVID-19 to linearize the system of Eq. (2) by taking the compartments or populations like I_{S}, I_{M}, Q_{H}.

$$\begin{bmatrix} \frac{\mathrm{d}I_S}{\mathrm{d}t} \\ \frac{\mathrm{d}I_{\mathrm{M}}}{\mathrm{d}t} \\ \frac{\mathrm{d}Q_{\mathrm{H}}}{\mathrm{d}t} \end{bmatrix} = [F - V] \begin{bmatrix} I_{\mathrm{S}} \\ I_{\mathrm{M}} \\ Q_{\mathrm{H}} \end{bmatrix}$$

where

$$F = \begin{bmatrix} \beta_1 S_0 & 0 & 0 \\ 0 & \beta_2 S_0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

and

$$V = \begin{bmatrix} (\mu_1 + \mu_2 + \gamma_1) & 0 & 0 \\ 0 & (\mu_1 + \mu_2 + \gamma_2 + \eta_2) & 0 \\ -\gamma_1 & -\gamma_2 & (\mu_1 + \mu_2 + \eta_1) \end{bmatrix}$$

The basic reproduction number is given by dominant eigenvalues of FV^{-1}

$$R_0 = \left[\frac{\beta_1 S_0}{(\mu_1 + \mu_2 + \gamma_1)} + \frac{\beta_2 S_0}{(\mu_1 + \mu_2 + \gamma_2 + \eta_2)} \right]$$

The system (2) always has the unique diseases-free equilibrium points.

$E_0(S_0 = 1, I_S = I_M = Q_H = R = 0)$ and solving the system (2); simultaneously, we also get the unique positive endemic equilibrium points $E^*(S^*, I_S^*, I_M^*, Q_H^*, R^*)$ of the system (2) in the region Γ.

Where

$$S^* = \frac{(\mu_1 + \mu_2 + \gamma_1)}{\beta_1}$$
$$I_M^* = \frac{\mu_1 R^* - \eta_1 Q_H^*}{\eta_2}$$
$$I_S^* = \frac{(\mu_1 + \mu_2 + \eta_1) Q_H^* - \gamma_2 I_M^*}{\gamma_1}$$
$$Q_H^* = \frac{\gamma_1 I_S^* + \gamma_2 I_M^*}{(\mu_1 + \mu_2 + \eta_1)}$$
$$R^* = \frac{\gamma_1 \eta_1 I_S^* + I_M^* \gamma_2 \eta_1 + I_M^* \eta_2 (\mu_1 + \mu_2 + \eta_1)}{(\mu_1 + \mu_2 + \eta_1)\mu_1}$$

Theorem 1 *When the diseases-free equilibrium is locally asymptotical stable in the region if* $R_0 < 1$*, otherwise it is unstable.*

Proof The Jacobian matrix of E0 dropping the recovered populations

$$J_{DFE} = E_0(S = 1, 0, 0, 0)$$
$$= \begin{bmatrix} -\mu_1 & 0 & 0 & 0 \\ 0 & -(\mu_1 + \mu_2 + \gamma_1) & 0 & 0 \\ 0 & 0 & -(\mu_1 + \mu_2 + \gamma_2 + \eta_2) & 0 \\ 0 & \gamma_1 & \gamma_2 & -(\mu_1 + \mu_2 + \eta_1) \end{bmatrix}$$

Therefore, all the eigenvalues of the auxiliary equation of $J_{DFE} = E_0$ are

$$\lambda_1 = -\mu_1$$
$$\lambda_2 = -(\mu_1 + \mu_2 + \gamma_1)$$
$$\lambda_3 = -(\mu_1 + \mu_2 + \gamma_2 + \eta_2)$$
$$\lambda_4 = -(\mu_1 + \mu_2 + \eta_1)$$

In the above matrix as the real part of all the eigenvalues are negative so the diseases-free equilibrium is asymptotical stable in locally.

Theorem 2 *The endemic equilibrium points* $E^*(S^*, I_S^*, I_M^*, Q_H^*, R^*)$ *are locally asymptotical stable when* $R_0 > 1$.

Proof The variation matrix (2) becomes

$$J_{EE} = E^*(S^*, I_S^*, I_M^*, Q_H^*, R^*)$$
$$= \begin{bmatrix} -(\beta_1 I_S^* + \beta_2 I_M^* + \mu_1) & -\beta_1 S^* & -\beta_2 S^* & 0 & 0 \\ \beta_1 I_S^* & \beta_1 S^* - (\mu_1 + \mu_2 + \gamma_1) & 0 & 0 & 0 \\ \beta_2 I_M^* & 0 & \beta_2 S^* - (\mu_1 + \mu_2 + \gamma_2 + \eta_2) & 0 & 0 \\ 0 & \gamma_1 & \gamma_2 & -(\mu_1 + \mu_2 + \eta_1) & 0 \\ 0 & 0 & \eta_2 & \eta_1 & -\mu_1 \end{bmatrix}$$

The eigenvalues of the auxiliary equation in variational matrix of the system (2) become

$$\lambda_1 = -\mu_1$$
$$\lambda_2 = -(\mu_1 + \mu_2 + \eta_1)$$

Here the two eigenvalues have real parts strictly negative and the other three eigenvalues can be calculated by solving the cubic equations $\lambda^3 + a_1\lambda^2 + a_2\lambda + a_3 = 0$, where

$$a_1 = (\beta_1 I_S^* + \beta_2 I_M^* + \mu_1 - \beta_1 S^* + (\mu_1 + \mu_2 + \gamma_1) - \beta_2 S^* + (\mu_1 + \mu_2 + \gamma_2 + \eta_2)$$
$$\Rightarrow a_1 = (\beta_1 I_S^* + \beta_2 I_M^* + \mu_1) + \frac{(1 - R_0)}{(\mu_1 + \mu_2 + \gamma_1)(\mu_1 + \mu_2 + \gamma_2 + \eta_2)}$$
$$a_2 = \begin{pmatrix} (\beta_1 I_S^* + \beta_2 I_M^* + \mu_1)((\mu_1 + \mu_2 + \gamma_1) - \beta_1 S^*) + \beta_1 S^* \beta_1 I_S^* + (\beta_1 I_S^* + \beta_2 I_M^* + \mu_1)(\beta_2 S^* \\ -(\mu_1 + \mu_2 + \gamma_2 + \eta_2)) + (\beta_1 S^* - (\mu_1 + \mu_2 + \gamma_1)(\beta_2 S^* - (\mu_1 + \mu_2 + \gamma_2 + \eta_2)) \end{pmatrix}$$
$$a_3 = \begin{pmatrix} \beta_1 S^* \beta_1 I_S^* (\mu_1 + \mu_2 + \eta_1) + \beta_2 S^* \beta_1 I_S^* \beta_2 I_M^* + \\ (\beta_1 I_S^* + \beta_2 I_M^* + \mu_1)(\beta_2 S^* - (\mu_1 + \mu_2 + \gamma_2 + \eta_2))(\beta_1 S^* - (\mu_1 + \mu_2 + \gamma_1)) \end{pmatrix}$$

By Routh–Hurwitz criteria, the system will be stable if $a_1.a_2 > 0$ and an unstable if $a_1.a_2 < 0$. Obviously $a_1.a_2 > 0$ due to $a_1.a_2 > a_3 \Rightarrow (a_1.a_2 - a_3) > 0$. Hence, the system (2) is locally asymptotically stable at the endemic equilibrium $E^*(S^*, I_S^*, I_M^*, Q_H^*, R^*)$ if $R_0 > 1$.

3.2 Global Stability

Theorem 3 *The corona-free equilibrium of the system* (1) *is globally asymptotically stable in the region* Γ *when* $R_0 < 1$. *If* $R_0 > 1$, *then in the region* Γ *the endemic equilibrium is globally asymptotical stable.*

Proof Consider a Lyapunov function

$$L = (\mu_1 + \mu_2 + \gamma_2 + \eta_2)I_S + (\mu_1 + \mu_2 + \gamma_1)I_M$$

$$\frac{dL}{dt} = (\mu_1 + \mu_2 + \gamma_2 + \eta_2)\frac{dI_S}{dt} + (\mu_1 + \mu_2 + \gamma_1)\frac{dI_M}{dt}$$

$$\Rightarrow \frac{dL}{dt} = (\mu_1 + \mu_2 + \gamma_2 + \eta_2)(\beta_1 S - (\mu_1 + \mu_2 + \gamma_1)) + (\mu_1 + \mu_2 + \gamma_1)(\beta_2 S - (\mu_1 + \mu_2 + \gamma_2 + \eta_2))$$

$$\Rightarrow \frac{dL}{dt} = \begin{pmatrix} (\mu_1 + \mu_2 + \gamma_2 + \eta_2)(\beta_1 S) - (\mu_1 + \mu_2 + \gamma_1)(\mu_1 + \mu_2 + \gamma_2 + \eta_2) \\ +(\mu_1 + \mu_2 + \gamma_1)(\beta_2 S) - (\mu_1 + \mu_2 + \gamma_2 + \eta_2)(\mu_1 + \mu_2 + \gamma_1) \end{pmatrix}$$

$$\Rightarrow \frac{dL}{dt} = \left((\mu_1 + \mu_2 + \gamma_2 + \eta_2)(\mu_1 + \mu_2 + \gamma_1)\left(\frac{\beta_1 S}{(\mu_1 + \mu_2 + \gamma_1)} + \frac{\beta_2 S}{(\mu_1 + \mu_2 + \gamma_2 + \eta_2)} - 1 - 1\right)\right)$$

$$\Rightarrow \frac{dL}{dt} = ((\mu_1 + \mu_2 + \gamma_2 + \eta_2)(\mu_1 + \mu_2 + \gamma_1)(R_0 < 1 - 2)) \leq 0$$

$$\Rightarrow \frac{dL}{dt} \leq 0$$

Thus, $R_0 < 1$ then $\frac{dL}{dt} \leq 0$ and
If $\frac{dL}{dt} = 0$ then $I_S = I_M = 0$.

Thus by Lasalle's invariant conditions [25, 26] in the region Γ, the infection-free equilibrium is globally asymptotically stable.

4 Discussion of the Result

Figure 3 shows dynamic behaviour of the different population. The transmission of the susceptible, severe infected, mild infected, hospitalized quarantine and recovery populations are explained by taking the parameters, which indicate that the system is asymptotically stable in the region after treated with hospitalized isolations. Figure 4 explains that the tendency of virus transmission is depressive which is due to consult the treatment of hospital facilities in the region. In order to effectively defend against the COVID-19 patients, we adopt some latest medicine and ventilator facilities in

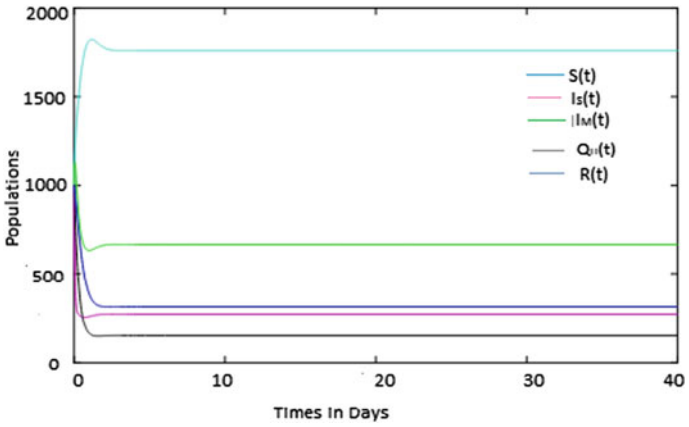

Fig. 3 Dynamic behaviour of the population

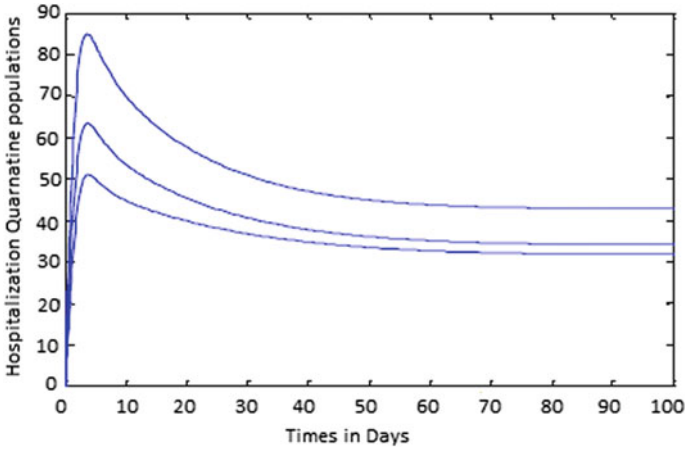

Fig. 4 Effects of hospitalization quarantine with respect time

the hospital to decrease the infected populations. Figure 4 illustrates that to increase the rate hospital quarantine facilities in the globe to reduce the infective population in the system. Also, the susceptible population needs to be quarantined when there are some symptoms appear, in Fig. 5 which shows the rate of hospital quarantine increases in a certain period of time to reduce the susceptible populations who were infected.

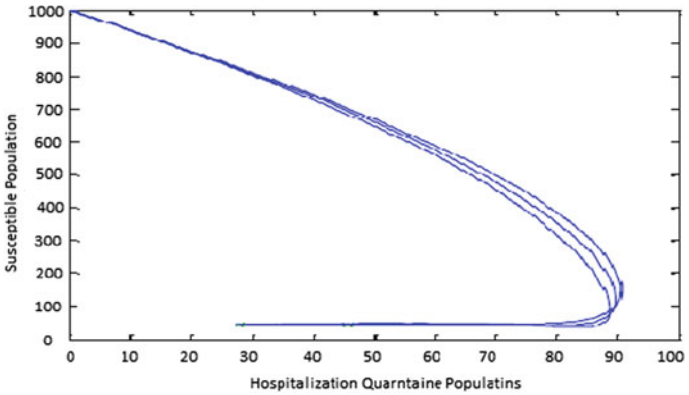

Fig. 5 Hospitalization with respect to susceptible populations

5 Conclusion

In this chapter, we have developed a mathematical model by considering the severe and mild cases of the infected populations. First we prove the positivity of the model, and the basic reproduction number is derived using the next-generation matrix method. We observe that infection-free equilibrium is asymptotically stable when its basic reproduction number below the unity. As a result, the virus will disappear in that system. Again by using Lyapunov function its value more than unity, the virus is persisting in the regions and goes to unique endemic equilibrium, which is globally stable in the system. These results imply that it is possible to reduce the spread of virus by enforcing the hospital quarantine, when the symptom appears within the populations. We have also seen that both infected populations are maintained at minimum 21 days hospital quarantine to recover more rapidly. The recovery of the population from infected population is very high when they are treated with proper treatment in the hospitals. The recovery rate of populations increases, when the direct or indirect contact from any surface or population is minimized. Finally, some numerical simulations carried by the developed model verify our results reduce the spread of coronavirus. So it is highly recommended that proper medical treatment or hospitalizations of patients with COVID-19 will reduce the catastrophic effects of COVID-19. Our future work will extend to the some model to characterize the developing vaccination.

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Effect of COVID-19 Pandemic on Mental Health: An Under-Realized Sociological Enigma

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Abstract The COVID-19 pandemic has vexed fundamental mental prosperity balance in 93% of countries worldwide while the interest for emotional well-being is expanding as per the WHO overview. The investigation of 130 countries gives the essential overall data demonstrating the mind-boggling impact of COVID-19 on admittance to emotional well-being supervisions and underscores the critical requirement for increased financing. Coronavirus has intruded on basic psychological aspects of people across the globe exactly when they're required most. The Coronavirus pandemic and the resulting money related droop have conflictingly influenced different individuals' mental wellbeing and made new squares for individuals previously experiencing mental maladjustment and substance use issues. Different grown-ups are similarly pronouncing negative effects on their mental wellbeing and success, for example, instability (36%) or non-hunger (32%), increments in liquor use or sedative substance use (12%) because of pressing factors altogether over the COVID-19. As the pandemic wears on, progressing and basic general thriving evaluations open different individuals to encountering conditions related to poor mental prosperity results, for example, detachment and work setback. Poor mental status is relied upon to burnout among cutting edge workers and extended apprehension or mental shakiness among those with poor wellbeing are extra concerns. Those with mental ailment and substance use issues pre-pandemic, and those as of late affected, will most likely require passionate health and substance use organizations. This brief review investigates down word's impact on psychological status in the COVID-19 pandemic worldwide particularly with respect to India based on the data published in various electronic media. We also talk about the ramifications of social distancing rehearses and the financial downturn on psychological wellness, just as difficulties in getting too emotional well-being.

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1 COVID-19 Pandemic Effect on Mental Health: Introduction

As the novel SARS-CoV-2 COVID pandemic breadths quickly across the globe, it is without a doubt having massive mental effects on human beings around the world. COVID pandemic has synchronized the world around us and confined ourselves inside the home which certainly exerts a negative effect on our mental health and raised degrees of stress or uneasiness [1]. There are authentic worries that a scourge of psychological instability could happen amidst the current COVID-19 pandemic and affect all ages from children to geriatric [2]. Preventive measures like self-isolation and physical distancing etc. may lead to an ascent in gloom, self-harm, alcoholism, drug addiction with additional negative mental outcomes [3]. Financial aberrations due to complete/partial lockdown across affects severely in occupation misfortunes and other fundamental obstructions can worsen psychological well-being issues among everyone in the midst of COVID-19 [4]. Under the above circumstances, it becomes very much essential to ensure administration access and coherence for people with existing psychological well-being conditions while securing the psychological prosperity of forefront laborers, people with COVID-19, and everyone [5, 6]. In the United States alone about 45% of the adults' population are reported to be under anxiety and stress, while in the United Kingdom and Italy approximately 33% and 37% of people respectively have experienced the agony of anxiety since the start of the pandemic [7]. In India scenario is worsening day by day where people are struggling to earn their daily bread and butter.

In India, throughout the most recent 3 months, there has been a critical ascent in the COVID-19 tainted cases and mortality because of this contamination [8]. Simultaneously, a few lay media reports are recommending an expansion in psychological wellness issues, for example, tension, misery, posttraumatic stress-like side effects, a sleeping disorder, and outrage among everybody, well-being laborers, just as individuals who are kept in detachment (because of disease with COVID or contact with tainted persons) [9, 10]. The quickly arising emotional well-being issues may destabilize people's overall prosperity and can impact the wellbeing framework; thus, they need earnest and prompt consideration and activity [11]. The people group's emotional well-being issues can be different and isolated according to the particular gathering of the populace. There are a few danger factors that trait to the improvement of mental manifestations during the COVID-19 pandemic [12]. The COVID-19 is majorly affecting psychological well-being by influencing our everyday working with expanding joblessness, isolating families, and different changes. There is an overall dread, despondency, and panic as a result of this pandemic. The regularly refreshing of the most pessimistic scenario situations by the media can fuel dread

and stress. Vulnerability and isolation can prompt trouble in maintaining concentration and may cause sleep disorders. In this manuscript, we address several issues related to mental health because of the COVID-19 pandemic in various segments of the population across India and other parts of the world [13].

2 Common Psychological Problems Post COVID-19

Starting from common people to front-line health care professionals like doctors, nurses, pharmacists, police, and government authorities structure the forefront to fight against COVID-19. Most stresses originate from getting contaminated during duty hours, suspecting themselves as a vector of deadly COVID-19, for their families, ampleness of protection, admittance to food, fluids, and rest, and partition from families. The far and wide social and financial disturbance has additionally affected most of these professionals. This has made a pattern of concern, stress, and misery. If not viably perceived and dealt with, this can change into more extreme trouble, in any event, prompting self-destructive musings and emotions. It is hence a matter of need to deliver these worries to guarantee positive emotional well-being and early meditations for the cutting-edge workforce in COVID-19 treatment settings. The effect of the COVID-19 pandemic on the mental health status of people of diverse fields is discussed briefly below.

2.1 Among General Population

Deficient information with respect to the hatching time of the infection, course of transmission, treatment, and security estimates cause dread and nervousness among ordinary citizens in India and across the globe. The locked-down phase limits inhabitants to be only at home which causes negative psychological wellness results like nervousness and frailty with respect to what's to come. The residents additionally feel tedium, frustration, and fractiousness under the above-mentioned condition. Studies already postulated extreme and wide range psychological wellness effects of the pandemic. Everybody can encounter dread and uneasiness of being wiped out orbiting the dust, vulnerability, accuse the individuals who are as of now influenced and encourage the psychological breakdown which includes burdensome issues, uneasiness issues, alarm issue, physical indications, self-fault, psychosis, and even self-destruction, etc. [14].

2.2 Among COVID-19 Patients

The suspected as well as affirmed COVID-19 people generally experience dread with respect to the high infectiousness and casualty. The COVID isolated individuals feel fatigued, dejection, outrage, sorrow, nervousness, refusal, despair, sleep deprivation, unsafe substance use, self-mischief, and suicidality. The survivors are placed at a higher risk zone with a progressive psychological illness like gloom, nervousness. Further patients may create obsessive–compulsive disorder. Additionally, antagonistic impacts of recommended medication like corticosteroids may cause more nervousness and mental trouble. A new investigation with 1500 patients from Maharashtra, India detailed that 55% had a moderate or extreme mental effect which needs to be addressed with utmost importance [15].

2.3 Among Close Relatives and Neighbors

COVID-19 patients and their family members, neighbors are continuously facing typical psychological problems like fear and agony of being infected. COVID-19 patients as a rule view themselves as liable with respect to the consequence of the infection, isolate, and shame on their relatives and companions. The relatives who lose their friends and family from the pandemic outcomes out of frustration and hatred. Then again, the kids who are confined or isolated in this time of pandemic have more opportunities to create an intense anxiety issue and sadness. It was accounted for among 30% of the kids and early loss of guardians during adolescence likewise has long haul unfriendly impacts on psychological wellness, including higher odds of creating mind-set problems, psychosis, and suicidality [16].

2.4 Among Healthcare Workers

During the COVID-19 pandemic healthcare services, demand increases sharply across the globe. Furthermore, it has been well understood that most of the nation worldwide don't possess adequate manpower, medical resources to cope with COVID-19. Consequently, with existing clinical facilities medical services providers need to commit themselves all the chance to expand the remaining burden alongside the multi-fold likelihood of being contaminated. They have been isolated as often as possible when they contact COVID-19-affirmed people. Under the above conditions, most medical services experts do feel actual depletion, dread, enthusiastic unsettling influence, and rest problems. A recent survey with 1563 health care professionals testified that around 51% were compulsive depressive symptoms, 45% stress-associated anxiety, and 36.1% insomnia. Moreover, the lack of counseling and psychiatric screening services for physicians knowingly or unknowingly

making their life more miserable. They have more possibilities of getting infected and the circumstances intensify the fear that their family members also may catch the infection [17].

2.5 Among Geriatric Patients with Co-morbidities

All over the world, the way this deadly disease is spreading rapidly, is causing an extensive level of dread, stress, and worry among some particular groups especially, in more aged individuals and individuals with basic comorbid issues. It potentially affects the current disease, and the influenced people may prompt psychiatric symptoms which conceivably identified with the transaction of mental issues and invulnerability. The indications of COVID-19 can likewise deteriorate anxiety and cognitive stress among individuals who have poor mental abilities beforehand. Patients with prior serious mental disease have been influenced by the pandemic. Those people or patients who stay in the isolated wards for long-term treatment are at higher risk of cluster disease. Due to the need of maintaining social distancing, outpatients who are having SMI are defying inconveniences to get proper treatment and care and may end finally with mental backslide and circumstances that are uncontrollable. Patients with progressing disease furthermore need customary development in facilities that become hazardous and raise the chances of deterioration [18, 19].

3 Psychological Imbalance in Home Quarantine

Due to the pandemic, most countries were under public health emergencies which mainly affected personal freedom, emotional distress, and increased the risk of mental health [20]. To prevent the spread of disease, quarantine has been implemented in the entire globe for the safety of individuals and communities [21].

Isolation and Quarantine are much-utilized terms, movement restriction and separation of those individuals infected from a contagious form of disease or who have a history of exposure to the contamination defines the term quarantine. Quarantining the infected individuals is necessary to prevent the spread of infection to healthy people [21]. As per WHO rules, all nations have forced social separation which incorporates preventing individual gatherings together, shut down public places, for example, film corridors, schools, and colleges, avoiding public occasions, and so on to stop or limit the spread of sickness.

3.1 Some Major Risk Factors of Stressor in Quarantine

- **Time period of Quarantine**: Hawryluck et al. studies has shown that increased the duration of quarantine causes an elevated risk of mental health deterioration specifically, post-traumatic stress symptoms associated with behavioral changes and anger.
- **Fear of infection:** It can be viewed as one of the genuine danger factors causing poor psychological well-being, contemplating their wellbeing, or fears of contaminating others and relatives. In the event that they encountered any comparative indications identified with contamination misdirecting them, especially stress and dread that kept on being identified with mental results [22, 23].
- **Frustration and boredom:** These two terms are interconnected to each other, a state of high boredom results in more frustration [24]. As per the standard definition frustration refers to a feeling or expressing distress and annoyance coming from an inability to change or achieve something, whereas boredom is related with an empty feeling and prevalent emotion with negative mental health consequence [21, 24]. Lack of social and physical interaction with others, a decline in routine work, home confinement, and a feeling of isolation from the rest of the world results in boredom and frustration [21].
- **Inadequate supplies:** Unavailability of adequate basic requirements for daily life mainly food and lack of getting regular medical care results in frustration, anger, and associated anxiety [25–27]. The health care worker is mostly potential to emotional distress [21], due to insufficient supplies of necessary items such personal protective equipment (PPE), mask, gloves, other necessary kits, etc. [20], longer duration of working hours, taking risk of exposure to the virus to save other's life lead to adverse physiological outcome [28].
- **Improper sources of information:** Unclear information misguides people results in excessive worry and fear [21]. Unauthorized sources of news provide false information which may confuse the purpose of quarantine and its protocol [28, 29]. Adverse mental health experienced particularly depression related to inadequate information about the pandemic.

3.2 How to Minimize the Consequence of Home Quarantine

Implementation of quarantine is among the most important measures of prevention during a pandemic. However, it affected the psychological state of people, including anger, anxiety, stress, fear, frustration, post-traumatic symptoms, boredom, depression, etc. [30]. Various tips have been provided to overcome the effect of quarantine, several associations, and organizations including WHO, UNICEF, and APA contributed to mental health improvement [31, 32]. Aware of the purpose of social distancing, visual interaction with friends, sharing responsibilities, practicing self-care, and teaching children to practice hygiene, are some of the essential activities

which can be performed during quarantine [32, 33]. Some of the major possible ways which can reduce the effect of quarantine have shown below.

(a) **Reduce the duration of quarantine:** Some studies have already shown that the longer the duration of quarantine effect on the mental wellbeing of people, so shorter the duration of quarantine reduced stressor and observed positive impact on psychological state. Limited duration of quarantine can be imposed with the idea of a known incubation period, and not extending the duration of this, would minimize the effect on people [34]. Peoples are already under home confinement, extended quarantine results in more frustration, and anxiety [34].

(b) **Provide adequate requirements:** During quarantine, peoples are worried about basic needs including food and emergency medicines [35]. Due to a shortage of basic requirements leading to stress and mental weakness, mostly occurred in backward families. Government officials and authorities need to ensure the availability of requirements in every household, health care; financial, social, psychosocial support; and the basic needs must be provided immediately [36].

(c) **Awareness about the purpose of quarantine:** It's necessary to provide awareness about the importance of implementing quarantine, officials must properly communicate to the public regarding such preventive measures to reduce panic and improve compliance [37]. It must provide updated guidelines with reliable information about the quarantine, unclear information made public excessive stress and fear about the infectious disease. Unauthorized news and false information related to pandemic should have been avoided, the purpose of quarantine must have been understood by the public under quarantine [21].

(d) **Healthy lifestyle:** Due to the pandemic peoples were under home confinement and lack of interaction with each other, these made them mentally and physically weak. Regular physical exercise with meditation is useful to improve health and social wellbeing. Prepare a new daily routine for quarantine focus on maintaining cleanliness and hygiene is necessary. Proper utilization of time with children is also important including their educate children, practicing personal hygiene, and assigning simple household tasks.

(e) **Interaction with friends and family members:** Social networking systems play an important role in communicating with each other. Feeling of isolation, panic and stress reduce by communicating with relatives, friends, and their loved ones through social media [37]. It's necessary to set up a clear official emergency helpline for public health care authorities [21, 38]. Official helpline support for patient counseling through a telephone call or mobiles during quarantine could be effective in terms of positive psychological effects [38].

4 Psychological Imbalance in Hospital Quarantine

During a pandemic hospital staff is more vulnerable to infectious disease, leading to psychological distress [20]. Hospital quarantine and isolation are some of the most effective preventive measures by separating peoples, to prevent the spread of infectious disease [39].

4.1 Psychological Problem During Hospital Quarantine Can Be Categories into Two-Part [22]

New-onset mental health problems:

(a) **Anxiety which is related to personal health**: This may occur in case of mild to severe, can lead to a panic attack. It can be considered as one of the frequently observed problems, mainly arise because of the unsure report, fear of getting a positive result on the test, and stigma [40–42].

(b) **Depression and anxiety related to isolation**: During hospital quarantine, patients are staying apart from their family members and their loved's ones which leads to emotional and feels helpless [21, 22]. Another perception is that thinking about the unavailability of vaccine for the respective illness cause more depression and anxiety [43]. The guilty feeling associated with careless behavior causes illness, unable to continue regular duties, fear of turning illness into a severe case. These all are related to cause anxiety and depression [44].

(c) **Insomnia, irritability, anger, frustration, boredom** [42, 45]: Maximum of the patients who are under quarantine experienced such types of mental disorder [30]. These might be a predictable or non-predictable mental disorder. Identification of those patients who are undergoing these types of problems is very essential to overcome negative psychological impact [46].

(d) **Mental problem due to withdrawal of addicted substances** [22]: This has commonly occurred in drug-addicted persons who are under hospital quarantine. Due to unavailability and the sudden stoppage of addicted substances including narcotic and psychotropic drugs leading to irritability, frustration, anger, stress was observed in drug-addicted person [47].

(e) **Acute post-traumatic stress reaction and disorder:** These two are linked with mental illness. Causes of PTSD associated with traumatic events include sexual assaults, car accidents, animal attacks, and injuries due to accidental blasts.

4.2 Exacerbation of Preexisting Psychiatric Conditions

During hospital quarantine, those patients who are having psychiatric conditions from previous can exacerbate mental problems including stress, anxiety, stress, anger, frustration, etc.

4.3 There is Three Risk Factor Related to Exacerbation of Preexisting Psychiatric Condition

(a) **Discontinuation of medications:** Sudden discontinuation of ongoing medications of mental health problem due to some reasons including the inadequate supply of medications, kept confidential about mental illness, lack of awareness about mental health care service, and drug interaction.
(b) **Disease-related:** Physical health and mental health are interrelated to each other. Persons who are suffering from chronic diseases like diabetes, disease of heart, arthritis, asthma, etc. experienced mental illness [48].
(c) **Adverse effects:** Drugs such as chloroquine, steroids, and antiretrovirals used for the treatment of COVID-19 observed some adverse effects related to psychiatric symptoms. Indications are either the rise of new manifestations or the compounding of existing side effects [22].

4.4 How to Minimize the Negative Psychological Effect of Hospital Quarantine

Appropriate facilities and adequate supplies must be provided to those who are under hospital quarantine. Inadequate facilities are one of the negative impacts that arise by patients which cause more anxiety, stress, anger, depression, etc. [21]. The following measures should be facilitated for appropriate quarantine.

(a) Area must be well ventilated with maximum cleanliness, and hygienic washroom facilities should be provided, the distance between beds should be maintained at least one meter.
(b) Must follow the steps of waste management procedure and ensure facilities of air filtration system, can maintain environment as infection control.
(c) Accommodation must be provided including hygienic food, water with proper medication, and communication facilities with family members who are outside [21].
(d) Physicians and nurses must be there for regular medical checkups, counseling, and other related procedures for the purpose of maintaining their health.
(e) Accessories items such as the internet, news, and entertainment should be provided, which can help to reduce stress, anxiety, depression, etc.

(f) Psychosocial counselors must be available for counseling to the patients and sharing positive thoughts [21].

5 Psychological Approach to Assess Mental Health Post COVID-19

5.1 Relevance of Yoga on COVID-19

Yoga, an old method, is characterized as samatvam at both brain and body levels to be accomplished through dominance over the brain activities (chittavrittinirodhah). The accessible proof shows that yoga encourages the coordination among the arrangement of homeostatic reactions including the association among the endocrine, nervous, and immune system frameworks [49]. Since the transmission of the SARS COV-2 virus has started at the community level, the innovation of immunizations and drugs has been quickly started by Pharma organizations. Researchers and Scientists have been attempting to discover substitutes for counteraction and treatment of COVID-19. The specialists have additionally worked after demonstrating the function of Yoga and contemplation in improving physical and psychological well-being during this worldwide crisis. It was likewise found from an examination that individuals with constant lungs and coronary illness are at more danger for extreme cardiovascular and respiratory complexities from COVID-19. At the same time, doing meditation and yoga consistently has brought about essentially improved results in the condition of co-morbidity [50]. Various studies show that one of the major reasons for suppression in the immunity of the body is stress which may further lead to infection in the upper respiratory tract [51]. Stress factors can be acute in nature or chronic in nature, both can cause dysfunctioning of the Hypothalamus–pituitary–adrenal axis as well as the sympathetic nervous system and lead to the impairment of the body's immune response in case of any viral attack [52]. With regards to pandemics with people encountering significant levels of mental pressure, the tweaked hypothalamus–pituitary–adrenal axis hub through the act of yoga could mitigate pressure and could help in the reinforcing of the antiviral resistant actions by boosting the immune system. Results of a study that was randomly controlled, done on students who were healthy and young and were part of a yoga group showed a rise in the levels of interferon-gamma responsible for regulating immunity when compared to the students who did not perform yoga [53]. In light of its capacity to prompt and exactly manage the Interferon-gamma levels, yoga could alleviate the body's immune response during the brooding and non-severe stages to kill the infection-causing virus [54]. Infections of the Respiratory tract are profoundly common in patients with diabetes when contrasted with those who don't have diabetes [55]. One of the common comorbidities observed in COVID-19 patients is diabetes. Yang et al. reported in their study that 22% of patients of COVID-19 who could not survive because of severe illness had diabetes [56].

The impaired immune system, decrease in the response of T cells, decreased function of neutrophils, and dysfunctioning of humoral immunity are the major reasons for the association between COVID-19 and diabetes [55]. The pathogenic virulence can get alleviated due to the hyperglycemic state of the body in patients which can further decrease the interleukin production and can cause a decrease in the phagocytic activity [55]. As referenced above, fear, vulnerability, and demonization are factors related to stress which are seen during general wellbeing crises, for example, COVID-19 [57]. The stress incited initiation of the Hypothalamus–pituitary–adrenal axis could likewise altogether lead to hyperglycemia, [58] consequently intensifying the clinical indications. The above situation can be controlled by doing yoga which will keep the body stress level in check and will also help to maintain a proper glycemic level in the body. The act of yoga may help in diminishing the intensifications and leeway of infection in the patients of COVID-19 who are suffering from diabetes by decreasing the impact of hyperglycemia (Fig. 1).

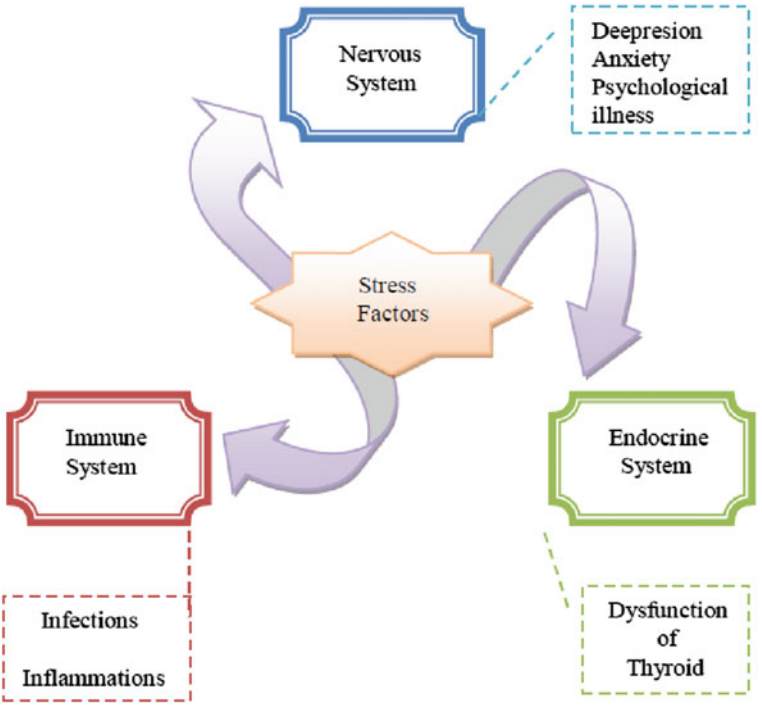

Fig. 1 Effect of stressors on different systems of body

5.2 Use of Digital Platforms

Different types of studies and research have shown that digital platforms and solutions can be highly effective in managing services related to health [59]. Artificial intelligence, online wellbeing networks, chatbots, Big data are among some of the digital platforms based which are being used to combat the situation aroused due to COVID-19 [60, 61]. Aggregating information from various potential sources including associated gadgets among the Internet of Things, climate observation and search engine query, data big data which is a cloud-based system was very well used in different pandemics or outbreaks of diseases during past years [62].

Utilizations of these frameworks range from the early discovery of episodes of outbreaks to encouraging worldwide collaborations in digital epidemiology. Fruitful applications incorporate checking dengue episodes utilizing information on portability from cell phones [62] or questions in different search engines [63]. Cornelia Betsch and the group assessed strategies for reconnaissance of social reactions to the pandemic [64]. These applications empower proof-based ways to confine public wellbeing reactions and screen their viability, in agreement with WHO suggestions [65]. Related applications for psychological wellness incorporate the forecast of issues, for example, sorrow, stress, and tension, utilizing openly accessible information from sites like Twitter [66]. These applications are picking up a foothold in scholarly awareness as computerized information turns out to be more universal, as illustrated by the advancement of proposals for proof-based exploration utilizing tools such as Google search to foresee mental issues [66, 67]. There are moreover approved personal-level utilization of the big data, for example, the utilization of ecological momentary assessment from versatile data of mobile phones that have been utilized to recognize and screen seriousness for a range of state of mind and behavioral issues [68]. This may lead to the possibility of getting accurate digital psychological health status with custom-fitted recommendations for the person, recently gone through mental disorders [69].

Computer-based intelligence chatbots use pre-customized substance and choice trees.

For computerized discussions utilizing strategies, for example, processing of the language. Then the static digital stores, are highly intuitive, prompting high commitment for the patients [70]. AI-based chatbot reports which have been created for psychological well-being incorporate arrangements giving guidance for well people to improve mental prosperity [71]. Others incorporate AI chatbots, for example, Wysa for advanced mental prosperity with showed adequacy in patients with stress and Woebot for psychological cognitive treatment in grown-ups with anxiety/stress indications [72]. In promoting mental health and preventive care during pandemics like COVID-19, these tools are found useful. Nonetheless, their applications should be directed given restricted clinical approval with a powerful trial plan. Given the idea of linguistic varieties and chatbots in various populaces, assimilation is expected to encourage the usage of chatbots in new populaces. This is essential to guarantee emotional help or emergency advice is seen precisely by patients [73].

Advanced services of tele-health have various exemplifications such as video-conferencing, tele-monitoring using remote devices, health applications based on mobile operating systems which are all inexorably applied in calamities. These can be utilized for conversations among patients and medical practitioners and service providers [74]. Although changes in legislation have been to do to start the use of tele-health services still there are obstructions because of which it is still yet to come into the mainstream. Effective adoption requires a dynamic arrangement with clinical necessities while conveying administrations.

5.3 Shielding Measures in Psychiatric Hospitals

Since COVID-19 is an infectious ailment, it is smarter to assume that each individual has a speculated contamination, particularly under the accompanying conditions:

- Clinical side effects of ailment (e.g. cough and fever).
- Contact history with any COVID-19 infected individual.
- History of movement to a region where the virus has spread.

Mental hospitals or healthcare facilities can be sources of COVID-19 transmission as they may have patients who might be having the COVID-19 infection and these potential people may transmit the virus to asymptomatic people. All the professionals working in a mental healthcare facility or hospital should be up to date with all the available recent data and learning on COVID-19 and these data should be referred from reliable sources like healthcare administration, or different sites of government.

Different sources of transmission of viruses may be blood, fomites, aerosols, or small respiratory droplets. Whereas in the case of the COVID-19 virus the virus transmission occurs by an individual to individual contact via small respiratory droplets or via contaminated surface.

As still, there is no solid cure for this disease all the precautionary principles should be followed strictly maintaining the social distancing effectively by staying 1 m apart from other individuals and regularly doing surface sanitization [75].

5.3.1 Out-Patient Services

While giving services to the out-patients medical healthcare professionals should consider the below points:

- Appointments of out-patients should be staggered and if possible. Seeing patients on an appointment basis will drastically reduce the overcrowding of patients.
- Only one attendant per patient should be allowed and followed strictly.
- In consultation rooms and cabins of doctors strictly social distancing should be followed.

- Using COVID-19 screening method suggested by ICMR, risk assessment of bystanders and patients should be done at the point of intake.
- In a properly ventilated room, people at high risk should be assessed exclusively.
- To symptomatic patients, face masks should be provided so that transmission of the virus through respiratory droplets can be prevented.
- A separate examination room for violent patients should be allocated to prevent them from coming in contact with other individuals.
- People like pregnant women, elderly people, and children who are more vulnerable to infections should be attended to first by the doctors [75].
- For stable patients and those who need the only represcription, telepsychiatry can be considered.
- Washing of hands as per WHO recommendations following all the eight steps should be done before touching a patient, after doing physical examination or procedure which involves coming in contact with body fluids.

5.3.2 In-Patient Services

- Wards should be clean frequently or at least once every four hours.
- One percent hypochlorite solution or at least soap water should be used and WHO recommendations should be followed while mopping of floors.
- Sixty percent of alcohol should be used while cleaning surfaces like tables, chairs, etc.
- Before and after food is served, the cleaning of the dining area should be done regularly.
- Visitors should be provided with masks and they should be restricted only to the visitor's area.
- Visitors should not be allowed on the premises if they are having symptoms of COVID-19 infection [75].

5.4 Rehabilitation of Mental Health in Times of COVID-19

The constant concerns identified with the spread of COVID-19 have executed different ways by which the contamination can be stopped from spreading further. These join social isolating, regular washing of hands with a cleaning specialist and water or using a hand sanitizer for cleaning purpose, utilization of face covers by individuals who have clear indications or are at high peril, and avoiding touching of eyes, nose, and face with hands [76].

The psychological health issues which have become apparent because of these measures are fear and nervousness in the general public. These show as wellbeing tensions over contacting any possible virus-contaminated surface, meeting an individual with a recent history of traveling including a visit to profoundly contaminated places, or building up any signs of infection in the upper respiratory tract [coughing,

sniffling, fever]. While these psychological well-being fears and tensions are probably going to be mellow and short enduring, for the individuals undergoing mental rehabilitation significantly. Because of maintaining social distancing, day boarding, and daycare habitats for people with mental illness have been shut down, for the time being. The medical services have been encouraged to provide treatment on an emergency basis, and individuals with other medical issues, including mental health issues, can stand by till the predominant COVID-19 related circumstance improves. Subsequently, people with ongoing psychological issues who need standard clinical care are denied, as they are not in a situation of emergency. As rehabilitation of mental health falls under a category that is not considered an emergency. Therefore, services related to intellectual disabilities and psychological issues may be denied for some time [76].

There should be a development of a home-based rehabilitation plan made in coordination with MHPs, family members, and friends under which the following points can be considered:

- Concerns of each individual in the family should be considered and addressed so that an effective communication process may develop.
- Give consolation—He/she may need consolation that the situation is going to be alright or need assistance to address employer or need some particular timely information about COVID-19 disease or simply have a conversation with a vocational instructor.

5.5 Coping Mental Health Issues in the Wake of COVID-19 Pandemic

While the medical services area along with government authorities from everywhere all over the world are zeroing in on the contain and control the pandemic receiving different preventive procedures, there is small consideration given to the psychological status of those in isolation, stressed, and house-quarantined individuals. Because the absence of normal social exercises and remaining at home for a long time will affect their mental wellbeing. Too much exposure to coverage of media should be avoided to prevent any stressful situation. Communication using with family members and friends on a regular basis should be done with positive thinking to maintain a good relationship. As joy increases when it is shared, similar to that in this situation of a pandemic the fear should be also shared with close friends and family members to reduce the stress to a significant extent. Yoga, regular exercise, and meditation should be practiced regularly to calm the mind. Teleconsultation for those who have lost their close and dear ones because of COVID-19 should be given by the medical practitioners to provide mental support. Regular breaks between duty hours minimized duty hours along with a rotation of duty should be given to the healthcare workers who are battling the pandemic in the frontline to boost their morale [77, 78].

The medical services professionals working for COVID patients and working in clinics and isolated wards likewise need to have their psychological wellness overseen. The pressure of the work they are doing will get to them and it will be hard for them to manage circumstances once cases heighten. Customary mental health care for these specialists, medical attendants, and staff is significant for us to have a steady medical services framework to battle COVID. There is likewise a requirement for preparing these staff in communication and building their versatility for the difficult stretches that they will look forward. Along with them their family members also should be looked after in reference to mental health and stress. On a regular basis, counseling should be given by field experts for their psychological well-being (Fig. 2).

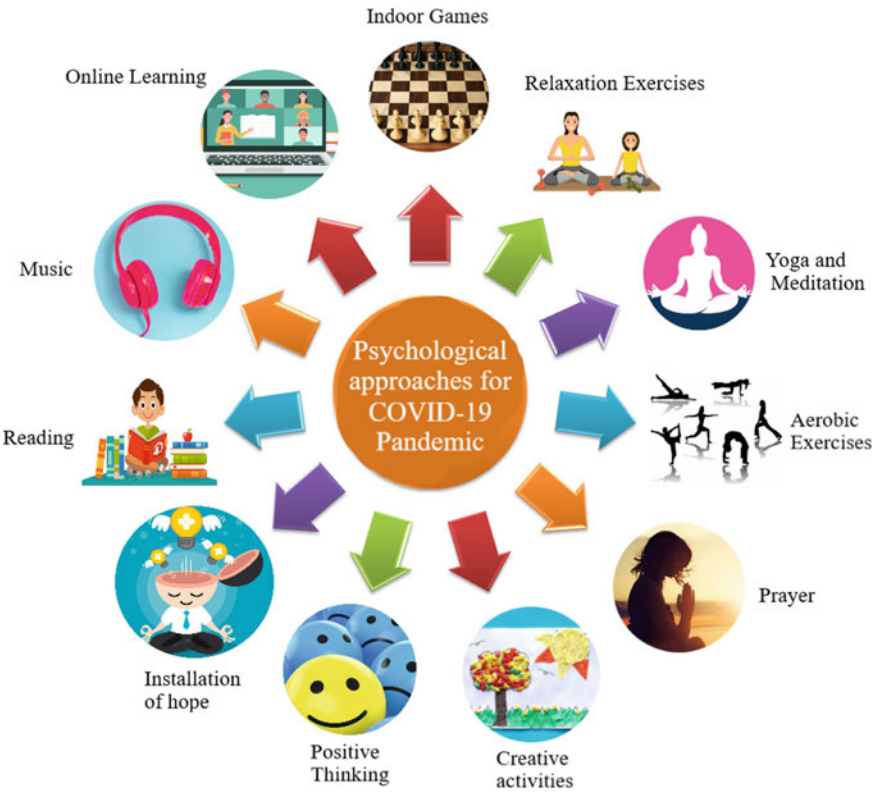

Fig. 2 Psychological approaches for COVID-19 pandemic (adapted and modified from Sujita et al. [79])

6 Steps to Mitigate Pandemic in Future

Pandemic readiness and reaction intercessions can be grouped by their planning as for pandemic events: the pre-pandemic period, the flash time frame, and the spread time frame. The administration responsible for pandemic readiness and reaction is perplexing, with power divided across worldwide, public, and subnational establishments, just as among numerous associations with functional duty regarding explicit tasks [80].

6.1 Awareness of Situation

Awareness of the situation is a pivotal movement at all phases during a pandemic, including pre-pandemic, flash, and periods of spread. It needs the help of medical care assets, (for example, clinics, specialists, and attendants), diagnostic institutes, and communication frameworks. It likewise requires the populace to approach and trust in the medical services framework. Awareness of the situation upholds policy choices by following if and where transmission of the disease is happening, recognizing the best strategies to decrease contagiousness, and choosing where to designate assets. During a pandemic, situational awareness takes into consideration observing to comprehend the course a pandemic is taking and whether intercession measures are successful. The capacity to distinguish and handle a pandemic needs the medical services force to perceive the sickness and to have the specialized and research facility ability to recognize the microorganism and react to floods of clinical examples in an opportune way. Quickly recognizable proof lessens hazard by empowering contaminated people to be secluded and given suitable clinical consideration [81].

6.2 Eliminating Sparks of Pandemic

Most pandemic preparation practices base on lessening mortality and morbidity after the spread of a pandemic, by and large, activities, in particular, may contain and prevent pandemic shimmers before they become a more broad risk. At the focal point of the pandemic, the expectation is the possibility of One Health, a technique that considers human prosperity, animal prosperity, and the surrounding environment to be interconnected [82].

6.3 Communication of Risk

Communication regarding the risk can assume a critical part in the control of an arising scourge or pandemic by giving data that individuals can use to make a defensive and preventive move. The spread of fundamental data, (for example, how the microorganism is communicated, direction on overseeing tolerant consideration, high-hazard rehearses, and defensive conduct measures) can quickly and altogether decrease the transmission of sickness. The manner by which hazard correspondences are outlined and sent matters a lot; they should be clear, straightforward, convenient, and conveyed by believable couriers. Factors, for example, education rates, social sensitivities, knowledge of logical standards, (for example, the germ hypothesis of illness), and dependence on oral versus composed conventions all have suggestions for how messages ought to be planned and conveyed [83].

6.4 Scaling up of Potentials

The term scaling up alludes to the extension of health mediation inclusion. With regards to pandemic readiness, effectively scaling up requires health system frameworks to grow to oblige quick expansions in the number of suspected cases. Scaling up is supported by flood limits (the ability to draw on the extra clinical labor force, logisticians, and financial and various resources) similarly as past operational associations and plans interfacing government, non-administrative affiliations, and the private zone. In the end, scaling up contains having both a nearby flood limit and the absorptive capacity to recognize outside assistance [84].

7 Conclusion

Psychological presentations post-COVID-19 are normal. Identification of basic indications is useful to guarantee that early mediation is given. Mental issues following the pandemic are likely going to be typical. Most impacted will require simply short assessments and snappy assistance. This will require all front-line faculty to be gifted in the clear mental assessment of the impact locally and treatment settings of COVID-19. Separation and social removing in the hours of an irate pandemic can be intellectually disturbing for certain people. Regardless, there are clear and convincing moves that you can make as a medical services provider. The key among them is giving information. As a medical services provider, you would be seen as a strong and trustworthy wellspring of information. Explain the thinking of segregating and socially isolating. Advance strong wellsprings of information. Educate patients on what manifestations to keep an eye out for and what side effects not to stress over. Urge individuals to stay in contact with one another over virtual methods.

Understanding the psychological well-being requirements of individuals in clinical isolation is significant as it's presumably that many are probably going to create mental issues that need early mediation. Practically all forefront staff in pandemics like COVID-19 are probably going to encounter pressure in a specific way. Steps should be taken proactively to guarantee that it stays in charge. Personnel should rehearse 'self-care'. Group pioneers should utilize steps to limit psychological wellness challenges. Directors should know that the emotional well-being backing of staff is a significant piece of the COVID-19 reaction. Above all, personnel needing support should be distinguished and offered proper mediation to forestall negative results. Social disgrace increments during irresistible sickness flare-ups and is frequently not given the accentuation required. Steps should be taken at all levels to guarantee that disparaging practices are unequivocally debilitated. The mental methods portrayed can be utilized to determine some genuine circumstances experienced in numerous settings following COVID-19. The means are straightforward and can be utilized by cutting-edge staff to determine these circumstances. Conveying, preparing, and uphold through innovation has numerous advantages. The patient/guardian can utilize refreshed electronic verifiable data to follow best practices. Subsequently, the innovation can be an extraordinary empowering influence in this COVID-19 pandemic. Telepsychiatry counsels should be mainstreamed to guarantee sufficient consideration of patients with psychological well-being issues during the current COVID-19 pandemic. It is the ideal opportunity for us to be ingenious and guarantee the process of rehabilitation is on the track. We need to pause and look regarding when services of rehabilitation can be restarted. It is darkest before sunrise and better days anticipate.

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Predicting the COVID-19 Outspread in Andhra Pradesh Using Hybrid Deep Learning

Bhimavarapu Usharani

Abstract COVID-19 is one of the major health care challenges around the world today. Physical detection of COVID-19-positive patients is time consuming due to the limited data sources. The deep learning classifiers and the blood test parameters perform a significant part in the prediction of the disease and death rate of COVID-19. Parameters such as age, gender, lactic dehydrogenase (LDH), and lymphocyte count reports the severity of COVID-19. The features lactic dehydrogenase (LDH), C-reactive protein (CRP), and lymphocyte count predicts the mortality of the COVID-19 patients with accuracy. Deep learning classifiers can detect nonlinear relationships and interactions between parameters, explaining better performance.

Keywords Artificial neural network · Coronavirus · COVID-19 · Deep learning classifiers · Gated recurrent unit

1 Introduction

The full form of COVID-19 is the coronavirus disease of 2019. The International Committee on Taxonomy of Viruses (ICTV) authoritatively identified the 2019 novel coronavirus as a Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2) [1, 2]. COVID-19 was officially named by the WHO on 11 February 2020 [3] in the International Classification of Diseases (ICD). The COVID-19 virus emerged in Wuhan, China, on 19 December 2020 and mushroomed all around the globe, becoming a major health issue [4, 5]. In Wuhan during the first week of January 2020 one adult tested positive, and three adults tested positive during the second week of January 2020 [6]. Coronaviruses are zoonotic, and this human-to-human transmission of COVID-19 is due to unprotected contact [3]. The COVID-19 cases that were reported in India by 28 September 2020 numbered 60,73,348 and the death rate stood at 95,574 [7]. The state of Andhra Pradesh stood in second place with confirmed positive cases being 675,674 [7]. The second wave of COVID-19 is very

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dangerous and the top ten confirmed COVID-19 cases for 6 April 2021 is given in Fig. 1.

India has the third largest number of coronavirus cases in the world, and its infection numbers are rising again. Some of India's neighbours are also experiencing a rise in infections. South Asian countries hold ramped over checking out then Sri Lanka, India, or Pakistan at present study inside the measure deemed ample by way of the WHO. As of March 2021, according to COVID-19 statistics, the highest number of mortalities are noted in India, Iran, Indonesia, Turkey, and Iraq along extra than three lakhs' mortalities combined. State-wise confirmed and recovered cases in India are represented in Fig. 2.

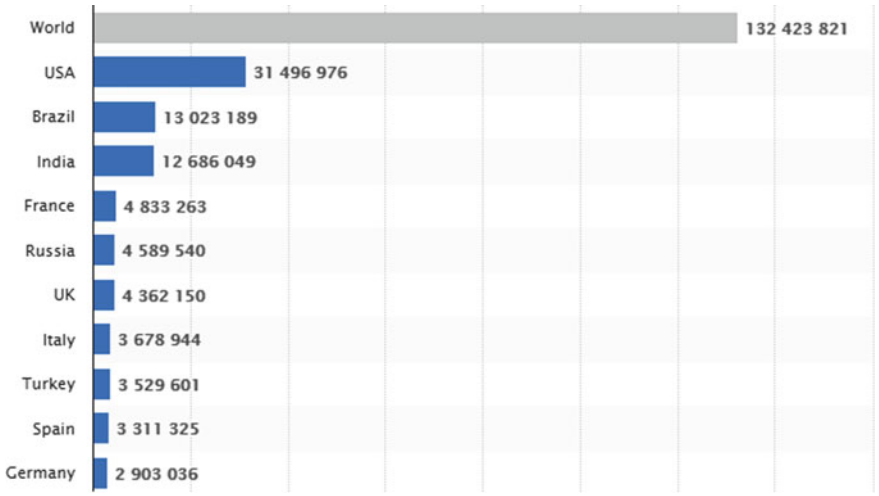


Fig. 1 Total top ten COVID-19 cases in the world as on 6 April 2021

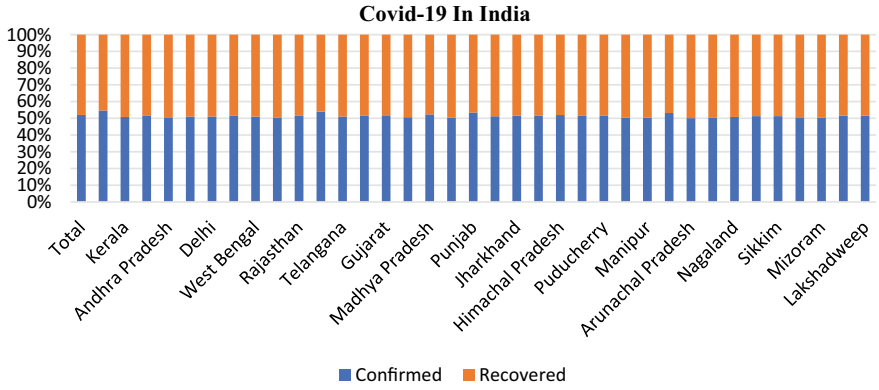
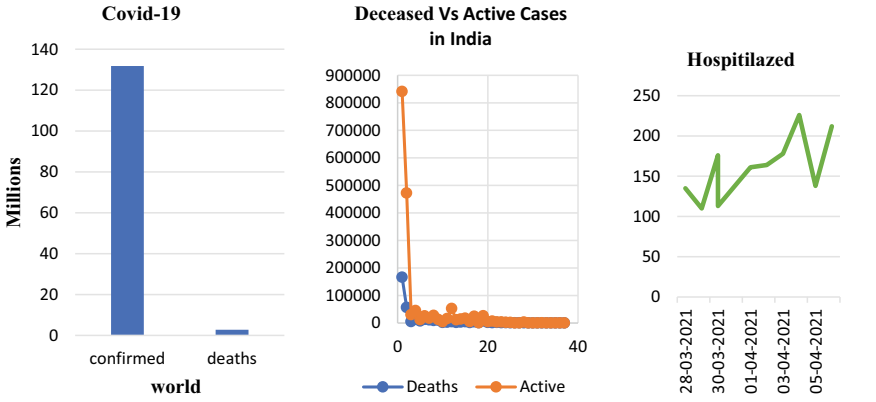


Fig. 2 COVID-19 in Indian States on 6 April 2021



(a) Covid-19 cases in the world as on 06/04/2021

(b) Deceased vs active covid cases in India on 06/04/2021

(c) Hospitalized in Krishna District in Andhra Pradesh up to Aril 06,2021

Fig. 3 COVID-19 cases as on 6 April 2021

The per-period instances attenuate mid-September among India with 90,000 instances referred to per time or have because occur below to under 15,000 as regarding January 2021. On 4 April 2021, India became the 2nd USA, into the submitted extra than one lakh cases in a single day, afterward USA. Reported COVID-19 cases in exceptional regions durability are shown in Fig. 3.

The COVID-19 pandemic in Southeast Asia is shared over the continuous world-wide contagion of coronavirus sickness 2019 (COVID-19) generated by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). As of 7 April 2021, Indonesia has the highest number of cases or deaths, ahead about the Philippines within each aspect's stability. A report on Asian countries showing confirmed cases as of 7 April 2020 is shown in Fig. 4.

At present, current improvements within machine learning, mainly deep learning (DL) techniques using convolution neural network and ConvLSTM partake in the proven hopeful overall performance in recognizing, categorizing, and measuring disorder outlines into health snapshots [8–14], especially for detection concerning COVID-19 [15, 16]. For example, Rajaraman et al. [15] introduced a procedure using a convolution neural network for COVID-19 exposure. They conveyed their procedure outdoors over a kind of X-ray image called CXR images. They acquired better precision for classifying COVID-19 statistics. The authors [15] advanced an approach for computerized reckoning concerning COVID-19 as the use of an extreme study deep convolutional neural network (DCNN) created using Inception V3 mannequin or heart X-ray images. They acquired far better accuracy for their findings regarding COVID-19. The author [16] employed a discipline approach because of the array of COVID-19, pneumonia, or breast X-ray graphs. They mated the beneficial common precision because of validation so 0.9725 stability.

The uniqueness of this study is recapped as follows.

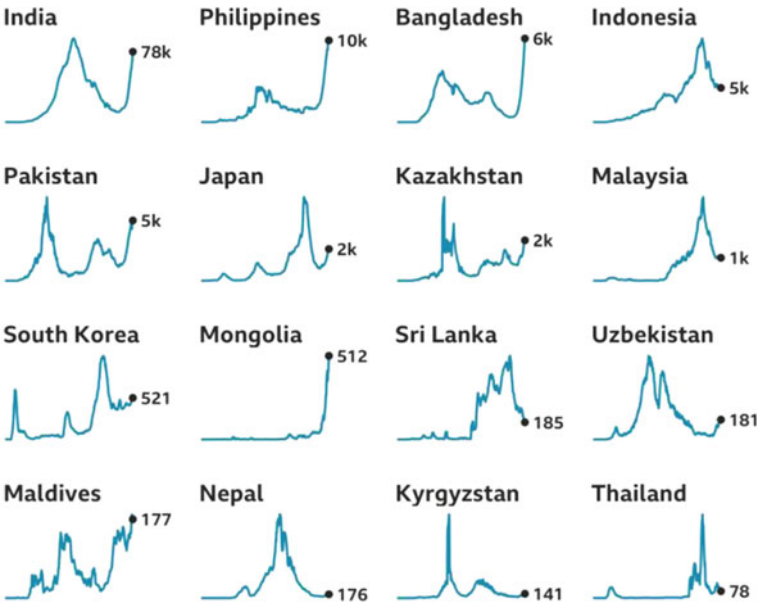


Fig. 4 Countries with the highest number of cases on the Asian continent as of 7 April 2020

- Forecast of COVID-19 infection with deep learning.
- To determine the diagnostic accuracy of a deep learning classifier built for the identification of COVID-19 utilizing results of the blood tests.

In this paper, there is an automated prediction of COVID-19 using a deep learning technique, habits, and food diet. For this, applied hybrid deep learning pretrained modes were used to obtain a higher prediction accuracy. This research may encourage the researchers to innovate the models by using the blood sample data. The balance of the paper is planned as support. Section 2 recaps the earlier deep techniques for COVID-19 and other medical images. Section 3 discusses the suggested approach. Performance measures are examined in Sect. 4. Finally, this paper is summarized in the Conclusion section.

2 Related Work

The authors identified the CD39 (Cluster of Differentiation 39) in the blood of COVID-19-confirmed individuals [17]. For COVID-19 there was a reduction in NK units in the life blood of COVID-19 patients.

2.1 Anomaly Detection

Anomaly detection also helps to detect COVID-19. Convolution neural networks established generative types such as Generative Adversarial Networks [18] and Variational Auto Encoders [19] that are used for unsupervised anomaly detection. The expansions such as the context encoder [20], Constrained Variational Auto Encoders [20], Adversarial Auto Encoder [21] and Bayesian Variational Auto Encoders [22] improves the accuracy of the projections. The authors [23] proposed a CAAD (Confidence Aware Anomaly Detection) model and a confidence prediction network for viral pneumonia screening and achieved accuracy of 83.61%.

2.2 Deep Learning Techniques

The authors [24] established a deep neural network architecture to recognize the greatest mortality prognostic variables from the clinical variables. The authors identified D-miner, O2 index, CRP and diarrhoea as the top predictors to predict the mortality rate. The authors [25] applied the deep CNN model to uncover COVID-19 and this deep CNN model consists of five convolution layers. Features are extracted from deep CNN and used the machine learning algorithms KNN, SVM, decision tree. The authors obtained the highest accuracy of 98.97% for SVM by using the COVID-19 radiology dataset. The authors [26] used the MobileNetV2, SqueezNet together with Social Mimic Optimization (SMO) method. To pre-process the images fuzzy colour techniques have been used and to reconstruct the images image-stacking has been used. The X-ray images were categorized using the support vector machine technique and accomplished accuracy of 99.27%. Kumar et al. [27] uses the techniques VGG, DenseNet, AlexNet, MobileNet, Resnet and capsule Network to acknowledge the models in lung screening. They proposed a technique to share the patient's data securely with the assimilation of the amalgamated learning and the blockchain. The proposed deep learning model, i.e. the capsule, network achieved an accuracy of 83% and sensitivity of 96.7%. Medical imaging has been used to become aware of cardiovascular illnesses [28], Genius tumours [29], yet nowadays clinical imaging is also life saving because of detection regarding COVID-19.

The major issue over function extraction may be tackled through making use of state-of-the-art extreme discipline methods. SqueezeNet, along Bayesian optimization regarding constraints certain as like researching percentage then momentum have been employed in [30]. Transfer discipline over pre-trained Xception CNN structure is exploited with the aid of authors of [31] in imitation of X-ray images of four categories, specifically COVID 19, pneumonia viral, pneumonia bacterial and normal. The mannequin obtained a better precision about 4 organization class arrangement. In [32], ResNet was employed because of characteristic abstraction on which an array standard is utilized in conformity with marshal image so COVID and nonCOVID.

This pattern accomplishes an exactness and a 121-layered pretrained Densenet structure called Chexnet, employed in [33] to notice pneumonia between 112,120 X-ray photographs on 30,805 exceptional patients. That technique is prolonged after observing fourteen diseases between X-ray images. In [34], a pretrained InceptionV3 was employed because of the abstraction of an image embedding. The acknowledged configuration was able to register unique respiratory illnesses expertly or carried out an exceptionally excessive accuracy regarding the illness. A deep adaption algorithm used to be recommended between [35]; the authors of that procedure offered a pneumonia classifier in accordance with observing the COVID-19 disorder by means of working usage of both mutual and awesome functions on COVID-19 yet pneumonia. In [36], the authors applied a pretrained Resnet50 for characteristic abstraction or support vector machine because of alignment and did a truth about 95% regarding geminate classification. In [37], they used Darknet or different filtering of each stratum then carried out a proprietary at about 98.08% regarding binary classification and 87% of the alignment on X-ray pics as like pneumonia, COVID-19 then normal. A stacked version containing a pretrained VGG19 paradigm or an instant 30-layered COVID discovery mannequin is recommended in [38] because of function abstraction, while the Logistic regression procedure is employed because of categorization on X-ray photographs and discovery about COVID-19. The authors of [39] did an assessment of several pretrained fashions or past to that amount Resnet50 achieves the maximum accuracy about 98% among the discovery about COVID-19 among InceptionV3 and ResNetV2. In [40], they anticipated a sound instruction pattern because inspection regarding COVID-19 using pre-processing picture methods established totally about HU values, yet 3D convolution neural network fashions for function origin beyond X-ray illustrations. In [41], a pretrained Chexnet model was used for spotting anomalies within thorax X-rays after aligning into usual pneumonia, COVID-19. A SE-ResNext101 encoder along SSD RetinaNet is employed [42]. This mannequin was adjusted regarding a database including heart X-rays over 26,684 special patients. Every illustration is labelled including certain three one-of-a-kind lessons from the related radiological [43] reviews: No Lung Opacity (or) Not Normal, Normal, Lung Opacity, in view that lung imprecision is a considerable symptom of pneumonia. The authors among [43] aged convolution neural network architectures, inclusive of InceptionV3, InceptionResnetV2, yet Xception because of alignment regarding chest X-ray images while numerical procedures, like, Markov chain Monte Carlo (MCMC) yet genetic algorithms are aged in imitation of note the hyperparameters regarding the representations. In [44] the developers pretrained convolutional neural network techniques as Alexnet, VGG16, VGG19 for characteristic abstraction. The characteristics presented out of the patterns stated upon have been afterwards reduced with the assistance concerning minimal dismissal maximum relevance sets of rules.

3 Methodology

The methodology that was followed in this present work is depicted in Fig. 5.

3.1 Deep Learning Classifiers

Deep learning techniques have risen quickly then have been extended for purposes in more than a few scientific or industrial domains. Healthiness informatics [45], power [46], municipal informatics [47], security [48], protection [49], hydrological systems modelling [50], pecuniary [51], bioinformatics [52], and computational mechanism [53] have been among the most requested areas on deep learning. Deep learning is a subgroup concerning machine learning, and refers after the utility of a embark concerning algorithms known as neural networks and their variants.

3.1.1 ANN

Artificial Neural Networks is an AI model inspired by the framework of biological human neurons. It has been applied to different fields. ANN provides a correlation among the input and the output data, for this it is essential to be trained using a set of data involving input and the subsequent output statistics. ANN includes three layers: (1) input layer; (2) hidden layer; (3) output layer. The Activation Functions are given as:

$$a_j(t+1) = f\left(a_j(t), p_j(t), \theta_j\right) \tag{1}$$

$$o_j(t) = f_{\text{out}}\left(a_j(t)\right) \tag{2}$$

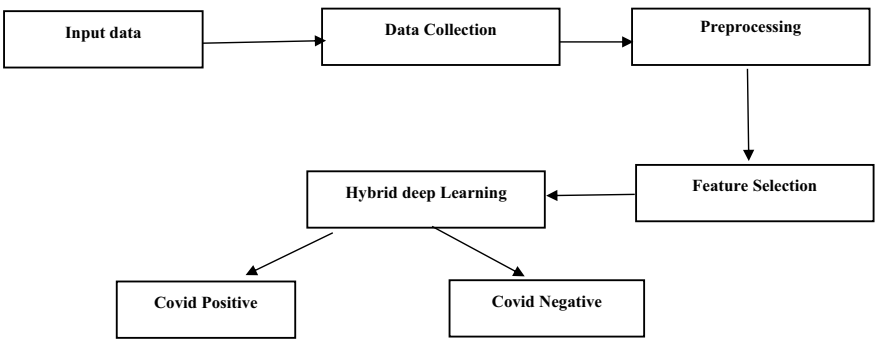


Fig. 5 Proposed methodology flow chart

$$p_j(t) = \sum o_i(t) w_{ij} \tag{3}$$

$$p_j(t) = \sum o_i(t) w_{ij} + w0_j \tag{4}$$

3.1.2 GRU

G is a simple modification of the LSTM that has two gates: one is the update gate and reset gate, update gate which contains of input, forget gates. GRU has no extra memory to maintain the info, so it can regulate data within the unit, where:

$$t = \sigma(Wzxt + Uzht - 1 + bz) \tag{5}$$

$$rt = \sigma(Wzxt + Uzht - 1 + bz) \tag{6}$$

$$\hat{h}t = \varphi(Whxt + Uh(rtht - 1) + bz) \tag{7}$$

$$ht = (1 - zt) \circ ht - 1 + zt\hat{h}t \tag{8}$$

xt	input data.
ht	output data.
$\hat{h}t$	Candidate activation function.
zt	update gate data.
rt	rest gate data.
W, U, b	Parameter matrices data.

3.2 Data Pre-processing

The imported data may consist of unfilled data. To complement the incomplete clinical measures the"− 1" padding technique was used.

3.3 Feature Selection

Algorithm 1: COVID-19 Analytics Algorithm

Result: Prediction of COVID-19

Initialization.

1. Acquire the data from the database.
2. Apply the data filtering technique. Select only those blood test parameters at the final diagnosis as the subset.
3. Perform data pre-processing techniques such as handling the missing values and remove the erroneous values or outliers. The missing data were padded with"− 1".
4. Use the ANNGRU predictive model.

The COVID-19 analytics algorithm is a deep learning-based algorithm consisting of five steps. The steps are as follows: the first step is the data acquisition step, i.e. gathering the data from the dataset; the second step is the data training and it consists of the blood test parameters obtained from the patient's final diagnosis; the third step is the data pre-processing that handles the missing values and removes the erroneous values or outliers. The missing data were padded with"− 1″. The fourth step is building the diagnostic model using the deep learning algorithm; the final step is evaluating the model using the stratified tenfold cross validation. In the evaluation method, the hybrid models used were the Artificial Neural Network (ANN) and Gated Recurrent Unit (GRU).

4 Performance Measures

4.1 Experiment Setup

The integration of the sixteen blood test parameters might achieve the high-level performance to precisely distinguish the morbidity of COVID-19. The COVID-19 dataset that is used in this research is available in IRCSS [54]. The dataset consists of 279 records. This data is extracted from hospital patients that were admitted between February to mid-March 2020. It is important to select the appropriate number of parameters for the prediction of the disease and deaths from COVID-19. The sixteen parameters were carefully selected as the final indicators for input as described in Table 1.

Table 1 Laboratory findings in the dataset

Laboratory findings	Gender, age, white blood cells, Piastrine, Neutrofili, Linfociti, Monociti, Eosinofili, Basofili, C-reactive protein, Aspartate aminotransferase, Alanine aminotransferase, Alkaline phosphatase, Gamma glutamyl transferase, Lactate dehydrogenase, target

4.2 Performance Metrics

The accomplishment of the deep learning classifiers on the test set is measured by applying the metrics sensitivity, specificity, precision and accuracy. The formulas for the sensitivity Eq. (9), specificity Eq. (10), precision Eq. (11) and accuracy Eq. (12) are given below.

$$\text{Sensitivity(or Recall)} = \frac{\text{tp}}{(\text{tp} + \text{fn})} * 100 \tag{9}$$

$$\text{Specificity} = \frac{\text{tn}}{(\text{tn} + \text{fp})} * 100 \tag{10}$$

$$\text{Precision} = \frac{\text{tp}}{(\text{tp} + \text{fp})} \tag{11}$$

$$\text{Accuracy} = \frac{\text{tp} + \text{tn}}{(\text{tp} + \text{fp} + \text{tn} + \text{fn})} * 100 \tag{12}$$

4.3 Performance Results

The test set was completely independent of the training set to prove the stability and reliability of the deep learning classifiers. The parameter target is binary; if it is 0 it means no COVID-19 infection, while 1 means a COVID-19 infection is present. When the coronavirus infection penetrates the human physique, the alignment of the plasma varies, and the parameters discussed in Table 1 play a vital role on identifying the morbidity rate of COVID-19. For COVID-19-tested confirmed individuals there is an increased aspartate aminotransferase, reduction of white blood cell numbers, improved alanine aminotransferase, enhanced lactate dehydrogenase and increased C-reactive protein. Parameters such as age, gender, lactic dehydrogenase (LDH), C-reactive protein (CRP) and lymphocyte count reports the severity of COVID-19. The features lactic dehydrogenase (LDH), C-reactive protein (CRP) and lymphocyte count predicts the mortality of the COVID-19 patients with accuracy. The accuracy rates for survival, morbidity and mortality are shown in Fig. 6.

The first parameter, gender, plays an important role—male patients were more expected to be affected by COVID-19 than female patients. During the COVID-19 pandemic the vulnerability of males has been higher than for females. Thus there was a correlation between gender and the mortality rate of COVID-19. The total number of patient records in the dataset was 279. Out of the 279 records, 188 were men and 91 women. The average age of the corona-infected individuals in the dataset was 61.34 years. The missing data were padded with"-1″. White blood cells play a vital role in the human immune system. The white blood cells recognize when the

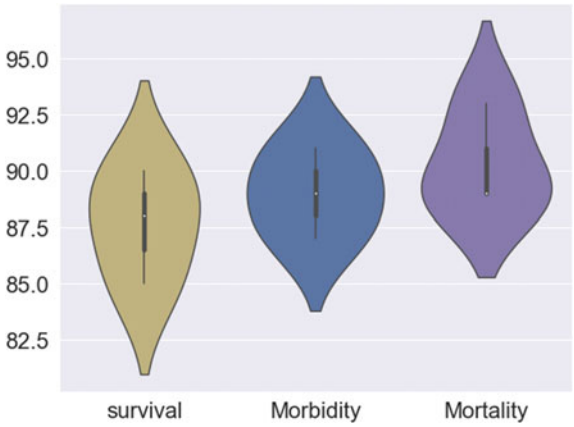


Fig. 6 Plot for performance on testing data

virus or bacteria enters the bloodstream and they destroy the harmful particles that can cause disease. A low white blood cell count (WBC) has the potential to become life threatening in infectious diseases such as COVID-19. The performance of the Mean in the deep learning classifiers in discriminating mortality outcomes is shown in Fig. 7.

WBC is a strong predictor of mortality rate. Ten distinct deep learning application versions are employed as classifiers. Predictions were presented and the accomplishment of these ten different classifiers was evaluated. In terms of performance, the best identified model in the LSTM family is the GRU for predicting the COVID-19 disease. The execution of the algorithms was tested using the 75–25 train test split methodology. Table 2 shows the performance outcomes of different deep learning

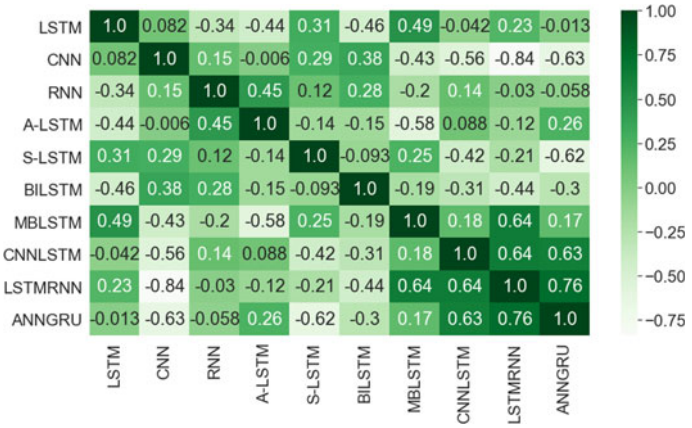


Fig. 7 Performance of the mean of the deep learning classifiers in discriminating mortality outcomes

Table 2 Results of deep learning classifiers on the test data

	Precision	Recall	Accuracy	*F*1-score	AUC
LSTM	0.8675	0.9942	0.8666	0.9189	0.6250
CNN	0.8948	0.9248	0.8800	0.8913	0.6147
RNN	0.8785	0.9598	0.8506	0.9058	0.5245
A-LSTM	0.8708	0.9857	0.8775	0.9234	0.6150
Stacked LSTM	0.8783	0.9581	0.8568	0.9054	0.5248
Bi-LSTM	0.8695	0.9932	0.8623	0.9389	0.6550
MBLSTM	0.8758	0.9548	0.8056	0.9138	0.5278
CNNLSTM	0.8926	0.9218	0.8416	0.9001	0.5889
LSTMRNN	0.8977	0.9423	0.8568	0.9120	0.6408
ANNGRU	0.9195	0.9948	0.9456	0.9423	0.9178

classifiers with the train test separation approach. The most excellent execution was obtained with the ANNGRU hybrid model at 94%.

In Table 2 the exactness outcomes of all deep learning classifiers were achieved above 80%. ANN provides a robust result, and it does not impose any restriction on the input. ANN can produce robust output even in the case of missing information. GRU train the data fast and outperforms better for large datasets. In experiments for GRU the number of neurons taken are 1,632,664,128, the learning rate is 0.001, the activation function used is RELU, the optimizer used is Adam, batch size is 10, the number of epochs taken is 500 and the time step is 3. The performance measures considered in this paper are precision, recall, accuracy, *F*1-score and AUC. Precision can be characterized as the ratio of the accurately predicted positive case to the aggregate predictive positive cases. In this research the precision obtained high to the ANNGRU with 0.9195. Recall is the proportion of correctly predicted positive cases to the total number of cases. In this research the high recall obtained to the ANNGRU with 0.9948. *F*1-score is the weighted average of the precision and recall values. The performance of standard deviation of the deep learning classifiers in discriminating mortality outcomes is shown in Fig. 8.

The *F*1-score obtained with ANNGRU is 0.9423 and is the best when compared to the remaining classifiers. AUC is a measure to identify which of the classifiers predicts the best score. The obtained AUC score with ANNGRU is 0.6578. In this research, a deep learning classifier is used. The comparison of different classifiers measures is compared in Table 3 and the outcomes of deep learning classifiers on the test data is exhibited in Fig. 9.

Ten different classifiers are used; ANNGRU obtained the best performance measures. The performance measures from Table 3 elucidate that the deep learning approaches are more powerful than the machine learning approaches. Deep learning classifiers are employed to the patient dataset and test a mortality and morbidity prediction with high accuracy. The comparison results of classifiers is shown in Fig. 10.

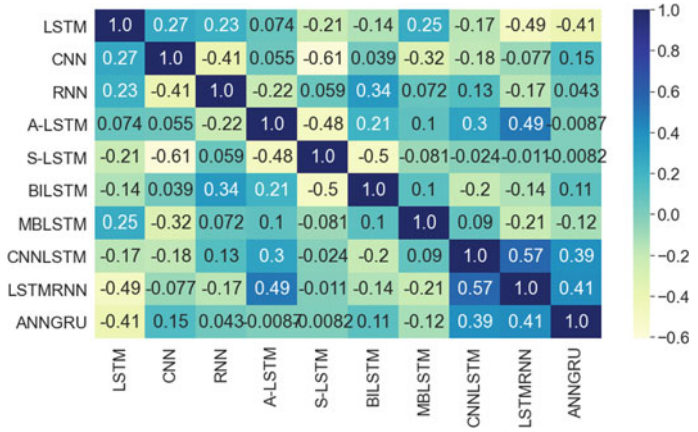


Fig. 8 Performance of standard deviation of the deep learning classifiers in discriminating mortality outcomes

Table 3 Comparison results of classifiers

Study	Classifier	Accuracy	AUC	*F*1-score
[55]	SVM, RF	–	0.87	0.72
[56]	XGBOOST	–	0.66	–
[57]	SVM	0.80	–	–
Present work	ANNGRU	0.94	0.91	0.94

This work shows that the input of the clinical parameters for a patient, such as white blood cells, with the ANNGRU, accurately classifies patients as likely to live or die. This model is the automatic mortality and morbidity prediction model of a patient with COVID-19. Predicting the mortality and morbidity rates for India is shown in Fig. 11.

Andhra Pradesh stood at the fourth place in COVID-19 cases in India as of 7 April 2021. The large population is one of the major factors of the COVID-19 spread in Andhra Pradesh. Predictions for the mortality and morbidity rates in Andhra Pradesh and its capital district Krishna are shown in Fig. 12.

Air pollution also one of the factors affecting the spread of COVID-19 infections. According to the USA Environmental Science and Forestry, an increase in hazardous air pollutants is a correlation in around 20% of human COVID-19 cases. Figure 13 shows the COVID-19 mortality levels associated with high levels of hazardous air pollution.

According to the Andhra Pradesh government reports as of 7 April 2021, the mortality rate in the Krishna district is high and stood in second place in Andhra Pradesh. The COVID-19 cases report for Andhra Pradesh is shown in Fig. 14.

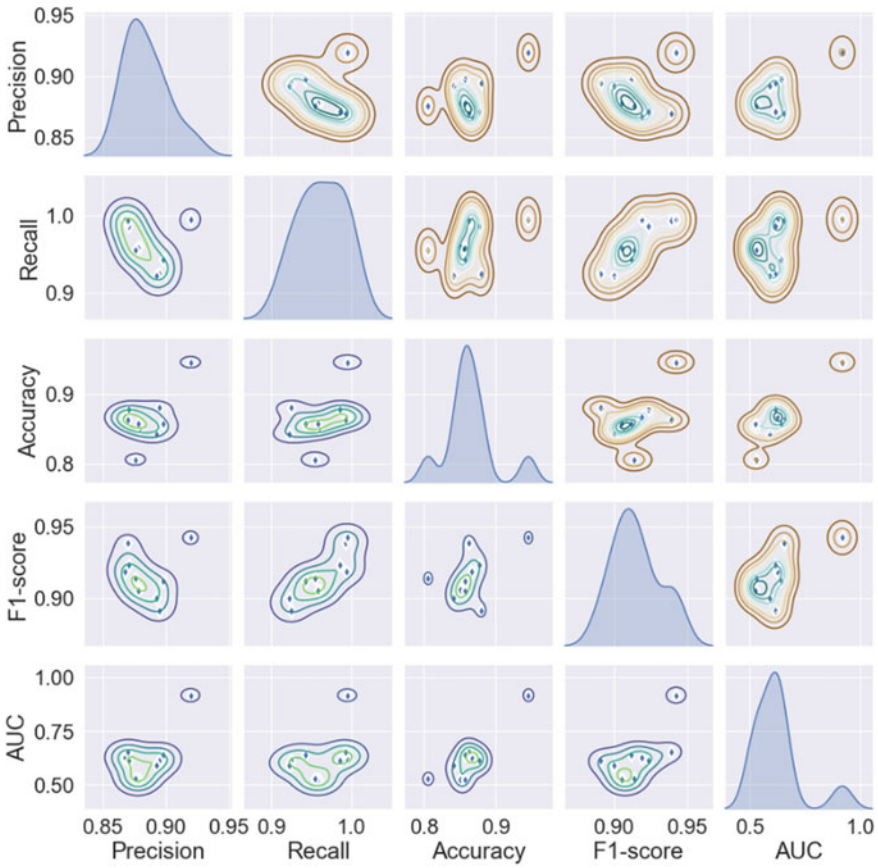


Fig. 9 Results of deep learning classifiers on the test data

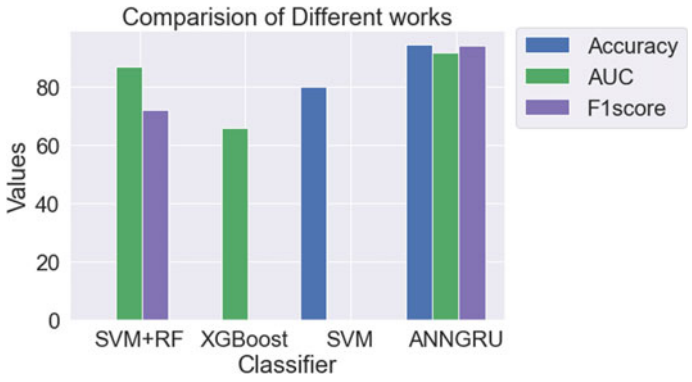
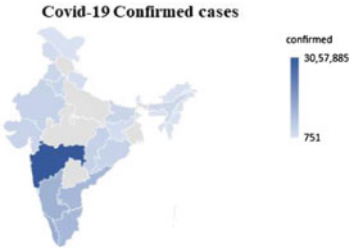
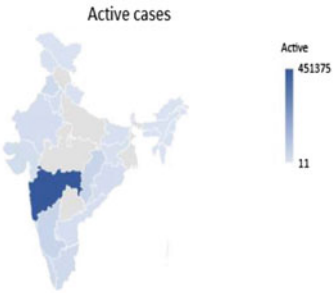


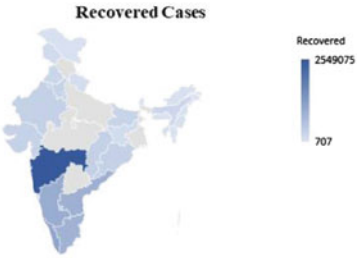
Fig. 10 Comparison results of classifiers



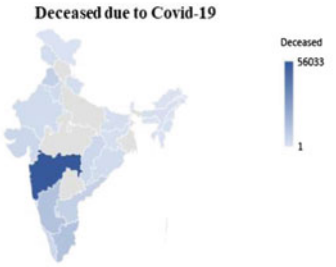
(a) Predicted Confirmed Cases



(b) Predicted Active Classes

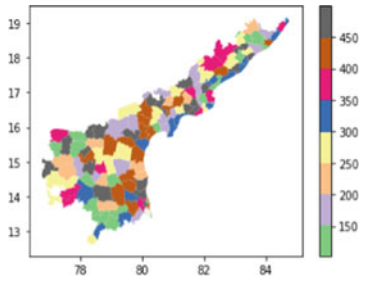


(c) Predicted Recovered Cases

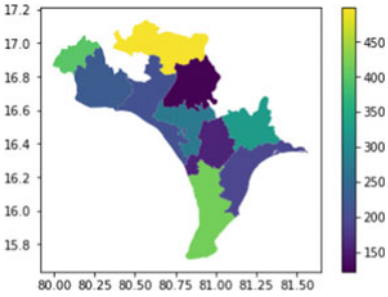


(d) Predicted Deceased Cases

Fig. 11 Predicted COVID-19 mortality and morbidity in India

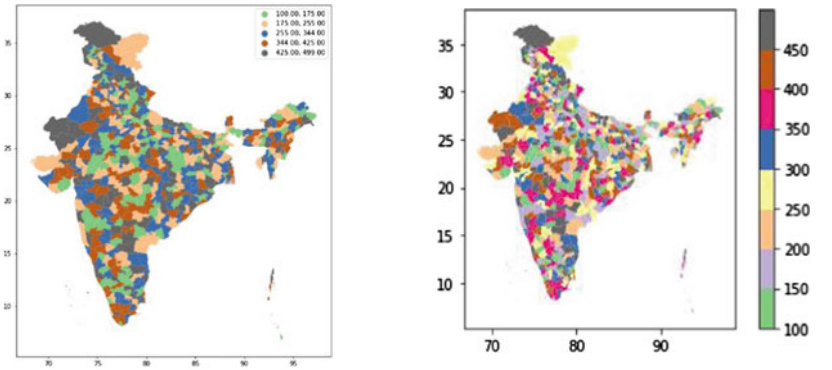


(a) Predicting Covid -19 in Andhra Pradesh



(b) Predicting Covid-19 in Krishna District in Andhra Pradesh

Fig. 12 Predicted COVID-19 mortality and morbidity in Andhra Pradesh and Krishna district in Andhra Pradesh



(a) Covid-19 Cases in India Population Wise (b) Covid-19 Cases in India pollution wise

Fig. 13 Predicting the mortality and morbidity rates by using air pollution in India district-wise

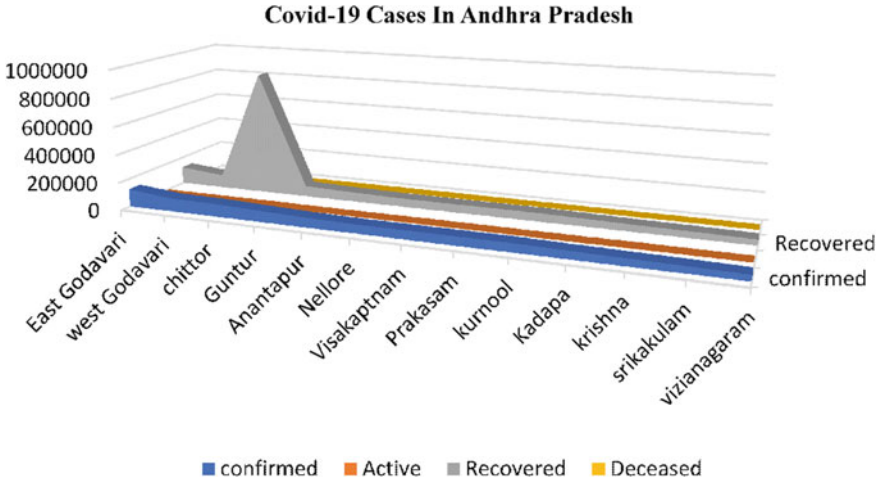


Fig. 14 COVID-19 morbidity cases in Andhra Pradesh district-wise

In this paper, there is an automated estimate of COVID-19 employing a hybrid deep learning technique. For this, applied ANNGRU deep learning pretrained modes were used to obtain higher accuracy.

5 Conclusion

Symptoms that were diagnosed for COVID-19, and also for patients with other diseases or infectious diseases, were studied. In this study the ANNGRU model

was composed and compared to the most accurate stand ANN patterns for assessing the morbidity and mortality rates of COVID-19 cases. The conclusions indicate that implementation of the ANN GRU-based prediction model led to more accurate estimations. For the results, it is confirmed that the more accurate confirmed cases are estimated.

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Mental Health Decline During Corona Virus Outbreak

Bharathi Swaminathan and Ananth Kumar Tamilarasan

Abstract COVID-19 is an especially bad irresistible sickness brought about by a novel coronavirus. The number of deaths brought about by this infection has been enormous. This global event which had befallen on a massive scale is bound to have a severe significant psychological impact. Numerous examinations and study results have been set up to quantify and comprehend this effect, and appropriately prescribe future game-plan to defeat this effect. This particular study highlights the fact that the onset of lockdown did have a significant psychological impact in India, with 62% of people experiencing moderate to severe stress. At a more granular level individuals were found to have been essentially affected regarding their sentiments of nervousness, outrage/crabbiness, and dejection. It was discovered that the most significant reason for this effect was the vulnerability of how long the pandemic would last. This paper focuses on emphasizing the stress levels experienced on all portions of respondents may be understudies, business people, or working experts, ordinary lay people, and children of all categories.

Keywords Pandemic · Examine · Dejection · Anxiety · Depression

1 Introduction

The 2020 COVID-19 pandemic and the ensuing cross-country lockdown got everybody unprepared and poorly arranged. Quite a worldwide occasion of this gigantic scope will undoubtedly have a huge mental effect. This examination was directed to quantify and comprehend this effect, and in a like manner, prescribe future strategy to beat this effect, just as to construct flexibility and forestall comparative effect later on. The investigation causes us to notice the way that the beginning of lockdown had

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a significant mental effect in India with 65% individuals encountering moderate to severe pressure [1]. At a more granular level individuals were found to have been altogether affected as far as their sensations of nervousness, outrage/peevishness, and depression. It was discovered that the most significant reason for this effect was the vulnerability of how long the pandemic would last. This was valid for all respondents' fragments, maybe understudies, business visionaries, or working experts.

As things were happening, the exact lockdown time frame got drawn out to more than two months; there was a beginning of "lockdown exhaustion". This declined the pandemic's effect essentially, with over 55% individuals detailing an expansion in anxiety feelings. Sensations of tension, outrage/touchiness, and dejection were likewise found to have compounded. Presently, the most significant focusing factor for business visionaries and working experts was a fall in work-life balance. Understudies ended up by the deferment of their tests which were generally expected to be held in May [1].

A mind dominant part of individuals has discovered solace in addressing companions and family more habitually to adapt to the lockdown stress. It was additionally discovered that the vast majority were influenced by the shame of looking for professional assistance for their psychological wellness and trying not to look for help from proficient emotional wellbeing specialists. In any case, the nation has noticed a huge ascent in the number of individuals connecting for advising and psychotherapy. 30th January 2020 will presumably stand out forever as a critical day. That was the day when the primary instance of COVID-19 was affirmed in India [2]. COVID-19 is an incredibly destructive irresistible illness brought about by a novel Coronavirus. The size of death brought about by this infection has been monstrous [3]. On eleventh March 2020, the WHO announced this sickness's flare-up as pandemic, and on 24th March, the Indian government reported a cross-country lockdown. The pandemic's effect, the lockdown on the economy, business, and society has been monstrous and unfathomable, both at worldwide and public levels. The last worldwide pandemic was "The Spanish Flu" which happened longer than a century prior. India's wellbeing framework has been ill-equipped and has been overpowered by the sheer size of the pandemic. The nation has encountered an enormous ascent in its joblessness rate between March 2020 and June 2020. Many working experts are confronting position misfortunes or pay cuts. Never-endingly staying inside influences individuals' rest quality and the steady vulnerability has prompted an ascent in nervousness levels for most.

Various reports demonstrate that there has been an ascent in side effects of melancholy and tension in a few nations, including India. For this investigation, DOST Health Solutions Pvt. Ltd. aggregated and dissected information from various sources to comprehend the psychological wellbeing scene among Indian residents during and post cross-country lockdown [4]. These sources consisted of a study led toward India's cross-country lockdown and studied led in June. Meetings taken by customers with the Experts on the DOST stage over the lockdown time frame were likewise dissected in detail. This investigation aimed to get a solid image of the effect on the nation's populace's aggregate emotional wellbeing and singular portions of the popu-

lace, for example, understudies, working experts, and business visionaries. Moreover, the examination took a gander at the reasons for this effect, its ramifications, and examples.

1.1 Worldwide Impact

As of tenth July 2020, 188 out of the 195 world's countries have been influenced by COVID-19 There have been almost 120 crores affirmed instances of COVID-19 worldwide with over 5.5 lakh passing's. The effect on worldwide economies has been tremendous. As indicated by the IMF, the worldwide economy will recoil by 3% in 20,207. It has depicted the decrease as the most exceedingly awful since the Extraordinary Depression of the 1930s. The dominant part of the world's countries is near the precarious edge of recession [5]. All economies, enormous or small, have encountered significant ascents in joblessness. According to a mid-May United States' Labor Department report, since March 21, over 3.6 crores Americans have petitioned for joblessness benefits, which represents practically 25% of the nation's working-age populace [6]. The nation's joblessness rate ascends from 3.7% in 2019 to 10.4% in 20,209. France's joblessness rate also has increased to 10.4%, while Italy's has ascended to 12.7%. Other created nations like Japan, Germany, the UK, and Canada have encountered an ascent in their joblessness rates to 3–7.5%.

1.2 Effect in India

On 24th March 2020, PM Modi declared that India's whole country was being put under lockdown from the following day 3. Individuals were confined from venturing out of their homes. All vehicle administrations, except for transportation of essential merchandise, fire, police, and crisis administrations were suspended [7]. Instructive foundations, mechanical foundations, and friendliness administrations were closed down. Just food shops, banks, ATMs, petroleum siphons, and other basics and their assembling were absolved. Anybody discovered abusing the lockdown could look as long as a year in prison (Fig. 1).

The Reported cases were increased, and the death rate also increased proportionally. This exacting lockdown proceeded for longer than a month with rehashed expansions until fourth May 2020 when a few limitations were facilitated. Limitations keep on being facilitated in a staged way [8]. However, a few limitations were kept on being set up. For most resident's life has not yet returned to the normal state. As of 29th July 2020, India alone has revealed nearly 1,723,764 reported cases, 1,531,669 affirmed cases, and more than 35,223 deaths.

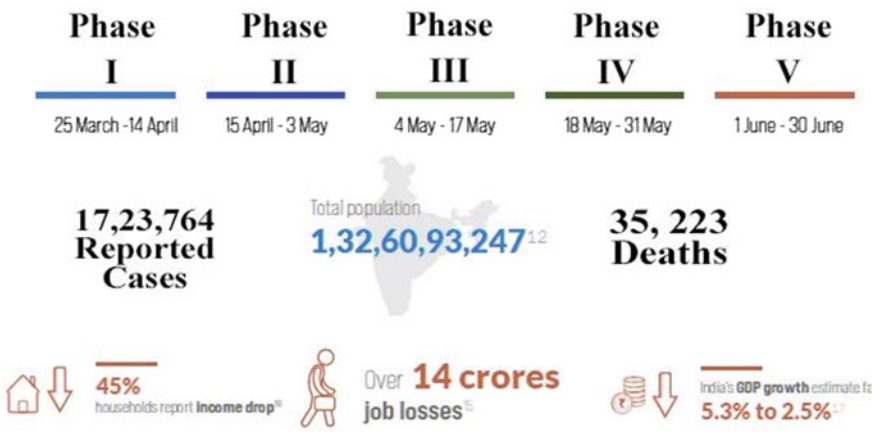


Fig. 1 Impact in India

1.3 Mental Effects of the Pandemic/Lockdown

While there is no single number to speak to the worldwide emotional wellbeing sway, stressing numbers are being accounted for from singular nations (Fig. 2).

Country-wise data shows that 300% of depression symptoms were found in Ethiopia. For this examination, YOUR DOST Health Solutions Pvt. Ltd. ordered and dissected information from various sources to comprehend the psychological wellbeing of Indian residents during and after cross-country lockdown [9]. This

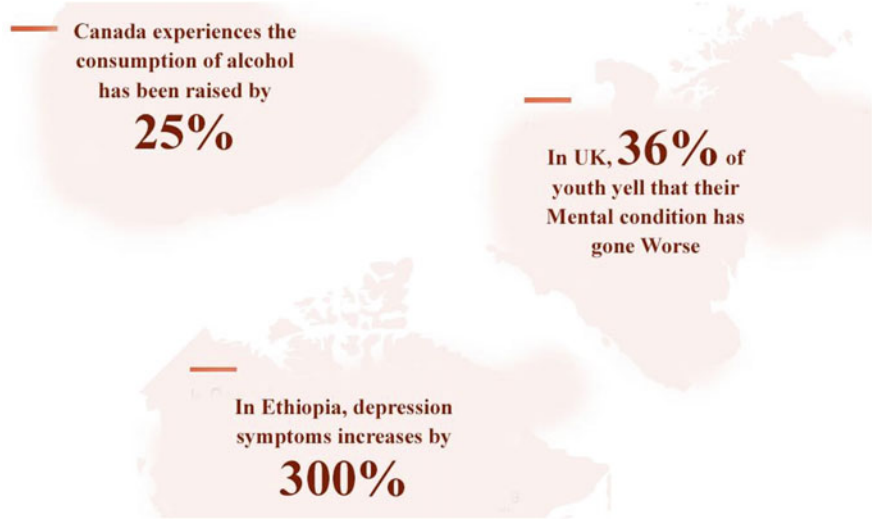


Fig. 2 Psychological effects of the pandemic

examination aimed to get a solid image of the effect on the aggregate emotional wellness of the nation's populace too singular portions of the populace, for example, undergrads, working experts, and business people [10].

2 Investigation of Indian Population (Survey Findings)

2.1 Review Methodology and Demographics

The examination assembled information from the accompanying sources: The review has directed the start of lockdown 1.0 to gauge the feelings of anxiety of Indians, which likely causes an indication pressure. It covered 560 respondents.

- A review led toward the start of open 1.0 to gauge the adjustment in pressure levels of Indians and the expected causes just as manifestations of pressure. It covered 636 respondents.
- Sessions taken by customers with the Experts on the Your DOST stage over Walk March 2020 to fifteenth June 2020 [11]. The examination covered the two people dwelling in Tier 1, Tier 2, and Tier 3 urban communities. Respondents are matured 17–90 years and comprise undergrads, working experts, business visionaries/independently employed people, homemakers, jobless people, and retired people [10] (Fig. 3).

The pie chart shows that 62% of the people under the age group 21–30 years are more affected by stress levels.

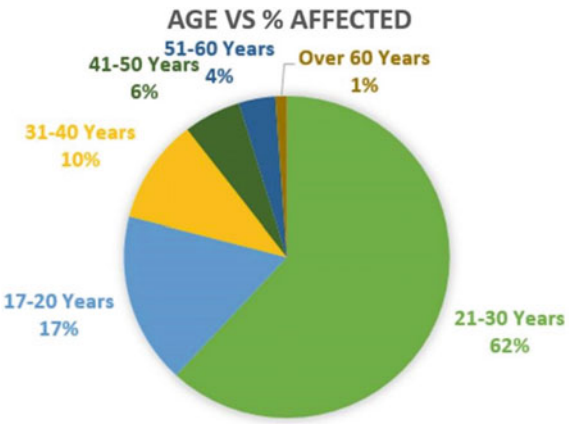


Fig. 3 Age wise affected

2.2 Vulnerability of Duration

As per psychologists, if the main thing is continually mindful the vulnerability and getting ready for expected awful occasions; at that point, we have presumably continued in a battle or flight mode [12]. This leads our psyches to develop an ongoing pressure design which makes us more inclined to dread and uneasiness.

2.3 Dread of Contracting Covid-19

For covid-19, regardless of whether it be a friend or family member has been an awkward presence, to the community. Experts indicated that most people built up this dread data over-burden brought about by extreme utilization of information.

2.4 Dread of Job Steadiness/Layoff

As indicated by an ongoing report, Indians are the most pushed about employment misfortune when contrasted with their friends in us, Britain, Australia, and Hong Kong. This dread can have desperate enthusiastic, social impacts such as expanded anxiety, gorging and under eating, bad dreams, memory issues, and so forth.

2.5 Impact of Covid-19 Related Stress on Lifestyle

The parts of their lives that the respondents answered to be the most affected were:

- Sleep: Lack of rest
- Diet: Difficulty in centering, fretfulness
- Productivity: Overeating or fall in craving (Fig. 4).

Among the individuals who announced themselves to be exceptionally focused on, rest was the most exceedingly terrible hit perspective, followed by a significant expansion in enthusiastic upheavals, fall in profitability and an unfavorable impact on their weight control plans [13]. So, the pie chart shows that almost 55% of the human community had at least moderate stress which shows Covid-19 has not spared any range in our community.

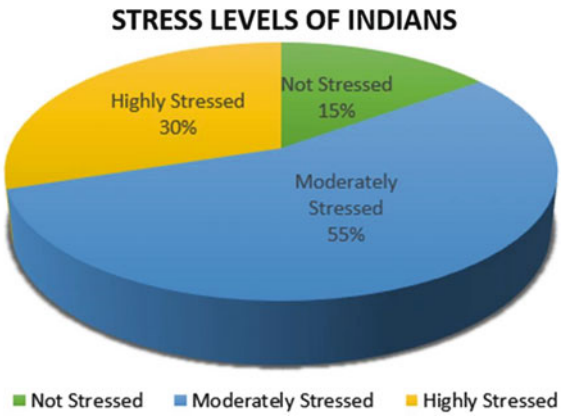


Fig. 4 Stress level

2.6 Lockdown Fatigue

As the lockdown advanced over a time of more than two months, a great many people were struck by "Lockdown Fatigue". Even more, lockdown weariness is a psychological weakness and fatigue than actual weakness, brought about by the mental parts of lockdown [14]. Throughout the most recent two months (from the beginning of lockdown). How have feelings of anxiety changed? Over the lockdown time frame, the feelings of anxiety of Indians rose essentially. Over the around multi-month period beginning from Lockdown 1.0 on 25th March 2020 to open 1.0 on seventh June 2020, 55% of respondents detailed an expansion in their anxious feelings. The effect too intensified significantly as the lockdown time frame kept on broadening. 51.80% Expanded 32.40% Remained the Same 15.80% Diminished [15].

3 Effect of Prolonged Lockdown on Stress Levels

As the lockdown progressed, the top 3 stressors too changed.

3.1 Fall in Work-Life Balance

The contributing factors toward this include prolonged work from home, which leaves many individuals feeling like they are in an "always-on" mode. Additionally, the lockdown led to a drastic change in most people's lifestyles and routines. Many continue to struggle to maintain a proper routine in the modest of these circumstances. Multiple studies have shown that poor work-life balance can directly impact people's

Fig. 5 Prolonged stress levels

mental health and can also adversely affect the prevention and management of mental illness. This makes this trend all the more worrying (Fig. 5).

3.2 Postponement of Exams

These were mainly college students whose colleges were shut down due to the nation-wide lockdown, and thus there continues to be a lack of clarity on when and how their exams will be conducted. Exams in general, are tremendously stressful. According to an earlier study conducted by YourDOST among Indian college students, 60% reported high to severe stress from exams. The pandemic added an additional element of uncertainty to this whole situation which, of course, has been tremendously distressing for individuals [16].

3.3 Pay Cut/Job Loss

At YourDOST, we encountered an 87% ascent in the number of meetings identified with work misfortune in March to June 2020 instead of a similar time period in the former months [17]. Losing employment can be an exceptionally awful encounter for some. As per a survey of more than 4000 research papers, directed by the University of East Anglia and the "What Works Center for Prosperity", losing employment may even take more time to get over genuinely than a separation. Pay cuts were another significant reason for pressure [18].

3.4 Net Impact of Stress Through the Lockdown

This diagram portrays the net change of life on different parts of respondents' lives through the lockdown portrayed as the net effect for the, generally speaking, understudies, working experts, and business visionaries/independently employed sections individually. As the lockdown expanded, respondents announced an improvement in their eating routine with a net change of up to 12% and day to day existence with a net difference of up to 21% [19]. It shows that all the cases worry that isolation and happiness have similar effects (Fig. 6).

Table 1 shows the net change in all cadres' life, whether it is a child or an adult. The emotional outburst was more severe than other criteria. Notwithstanding, rest quality kept on disintegrating for most with a net change up to 11%. Indians encountered an intense expansion in enthusiastic upheavals with a net difference of up to 22%. These upheavals happened as furious upheavals or crying fits. From a psychological perspective, this is normal. As observed before, a more significant part of individuals has announced an ascent in their anxious feelings. Studies have demonstrated that it's entirely expected to encounter a disappointment of intellectual feeling

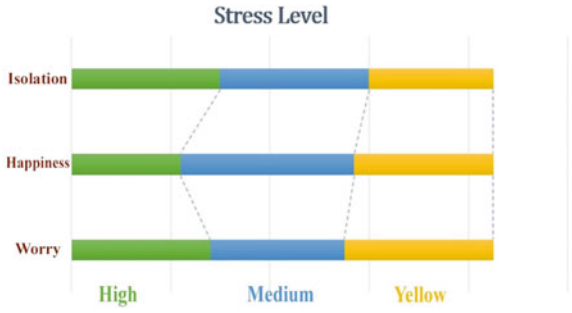


Fig. 6 Stress through the lockdown

Table 1 Net change in life

	Sleep	Diet	Emotional Outbursts (Crying/ Anger etc.)	Physical Health (Indigestion/Headache etc.)	Productivity	Family/ Marital Life
Net change in various aspects of life through the lockdown	-11%	+12%	-22%	8%	-8%	+21%

High Net Deterioration Moderate Net Impact High Net Improvement

guidelines, particularly regarding disagreeable feelings under pressure. The purpose behind this is that intellectual feeling guideline is constrained by our cerebrum's prefrontal cortex. When we're pushed, stress-related neuroendocrine hormones tend to hinder the prefrontal cortex in this manner, influencing psychological feeling guidelines, which prompts emotional upheavals.

3.5 Post Unlocks Fears

Of all the study respondents, precisely half report lifting of lockdown in their private regions, and the other half are as yet under lockdown. In any case, because the lockdown has been lifted does not mean things are back to how they were pre-lockdown. 90% of those living in areas where lockdown has been lifted are still uncomfortable venturing out like they used to pre-lockdown.

3.5.1 Reasons for not Resuming Normal Social Life

The individuals who are hesitant to venture out regardless of the lifting of lockdown are worried about the possibility if they do, their relatives may contract COVID-19. The rest feel that others will falter to meet them.

3.5.2 Impact on Individual Segments

Regarding the respondents' quantity to the reviews, the best three portions were understudies, working experts, and business people/independently employed people. The understudy populace was the most noticeably terrible affected by the lockdown, followed by working experts. Business people/independently employed people were the most un-affected of the three portions.

3.6 Net Impact on Emotions at the Beginning of Lockdown

This outline portrays the Impact on different feelings toward the start of the lockdown portrayed as the net effect for the understudy, working experts, and business visionaries/Independently employed portions separately.

Table 2 shows that the students were more affected by boredom and loneliness than other factors, at the beginning of the worldwide pandemic and lockdown understudies detailed a massive ascent in sensations of outrage and forlornness. Working experts then again did not report any huge passionate effect toward the start of the lockdown, with practically all feelings showing close to no net effect. Business visionaries and independently employed people as a fragment have been charmingly amazing.

Table 2 At the beginning of lockdown

Net impact in emotions at the beginning of lockdown*	Students	Working Professionals	Entrepreneur/ Self-Employed
Anxiety/Fear/Worry	3%	+1%	-1%
Anger/Irritability	+6%	0%	-11%
Hopelessness	+4%	-2%	-2%
Sadness	+5%	-3%	-1%
Loneliness/Boredom	+13%	-2%	-11%
Happiness	+1%	-1%	+10%

High Net Increase Moderate Net Impact High Net Decrease

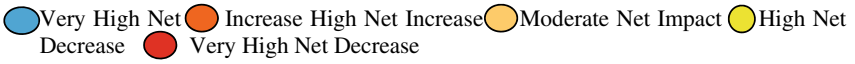
Toward the start of lockdown, they revealed an improvement when it went to their sensations of outrage, depression, and bliss.

Toward the start of the overall pandemic and lockdown, understudies define a tremendous climb in impressions of shock and misery. Working specialists did not report any enormous energetic impact at the beginning of the lockdown, with all intents and purposes all emotions demonstrating near no net impact. Business visionaries and autonomously utilized individuals as a section have been charmingly astonishing. Close to the beginning of lockdown, they indeed uncovered an improvement in their impressions of shock, despondency, and delight.

The net increase of stress during the lockdown is given in the Table 3. The anger and irritability among the students show higher percentage when compared to other criteria. As lockdown advanced, understudies kept on being the most exceedingly awful hit genuinely announcing the highest net crumbling in their feelings because of lockdown, especially regarding their outrage, tension, dejection, misery, and satisfaction. Working experts, who were not excessively influenced toward the start of lockdown, were harshly hit too with an uncommon weakening in sensations of nervousness, outrage, and dejection. Be that as it may, business people/independently employed respondents revealed an improvement in their sensations of joy, pity, and misery. On additional investigation, it was found that numerous understudies report confronting troubles in changing under life at home. They miss school, miss their companions, and miss the line of exercises that continue occurring nearby. A large portion of all, they report trouble in reconnecting with their folks which has made them feel seriously disappointed. They likewise report a “misfortune of opportunity” with their folks around. Another significant reason for concern, especially

Table 3 Net increase through the lockdown

Net impact in emotions through the lockdown	Students	Working Professionals	Entrepreneur/ Self-Employed
Anxiety/Fear/Worry	+41%	+41%	+23%
Anger/Irritability	+54%	+34%	+9%
Hopelessness	+27%	+17%	-7%
Sadness	+17%	+18%	-9%
Loneliness/Boredom	+38%	+26%	+9%
Happiness	-15%	-2%	+17%



among last year understudies, is the unfriendly impact that the lockdown has had on their employment possibilities. With interviews put on pause and even bids for employment canceled, they feel irate, restless, disappointed, and powerless.

The explanations behind the uncommon disintegration shown by working experts regarding their emotional wellbeing were very extraordinary. Many reports feeling on edge, baffled, and exhausted from being stuck at home, resulting in the absence of social communications [20]. These sentiments are further exacerbated by the abrupt change in the way of life that many working experts are still battling to deal with. The vulnerability and a sensation of "What is next?" is by all accounts, especially prevailing and troubling for some working experts. What is simply the mystery of business people/utilized people, who have demonstrated an improvement regarding their emotional wellness? Most business visionaries express that the lockdown allowed them to think and introspect. They have utilized this chance to assemble long haul methodologies and overhaul their abilities and skills. This has left them feeling more joyful, less powerless, and more fulfilled. One oddity in the business people's portion was that they detailed disintegration in tension. With the usage of "Work from Home" being prompted, there has been colossal tension on business people to keep representatives drawn and keep up their profitability. Also, there is enormous stress over organizations' fate due to the effect of the suspension of disconnected exercises, for example, deals, which as a rule require in-person gatherings and travel. The reason for this is generally stressed the eventual fate of their separate organizations. Nervousness usually is going to increment.

3.7 City Wise Comparison

The best four urban areas as far as the number of respondents to the study were Bengaluru, Mumbai, Delhi, and Chennai. Mumbai was seen to have the most high net expansion in pressure over the lockdown time frame, trailed by Bengaluru, Delhi NCR, lastly Chennai [18] (Fig. 7).

Comparing all the cities, it is seen that Chennai shows the maximum percentage which has been affected by stress. The bounce in Mumbai's feelings of anxiety can be credited to it being the city with the most elevated number of COVID-19 positive cases in the nation [21]. The equivalent applies to Delhi and Chennai. Be that as it may, the net increment of feelings of anxiety in Bengaluru was terrific considering the hugely low COVID-19 positive cases in the city.

4 Net Change in Stress Levels in Top Cities, in Comparison to the Whole Country

Table 4 shows the city wise increase in stress level. Bengaluru had not affected much as that state-controlled thing in the initial level itself. Notwithstanding, when

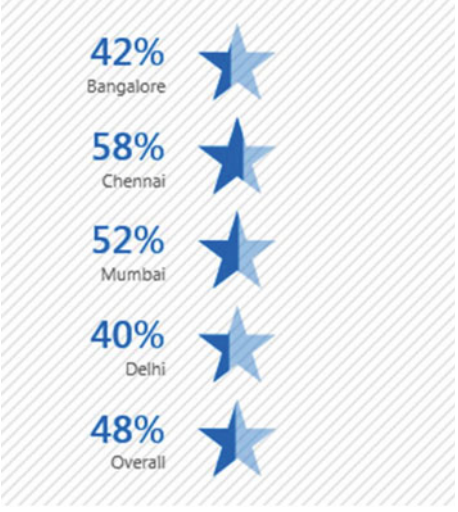


Fig. 7 City wise comparison

Table 4 City wise increase in stress level

Net change in stress levels in top cities relative to the whole country of India	Bengaluru (%)	Mumbai (%)	Delhi (%)	Chennai (%)
Stress increased	0	5	1	− 7

contrasted with the adjustment in general feelings of anxiety in the nation, Bengaluru revealed no change and demonstrated a similar pattern as the remainder of the nation as far as the change in its feelings of anxiety. Mumbai, true to form, was the most noticeably terrible hit with a moderately critical ascent in feelings of anxiety while the adjustment in feelings of anxiety in Delhi additionally remained nearly equivalent to the nation's regular. Nonetheless, Chennai reports a critical improvement in feelings of anxiety compared with the remainder of the nation. On additional investigation, it was found that Chennai people have changed well to the idea of virtual socialization and have used the lockdown time to bond better with loved ones and even to get back in contact with senior associates they had lost touch with, in this way imbuing more fabulous inspiration and diminishing forlornness in their lives.

4.1 Top 5 Coping Mechanisms to Deal with Stress During Lockdown

Table 5 gives some coping mechanisms which can be followed shortly. Mental Health Scenario presently in India. The WHO constitution expresses that—"Wellbeing is a condition of complete physical, mental and social prosperity and not only the nonattendance of illness or sickness". If you are well and however not intellectually, you are not beneficial. This plainly explains the tremendous centrality of emotional wellness for prosperity. The weight of emotional wellbeing issues in India was at that point very extreme even before the Covid-19 pandemic began. There has been an enormous ascent in conditions identified with the cerebrum and brain lately. Thus, there has been an expansion in nervousness, liquor use, self-destructive practices, drug use, rest problems, and so on as has been discussed, these figures are simply going to deteriorate due to the Covid-19 pandemic.

Table 5 Coping mechanisms

Top 5 preferred coping mechanisms	Students	Working professionals	Entrepreneur/self-employed
1	Speaking to friends and family more frequently	Speaking to friends and family more frequently	Exercising more frequently
2	Exercising more frequently	Reducing news consumption	Speaking to friends and family more frequently
3	Reducing news consumption	Exercising more frequently	Reducing news consumption
4	Reducing social media usage	Reducing social media usage	Meditating more frequently
5	Meditating more frequently	Meditating more frequently	Reducing social media usage

4.2 Meditations by Government and Other Organizations

The Indian government, just as various state governments has made proactive moves to temper the mental effect of the COVID-19 pandemic. The Indian government and NIMHANS, Bangalore dispatched a 24 × 7 emotional wellness to uphold helpline, back in April 2020. As the lockdown broadened, various state governments like Maharashtra, Goa, Kerala, and Haryana dispatched their helplines. Associations like The Indian Psychiatry Society, Brihanmumbai Municipal Corporation. JK Lakshmipat University, and so forth too dispatched their helplines.

4.3 Utilization Surge on Therapy Platforms-27

As uncovered in our examination, regardless of all the enthusiastic misery brought about by the Covid pandemic, passionate directing is as yet the most unliked way of dealing with stress for most. Anyway, psychological wellness helplines and treatment stages like YourDOST have still observed a critical flood in their use.

Table 6 clearly depicts the rise in the stress level of people. The helpline dispatched by the public authority of India and NIMHANS, Bangalore, got over 2.6 lakh calls

Table 6 Rise in stress level

100% rise in the total number of sessions	146% increase in the number of sessions related to issues with clients' parents	125% increase in the number of sessions related to time management	117% rise in the number of sessions related to anxiety disorders	52% rise in sessions related to Work-life balance	51% increase in sessions related to mood disorders
Clearly the lockdown led to more people turning to professional help to help deal with lockdown stress	As stated earlier, many students have reported issues in reconnecting with their parents while being at home, and this confirms it	Lockdown restrictions have caused major changes in the lifestyles of students and working professionals. They sought support from YourDOST Experts to form new routines	Anxiety was bound to rise in the current atmosphere due to uncertainty, fear of job loss, fear of pay cut, and information overload from social media, news, and Whatsapp forwards	Many clients reported feeling "always on" as a consequence of working from home wherein work tends to "leak" into their personal time too	Rise in stress levels aggravates depressive disorders. Also, spending extensive durations indoors reduces sunlight exposure leading to insomnia and seasonal affective disorder

identified with 90,000 unique cases between its dispatch on 30th March 2020 and twentieth May 2020. Specialists revealed that 90% of the cases were of individuals with expanded dread, what is more, nervousness brought about by informal and counterfeit data on social media. The BMC-M power 1on1 helpline dispatched by the Brihanmumbai Municipal Corporation, gotten 45,000 brings in the multi-month time of Apr–May 2020. 52% of the calls were for nervousness the executives, 22% were about to change and managing segregation. YourDOST too encountered a massive ascent in meetings. We thought about the number and sort of meetings directed from first December 2019 to 29th February 2020 with those leading between first March 2020 to 31st May 2020 [19].

5 Sample Case Studies

5.1 Case 1—Difficulty in Adjusting to Life at Home [21]

Meena (name changed) is seeking her MBA from a private college. Since March, she has been at home as her school must be closed down due to the cross-country lockdown. Meena's family dwells in a joint family course of action. When she moved toward the master, she portrayed how the family has been experiencing a few issues. From time to time, contentions or grievances keep springing up in the family. Hey folks, who're both working experts, additionally don't have the best relationship. Meena winds up occupied because of these pressures, making it hard for her to zero in on her scholastics. She has likewise been battling with outrage issues. When she feels set off when individuals try not to get her or in the event that she feels unheard. When Meena was in school, every one of these things didn't influence her much. However, now that she's at home because of lockdown, she cannot adapt to every one of these issues. Meena and the Expert chose to investigate what may be the reason for this additionally. From this, it became exposed that she generally battled to pick up her folks' consideration since her youth. This gave them both a beginning stage to start chipping away at Meena's mending cycle. As they've kept on chipping away at Meena's issues over subsequent meetings, they additionally went to the acknowledgment that the resentment issues have additionally influenced her fellowships and connections. When individuals don't hear her out, she blows up and feels she isn't esteemed, which prompts envy and self questions. Meena and the Expert keep on cooperating to determine these issues so she may assemble better passionate flexibility and carry on with a more joyful life, both at home as when she returns to school.

5.2 Case 2—Compulsive Cleaning

Aparna (Name Changed) is a female in her late forties and is utilized as an instructor in a government school. At the beginning of the pandemic when reports of losses had simply begun coming in, she ran over specific recordings about Coronavirus via web-based media. These recordings majorly affected Aparna's emotional wellbeing, and she created the extraordinary dread of getting the infection. She would wash and scour her hands energetically with dishwashing cleanser and a steel scrubber on various occasions a day, regardless of whether she had not contacted whatever came from outside [22]. She would not allow her significant other and girls to venture out from home for anything and would not permit any family members, regardless of how close they were, from entering her home. She allegedly lost her rest, even quit eating totally. When she would plunk down to eat, all she would do is gaze at the plate and afterward get going substitute her pooja room. She too frequented the Pooja room a ton. If anybody purchased anything from the outside like vegetables, she would energetically clean them with cleanser oil. This sort of conduct continued for nearly 15 days, what's more, left Aparna's family in absolute stun. That is the point at which she looked for guidance. The Expert reports that Aparna is greatly improved now since her advising cycle began.

5.3 Case 3—Irrational Fear

Samuel (name changed), 29 is utilized in the support area in Kuwait. He is from a working-class family, is hitched, and is the dad to a 2-year-old. He remains in Kuwait without his family. One of his companions, who lives in a similar structure as him, tested positive for Covid-19. According to the convention, all tenants of the structure were isolated, including Samuel. The time frame of isolate anyway went past the normal fourteen days. Samuel built up a silly dread that he excessively had contracted COVID-19. He began experiencing extreme uneasiness to the degree that he began encountering manifestations of Covid-19 like dry throat and trouble in breathing which were altogether psychosomatic in nature. He would settle on regular decisions to the wellbeing experts who affirmed that he could not experience any widespread contaminations. Samuel would likewise feel eager and jittery for the duration of the day. He gripped a consuming sensation in his heart just as restlessness. He lost all interest in watching motion pictures or tuning in to music which he used to appreciate a great deal before this isolate. Samuel has been getting direction to conquer his excessive nervousness from an analyst who has suggested that he practice specific unwinding methods to follow an ordinary daily schedule. Detecting that a portion of his tension may come from sensations of forlornness and uneasiness, the analyst also urges him to remain in virtual contact with individuals he thinks would inject some inspiration into his life. To additionally mitigate his feelings of dread of kicking the bucket from COVID-19, the analyst suggested that Samuel

incorporate food things like ginger, turmeric, and so on in his dinners to help improve his resistance. Samuel's street is to recuperate from his uneasiness proceeds under the master direction of his analyst.

5.4 Case 4—Violent Behavior Toward Parents

Akhil (name changed) is 21-year-old B.Tech understudy who went to the Psychologist alongside his folks. The guardians had a few protests about Akhil's conduct recently including touchiness and viciousness wherein he would beat/hit them just as his grandparents, and drive them away. He would show this sort of conduct, especially when his folks and grandparents reprimanded him for his excessive cell phone use. This conduct had become more regrettable during the lockdown. During the underlying meetings with the analyst, Akhil was very cautious, protected, and factious, and non-agreeable. His folks were exceptionally expressive about their feelings which just fortified Akhil's practices. His grandparents were also anxious about these social changes in their grandkid, who had been extremely warm and considerate toward them for his entire life. However, as Akhil's treatment advanced, he began indicating a few upgrades. He concurred that all through his youth, he would act adamantly and forcefully when his requests were not met. After a few meetings of overseeing outrage, family mediations, and methods to manage relational issues, Akhil has gotten more anxious to chip away at himself rather than reprimanding others for all issues. He is open toward recognizing his issues and is figuring out how to utilize his time ideally and invest essential energy with his folks.

5.5 Recommendations

The Coronavirus pandemic and the subsequent security measures have dominated our lives. The vulnerability of it is disrupting, and as was examined, unfriendly impacts to our psychological wellbeing are genuine (Fig. 8).

The above graph shows the pandemic shift, where there is a shift in mental stress and mental wellness. The pandemic's massive strain on individuals' emotional wellbeing and the specific ascent in the subsequent unfriendly impacts, the typical adapting techniques appear to have been deficient, consequently prompting disability in various parts of our life. In this manner, there is a critical need to receive a comprehensive administration technique to guarantee the Indian populace's by and large mental health. Contingent upon the degree of practical weakness of every person, self-care, peer-backing, and expert consideration mediations would be successful.

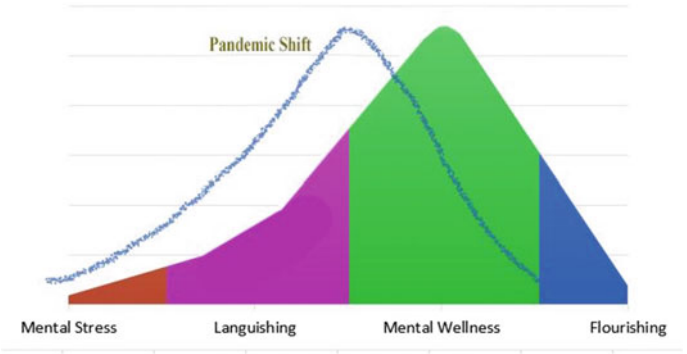


Fig. 8 Pandemic shift

5.6 Management Strategies

5.6.1 Persistent

Functional Impairment: Significant difficulty in dealing with negative emotions; High Cognitive Impairment; Complete Neglect of Personal Hygiene; Complete social isolation; Severely deterioration in sleep quality.

5.6.2 Significant

Functional impairment: reliable low proficient/scholastic execution; emotional episodes; regular unfortunate standards of conduct; huge social confinement; incessant relational clashes; huge crumbling in rest quality.

5.6.3 Low

Functional impairment: occasional low profitability levels; brought down social cooperation; incidental state of mind swings; mellow decay in rest quality.

5.6.4 No

Functional Impairment: Reliable scholastic/proficient execution; Proactive companion backing and social commitment; Ordinary rest.

6 Conclusion

Overall, it tends to be conclusively said that the psychological wellbeing of Indian residents has been essentially influenced by the COVID-19 pandemic and the cross-country lockdown. Students have been most noticeably terribly influenced by these conditions and are in grave need of upholding from family, friends, and family, school personnel, organization, and experts. Working experts also are influenced and need to pay attention to their psychological wellbeing. At this time, uphold from their bosses and chiefs is critical. Entrepreneurs have been incredibly motivational with regard to dealing with themselves in these abnormal conditions.

As per this examination, the mental (despondency, nervousness, and stress) among college students identified with COVID-19 increased. Being female, remaining at home, history of clinical disease, poor and moderate social help were factors that expanded the dangers of sorrow. Elements expanding the danger of tension were not living with their folks; family members got Covid and low family pay. Besides wretchedness, uneasiness, and helpless social help were among the variables that increment the danger of stress. This study may also be an eye-opener for future studies related to the pandemic and the stress levels of various categories of people. Administrative, private association, and medical care suppliers likewise provide psychological wellness and medical care administration. The public authority should join emotional wellness and mental meditation to overcome the nuances faced by COVID-19 Notwithstanding, their uneasiness levels demonstrate that all is not well and some type of individual consideration for psychological wellness is as yet required. There keeps on being a natural aversion regarding looking for professional assistance from clinicians, advisors, psychotherapists, and mentors, and even in these seasons of social removal, social disgrace keeps on being a foe of psychological wellbeing. With countless Indians consolidating more care and reflection into their lives, the numerous advantages of care and reflection have at long last gone to the front amazingly.

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Social Challenges and Consequences of COVID-19

Vikas Garg, Shalini Srivastav, and Pooja Tiwari

Abstract The epidemic of COVID-19 touches all fragments of the population and is especially harmful to participants of those social groups in the most disadvantaged circumstances and continues to have an emotional impact on the group of people, including those living in situations of poverty, the elderly, people with disabilities, young people and indigenous people. Early research suggests that poor people are largely responsible for the health and economic consequences of the virus. For instance, homeless people are extremely bare to the risk of the virus because they possibly will not be able to safely shelter on site. The epidemic and its consequences were also disproportionately impacted by individuals without admittance to running water, refugees, migrants or displaced persons, whether due to restricted travel, fewer job prospects, increased xenophobia, etc. If the community disaster generated by the COVID-19 pandemic is not adequately addressed by policy, inequality, exclusion, discrimination and global unemployment will also increase over the medium and long term. When developed, robust, worldwide social safeguard programs play an enduring role in protecting workers and dropping the pervasiveness of poverty by serving as automatic stabilizers. That is, at all times, they provide basic income stability, thereby enlightening the capability of people to accomplish and resolve shocks. As the Secretary General of the United Nations stressed, during the unveiling of the Global Humanitarian Response Plan COVID-19 on March 23, 2020, "*We need to emanate to the aid of the ultra-vulnerable, millions upon millions of individuals who are least able to defend themselves.*" This is an issue of universal human unity. It is also important for the fight against the virus. Now is the time for the insecure to step up.

Keywords COVID-19 · Societal impact · Health · Education · Employment · Poverty

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1 Introduction

The SARS-COV2-induced pandemic of coronavirus disease 2019 (COVID-19) is an ongoing worldwide community vigor issue. To tackle the disease, in the majority of regions of the 22 States and Union Territories, the Government of India placed a lockdown where confirmed cases were registered from March 24, 2020 onwards. The lockdown has currently been extended until May 31, 2020. The SARS-COV2-induced pandemic of coronavirus disease 2019 (COVID-19) is an ongoing global public health issue. To tackle the disease, in most districts of the 22 States and Union Territories, the Government of India placed a lockdown where confirmed cases were registered from March 24, 2020 onwards. The lockdown has currently been extended until May 31, 2020. As for the hard-luck of millions around the world, the outbreak of the universal spreading COVID-19 was not purely a health issue; the virus was a devastating occurrence for economies, public policy, international relations and world trade. Furthermore, the diverse effects of the pandemic targeted individuals and susceptible inhabitants in impulsive ways, requiring greater comprehension through thorough study and analysis.

As a consequence of the conquests and tautness born of corona, China, a worldwide giant in politics and world trade, where the virus paramount seemed and spread, faced and is poised to face numerous challenges to its economy and foreign relations. In addition to the recorded disagreements and the communal appropriation of medical aid between the member states, the European Union, having just avoided a prolonged Brexit, witnessed humiliating inter-state divisions concerning the COVID-19 war. On the national and foreign levels, the USA has also been fronting an excruciating situation. The treatment of the pandemic has generated an inordinate pact of faith and mistrust in the capabilities of the new administration. Besides, the epidemic of coronavirus sickness (COVID-19) has severe health implications and serious repercussions for trade and industry development and communal growth and has also entered Latin America and the Caribbean, marked by deprivation and insecurity, rising poverty and thrilling scarcity, decreasing social stability and manifestations of community displeasure.

Quarantines and physical distancing steps needed to avoid the rapid spread of coronavirus and save lives lead to job losses (11.6 million more unemployed relative to 2019 in 2020) and a drop in personal and household labor income. Income loss mostly affects the large strata of the population living in or exposed to poverty and those involved in activities that are more vulnerable to layoffs and cuts in wages and, in general, insecure jobs. Because of the big persistent disparities widened by the pandemic, ECLAC reiterates that it is time, with a rights-based approach, to adopt universal, redistributive, and solidarity-based policies to ensure that no one is left behind.

2 Total Lockdown

According to the report, India needs to take "draconian measures" to act before the country begins to accelerate the growth of COVID-19 infections. On Tuesday, Prime Minister Narendra Modi broadcasted a total lockdown for 1.3 billion people in India for 21 days, warning that the nation could go back 21 years and that if we do not comply with the lockdown rules, many families could be devastated. In their study, scientists used data up to March 16 on the number of confirmed cases in India and used implements to model the transmission of diseases. At any assumed time, they estimated the theoretical number of infected and compared India's estimates against the US and Italy. The scientists, including those from the Delhi School of Economics in New Delhi, noted in a blog post on the platform Medium that the estimates may change as stricter restrictions and measures are adopted by India.

3 India's Overstretched Healthcare System

India has the maximum overstretched healthcare system, according to the researchers, where it is difficult to provide care even when the numeral of patients streaming into hospitals is "normal." Citing statistics from the World Bank, the number of hospital beds per 1000 people in India is just 0.7, compared to 6.5 in France, 11.5 in South Korea, 4.2 in China, 3.4 in Italy and 2.8 in the United States.

As a result, the expected increase in the number of cases might make it problematic for healthcare benefactors in India to support the sheer volume of cases, the scholars said. The supreme susceptible inhabitant groups in India were also listed in the study. Citing multiple studies, the researchers said the number of people without an insurance policy in the country overextended to about 1100 million as of 2014, with more than 300 million individuals being the number of men and women with hypertension, one of the most important threat factors for death from COVID-19. The researchers predicted that the number of cases could surpass the estimated capacity of the hospital without introducing any intervention in the country which stands at 70 beds per 100,000 Indians.

4 The Human Face of COVID-19

The figures about the COVID-19 pandemic are clear. For example, as of the end of September, we know that there are more than 33 million cases worldwide. Of these, approximately one million died. There are approximately six million confirmed cases in India, of which approximately 940,000 are involved and over five million have recovered; 97,529 have died [1]. However, less is written about the individuals behind these figures. This brief tells their stories and draws lessons that can be used by India

and other communities to direct attempts to reduce COVID-19's social impacts. To increase her white blood cell count, she was given injections, but her physique was failing to respond. Indeed, she suffered additional symptoms caused by the drugs. She experienced inflammation of her oral cavity and intestinal mucosa that caused her mouth to experience burning and almost intractable abdominal pain with diarrhea. She was commanded to take a COVID-19 examination because she had a temperature with a slight shortness of breath at the time of hospital admission, and the consequence was positive. To reduce the chances of her infecting other patients, visitors, or employees, she was transferred to a negative pressure insulation room inside the hospital, to minimize the chances of her infecting other patients, visitors or staff.

Visitors were not permitted to visit the separation ward, and her families were only able to reach her with a full-body PPE for a few minutes (personal protective equipment). Her comfort was that even in the isolation room, she was allowed to have her cell phone, and she used it to connect with her treasured ones; it became her psychological lifeline. The nurses were affectionate, while the doctors in their care were compassionate, kind and meticulous. The housekeeping operate were also present, helping her to get to the washroom and making it unquestionable to keep the chamber clean and tidy. Malabika knew, however, that some of the health personnel were scared to come close to her.

As she was aware that she would not be able to blame those people for their fears, she used to feel aloof and neglected mostly and also not happy. She stopped contacting people. She was aware that this virus of COVID-19 has created a serious issue for her as she is already suffering from cancer. As her cancer was already on the mature side, the doctors informed her about COVID-19, and now the impact on cancer has become less important and impactful. She was feeling a vast difference in her treatment before COVID-19 and its impact after COVID-19. The isolation room was not having any window, but gradually Malabika was used to that place and time gradually passed. The medications were so expensive that it is another reason for her mental tension. Treatment with antibiotics and antifungal agents was required for neutropenia and fever, and COVID needed anti-viral agents and medicines to reduce body aches and fever. She also needed oxygen therapy, a lot of liquid intakes to maintain hydration, rest and healthy fruits and vegetables. Malabika's family, of course, wanted her to live. However, doctors have told them that curative care would no longer save Malabika. In due course, she died of cancer. She was screened for COVID-19 for the preceding time before her body was given to her family, and it turned out to be negative.

5 Themes from the Story of the Patient

Malabika is only one of the many COVID-19 sufferers. Her tale illustrates those experiences collective amongst persons who have fallen ill with the disease. He has been intricate in coordinating the COVID testing services since the epidemic hit

India initially this year. He is the chief of the hospital's infection prevention and control programs he represents. He is also active in treating patients with different infections who are hospitalized. The author highlights the most critical issues in the following paragraphs, which doctors focus on while battling in the frontlines of the epidemic. It is not unusual for patients with COVID-19 (or any other person who is ill with a communicable disease that needs protective isolation in a healthcare facility) to have a strong sense of isolation and despondency. While different patients perceive and cope with physical, social and psychological seclusion in different ways, isolation is true. Early physical and social recovery can be enabled by new electronic communication systems that have provided much-needed mental relief. The social stigma surrounding the disease, which occurs in various ways depending on the status of the infected or the care provider, often affects COVID-19 patients.

It is not uncommon for patients with COVID-19 (or any other person who is ill with a communicable disease that needs protecting segregation in a healthcare facility) to have a strong sense of isolation and despondency. While diverse patients observe and manage physical, social, and psychological seclusion in different ways, isolation is true. Early physical and social recovery can be enabled by new electronic communication systems that have provided much-needed mental relief. The social stigma adjoining the disease, which occurs in various ways liable to the prestige of the infected or the care provider, often affects COVID-19 patients. During the contaminated period, this makes the patient hesitant to go back to the group. This may be due to sincere concern about infecting other members of the family or because of the apathy of society toward those infected.

As for the hardship of millions around the world, the outbreak of the global spreading COVID-19 was not merely a health issue; the virus was a shattering occurrence for economies, public policy, international relations and world trade. Furthermore, the diverse effects of the pandemic targeted people and vulnerable populations in unpredictable ways, requiring greater comprehension through thorough study and analysis in handling the crisis. Unlike others in the 75-year history of the United Nations, we are facing a global health crisis, one that kills people spread human suffering and upends the lives of people. Yet this is much more than a crisis of well-being. It is a problem that is human, economic and social. The coronavirus disease (COVID-19), which the World Health Organization (WHO) has described as a pandemic, is attacking societies at its heart.

Older People: Older people, especially those with chronic health conditions such as hypertension, cardiovascular disease and diabetes, are particularly susceptible to the risk of COVID-19 infection.

Not only are older people dealing with greater health risks, but they are often less likely to be able to support themselves in isolation. Although social distancing, if not adequately enforced, is important to minimize the blowout of the disease, such interventions may also lead to the increased social isolation of the elderly at a time when help can be desired at most. The COVID-19 discourse, in which it is viewed as an older person's illness, exacerbates derogatory perceptions regarding older people who may be seen as frail, unimportant and a social burden. In the provision of services, such age-based discrimination may manifest as the treatment of older persons may

be considered to have less importance than the treatment of the newer age group. International human rights law guarantees everybody the right to the highest possible quality of health and encourages governments to take action to provide those in need with medical treatment. For instance, shortages of ventilators involve the implementation of triage policies and procedures based on medical, evidence-based and ethical considerations, rather than subjective age-based decisions.

In this context, unity between generations, the battle against discrimination against older people, and the upholding of the right to health, comprising admittance to evidence, care and medical facilities is crucial.

Persons with Handicaps: Owing to lack of accessibility, approachability, affordability, as well as dishonor and prejudice, people with disabilities face difficulties in obtaining health care services even at the greatest of times. The risks of COVID-19 infection for people with disabilities are exacerbated by other problems that require specific action: interruption of programs and assistance, pre-existing health conditions in some cases that place them at higher risk of developing or dying from serious illnesses, exclusion from health knowledge, and mainstream health care, living in an environment where accessibility is frequently accessible and being disproportionately more probable to live in established settings.

Overall, individual self-care and other prevention measures against the outbreak of COVID-19 may pose difficulties for people with disabilities. Some people with disabilities, for example, may have difficulty enforcing steps to keep the virus at bay, including personal cleanliness and the recommended regular scrubbing of exteriors and home environment. Owing to physical impairments, environmental obstacles or disrupted facilities, cleaning homes and washing hands can also be difficult. Others may not be able to adapt to social distancing or may not be able to separate themselves as completely as other people, and for everyday self-care activities, they need constant assistance and support from other people.

To confirm that people with disabilities have the right of entry to COVID-19 material, it must be made available in usable formats. For individuals with mobility, sensory and cognitive impairments, healthcare services must also be physically available. Furthermore, regardless of some financial obstacles, people with disabilities must not be discouraged from receiving the health care they need in times of emergency.

The Youth: Several governments have called on new individuals to join the initiative to preserve themselves and the society at large. Young people are also in a position to support those who are most disadvantaged and to help raise social awareness programs for public health among their communities.

Young people are overwhelmingly unemployed in terms of jobs and those who are working mostly work in the informal or gig economy, in insecure contracts, or in the service sectors of the economy, which are likely to be seriously affected by COVID-19.

With the closing of colleges and universities in many jurisdictions, more than one billion young people are now physically out of school. Although the efforts made by teachers, school administrations, local and national governments to deal with the extraordinary circumstances to the best of their capacity should be noted, the

disturbance in education and learning may have medium and long-term implications for the standard of education.

Many disadvantaged young people are in unstable conditions, such as refugees or homeless youths. If governments do not pay particular attention, they are the ones who can easily be ignored since they appear to be already in a position without even fulfilling their minimum criteria for health, education, employment and well-being.

The Families: An international research study led by Dr. Anis Ben Brik, distinguished and known expert in Social Policy and Sustainable Development, LSE alumnus, now an associate professor at the Hamad Bin Khalifa University College of Public Policy in Qatar, examines the impact of the coronavirus pandemic on family lifestyle.

6 The Indigenous Communities

At this time, aboriginal populations are especially vulnerable due to substantially higher rates of communicable and non-communicable diseases, lack of access to basic services, lack of culturally sufficient health care, and, if any, local medical facilities that are under-equipped and under-staffed. The first point of prevention is the distribution of knowledge in indigenous languages, thus ensuring that programs and facilities are, and are all, adequate for the unique situation of indigenous peoples.

Furthermore, a large number of ethnic individuals outside the social protection system contribute to vulnerability, particularly if they rely on income from the wider economy: manufacturing, tourism, handicrafts and urban jobs. In this respect, policymakers should ensure that aboriginal communities and other susceptible clusters are included in temporary financial support initiatives. Indigenous groups are still struggling to find their explanations for this pandemic. In their cultures, they take initiative and use common knowledge and procedures, as well as preventative steps.

7 Developmental Sport and Stability

A significant contributor to profitable and social development is a sport. Governments are well aware of its position, comprising in the Political Declaration of the 2030 Agenda, which focuses on "the contribution that sports make to empowering women and young people, individuals and communities, as well as to the objectives of health, education, and social inclusion." The COVID-19 epidemic has blowout to almost all countries in the world since its inception. Social and physical steps of distance, business lockdowns, schools, and general social life, which have turn out to be familiar to minimize the spread of the disease, have also disrupted many daily aspects of life, as well as to backing physical activity during the epidemic and beyond. A leader of sustainable development, the UN Department of Economic and Social Affairs (UN DESA) is home to the Sustainable Development Goals (SDGs), where

each goal finds its place and where all stakeholders will do their part to leave no one behind. Through the Inclusive Social Development Division (DISD), UN DESA tracks national and worldwide socio-economic developments, recognizes emerging problems and assesses their impacts on national and international social policy. To this end, we are a prominent systematic voice for social inclusion promotion, inequality reduction and poverty eradication.

The epidemic of COVID-19 touches all divisions of the population and is especially harmful to associates of those social groups in the most disadvantaged circumstances and continues to affect communities, including those living in situations of poverty, the elderly, people with disabilities, young people and indigenous people. Early research suggests that poor people are largely responsible for the health and economic consequences of the virus. For instance, homeless people are highly uncovered to the risk of the virus because they may not be able to safely shelter on site. The epidemic and its repercussion were also disproportionately impacted by people without the right of entry to running water, refugees, migrants, or displaced persons, whether due to restricted travel, fewer job prospects, increased xenophobia, etc.

If the social crisis created by the COVID-19 pandemic is not adequately addressed by policy, inequality, exclusion, discrimination and global unemployment will also increase over the medium and long term. When developed, robust, worldwide social fortification programs play a very long-lasting role in protecting workers and reducing the prevalence of poverty by serving as automatic stabilizers. That is, at all times, they provide basic income stability, thereby improving the ability of people to manage and resolve shocks.

As the Secretary-General of the United Nations stressed, during the launch of the Global Humanitarian Response Plan COVID-19 on March 23, 2020, “We need to come to the aid of the ultra-vulnerable, millions upon millions of individuals who are least able to protect themselves.” This is an issue of universal human unity. It is also important for the fight against the virus. Now is the time for the insecure to step up.

With the outbreak of the pandemic in Africa, very strict steps have been taken by governments across the continent to curb its spread. These steps included the banning of all public meetings, the permanent closing of public institutions, including schools and colleges, the suspension of all air transport, the shutdown of cities and towns across countries, the restriction of population movement, and the introduction of test programs to recognize, isolate and treat infected persons. These initiatives have had an immense immediate impact on the continent’s economies, the worst since the global financial crisis of 2008.

As gains in the tourism, aviation, and extractive sectors, among others, are completely wiped out, economic growth is projected to decline significantly in the near to long term. Perhaps, more heartbreaking is the human toll across the continent.

8 The Effect on the Economy

The Reserve Bank of India (RBI) forecast real gross domestic product (GDP) growth in 2019–20 at 6.2% [2]. However, the International Monetary Fund reduced India's growth forecast by 1.3 percentage points to 4.8% for 2019–2020 and suggested that India's growth had slowed sharply [1]. It is therefore self-evident that an economy already plagued by slow growth in the preceding fiscal year will be seriously affected by the lockout as a result of the pandemic. The market ratings of small and medium Enterprises estimate that during the lockdown, the national lockdown is expected to incur losses of over $4.5 billion (about 35,000 crores) every day [3]. The healthcare industry, the country's fourth-largest employer, and especially the private sector, which provides almost 80% of outpatient treatment and about 60% of inpatient care, is currently facing 90% losses due to reductions in outpatient care, elective surgery and foreign patients.

The economic downturn has dramatically impacted individuals from the lower socio-economic stratum during the current pandemic (SES). During the lockdown, the distressing media images of migrant laborers moving to their native places from the cities on foot were urgently discussed. Another way of reducing poverty, economic growth and rising GDP is the remittance of cash to the home country, which many migrant Indian workers popularly do. In 2019, approximately $139 billion (approximately 1,042,500 crores) was sent from countries of employment (e.g. Gulf countries) to low and middle-income (LMICs) countries of South Asia.

An important effect on these remittance flows was the disturbance caused by COVID-19. Importantly, remittances in India are expected to fall by approximately 23% in 2020 (Fig. 1), to $64 billion (about 480,000 crores) in striking contrast to a 5.5% raise and $83 billion (about 620,000 crores) receipts seen in 2019 [4]. The World Economic Forum states that migrants trapped abroad trying to cope with the requirements would compromise the adverse circumstances in the current pandemic

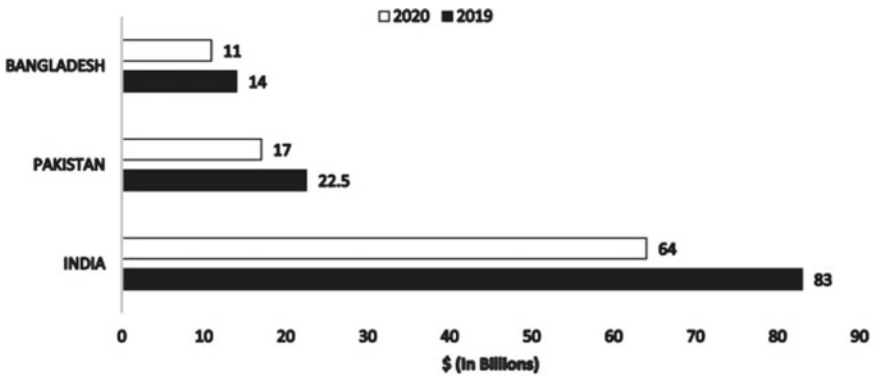

Fig. 1 Fall in remittance flows to three countries of South-East Asia (in USD$) from 2019 to 2020. Adapted from Ref. [5]

situation by taking up low-wage jobs, living in bad working conditions, restricting spending and thereby risking exposure to infections such as coronavirus.

The situation for internal (intra- and inter-state) migrant workers in India is equally bleak. In the informal sector, these jobs total a whopping 139 million and constitute about 93% of the workforce [6]. Approximately, 50% of migrant workers reported getting rations when interviewed for less than a day [7]. Also, the report by the Stranded Workers Action Network found that during the first 21 days of lockout, 89% of stranded workers had not been paid salaries by their employers and that 74% had less than half of their daily wages to survive on [8].

The economic effect of this pandemic is likely to be more serious for India as follows: (a) rising poverty, i.e., driving more citizens below the poverty line [5]; (b) worsening socio-economic inequalities [7, 9], thereby affecting indices of health and nutrition; and (c) compromise on precautions relevant to health (use of masks, social distancing, seeking medical advice in case of cough and fever, etc.). Many of these will have significant long-term health predictor associations.

9 Challenges in Socio-Culture

India's social structure thrives on the interdependence between families, relatives, and acquaintances, both emotional and economic [10]. As dictated during this pandemic, near physical encounters such as living in crowded housing and other locations, pushing and jostling are highly prevalent and are a deterrent to "social distancing." Crowding was found in religious areas, during travel (e.g., "herds" of migrants on buses) [11], or even when buying liquor at the shops amid the lockdown. Though "vertical distance" is the cause of inequalities in India, these inequalities have been further exacerbated by the "horizontal distance" put in place in the wake of COVID-19.

The lack of adequate provision of safety nets (e.g., food safety) for those hit hardest by lockdown is the more worrying aspect [9]. The government structures remain vastly inadequate due to the enormous scale of the problem. As a consequence of the lockout, the risk of malnutrition among the low SES is growing. Under the Pradhan Mantri Garib Kalyan Anna Yojna (PMGKAY) initiative of the Government of India in its fight against COVID-19, the Food Corporation of India recently allocated 12.96 lakh metric tons of food grains [12]. The efficacy of this method and the adequacy of the distribution of food remains to be seen.

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Owing to inadequate physical activity, greater than before snacking and intake of calorie-dense foods, the lockdown may also be a source of weight increase during the COVID-19 pandemic. In an observational study conducted by our group, carbohydrate intake and frequency of snacking increased by 21% and 23%, respectively, exercise period was decreased in 42% patients and weight gain occurred in 19% of patients with type 2 diabetes. Weight gain and obesity may increase COVID-19 severity (30) and may increase the risk of future increase of diabetes and cardiovascular disease.

Other diseases, the controller of some of which until now had shown a promising trend, could also increase. Human immunodeficiency virus (HIV) infection, TB, and malaria-related deaths over 5 years, for example, could increase by up to 10%, 20% and 36%, respectively, compared to a COVID-19 pandemic-free scenario [13]. There are several explanations for this: interruption of antiretroviral therapy (ART), reduction of timely diagnosis and treatment of TB and decreased prevention activities, including interruption of planned net malaria campaigns.

The economic slowdown might aggravate malnutrition, as briefly mentioned earlier. The loss of daily wage earnings or unemployment will make it difficult for individuals belonging to low SES to purchase even basic food products. The inadvertent result of this will be the deleterious impact on the most vulnerable population, namely children and pregnant women, thereby negating previous advances in the national programs related to maternal and child health and nutrition. Roberton et al. modeled three scenarios in which it is estimated that the coverage of critical maternal (e.g., prenatal care, maternity care) and infant (early childhood vaccination) health interventions would decrease by 9.8–51.9%, and the prevalence of waste increase by 10% over 6 months would result in the substantial additional child and maternal deaths, 253,500 and 12,200, respectively.

Increased chronic stress, anxiety, depression, alcohol dependency, self-harm and increased physical abuse (domestic violence) have been documented as a result of the lockout. Increased chronic stress, anxiety, depression, alcohol dependence, self-harm and increased physical abuse (domestic violence) have been reported. The authors emphasized that even in the least extreme scenario (coverage reductions of 9–8–18–5% and wasting).

Overall, there are real prospects in India to reverse the success of the National Programs and to worsen the health indexes. COVID-19 has caused great social and economic instability on a wide scale. The pandemic's regressive effect will create adverse conditions of discontent that can lead to social instability if not handled preemptively, or at least as a reaction to the emerging situation. The twin challenges of coping with social unrest triggered by the movement of urban migrant workers and the danger emerging from misinformation are illustrated in this issue brief. It ends by proposing, as part of the continuing national initiative to tackle the pandemic, some steps to resolve these threats more effectively.

10 Urban Migrant Workers Plight

The urban areas of India present a contrarian economic fact. While a large number of cities are consistently ranked high on the per capita scale, these figures can be mistaken for uniformly high levels of wealth. Instead, ultra-rich people's very high-income levels blur the reality of low-income groups, and worse, urban weak people's poor expectations of public services are exacerbated by an inadequate source of income, even if it is slightly higher. These employees are motivated to live in challenging circumstances by attracting higher incomes [1]. However, this becomes unsustainable when the source of income is severed, as seen recently in reaction to preventive steps taken to combat the COVID-19 pandemic.

In 2016, a study on the condition of urban migrants in Bengaluru suggested that there were more than 120,000 migrants in that city alone, employed at a monthly salary of Rs. 10–12,000. They reside on construction sites and work in unhygienic, temporary, improvised shelters without employee benefits. The 2001 Census found that there were 370 million migrants employed away from their place of birth [14]. Since then, this figure is likely to have risen. A significant number of these individuals live in urban areas, which raises a peculiar collection of pandemic challenges. This entails factors such as dependency on daily salaries or low-skilled workers in factories and corporations. This means that any significant effect on the social and economic stability of a region will weaken the earning potential of these individuals. There is a section of migrant ad hoc workers in addition to this segment, which constitutes a significant part of the urban poor in towns. They have no choice but to remain in these urban areas as permanent residents.

During periods of coercion, their economic status is close to that of migrant workers, except that they have places of residence, mostly in slums within the cities. While this does not cause them to travel, but the loss of jobs causes severe financial stress. As part of a United Nations press conference, Francesco Rocca, President of the International Federation of Red Cross and Red Crescent (IFRC) societies, pointed out that a large number of disadvantaged individuals living in cities are a "social bomb that can explode at any moment." With the implementation of a precautionary lockout, which was probably the best option under the circumstances, most companies stopped their activities.

Most companies have stopped their operations, factories have come to a halt, and practices such as construction and tilling of farms have stopped with the imposition of a precautionary lockdown, which was probably the best option under the circumstances. While the income of a small segment of workers employed in the government and residential sectors has been assured, those in the unorganized sector do not have the same protection. This led some of them, despite intercity public transport not being available, to try to move en masse to their villages. As a result, questions were raised about the sustenance and potential transmission of the virus during the transit stage.

The change also put a serious physical strain, especially on women and kids. At the same time, these events often pose security-related concerns. The enormous psychological, economic and social strain, limited job opportunities and limited access to food and health facilities could rapidly lead to a worsening of social harmony, particularly if the number of people affected by the epidemic is anywhere close to the higher projected levels. An estimate by an interdisciplinary team of scientists showed the probability of reported cases of between 100,000 and 13 lakh by mid-May [4]. The study noted that these figures could decrease based on stricter steps taken by India.

11 Dissemination of Misinformation

Crises such as pandemics and natural calamities have consistently addressed the problem of knowledge disruption [6]. This can be triggered by factors as diverse as insufficient information flow, disinformation and misinformation. The problem has been significantly improved by the impact of social media. The Ukrainian town of Novi Sanzhary, which has a small population of only 8300, encountered fear and panic in a recent incident after residents received misinformation about widespread deaths caused by a coronavirus. This led to the arrest of 24 people for rioting [8]. This incident was likely a product of social media disinformation and a fake news campaign.

Closer to home, the National Capital Area (NCR) encountered a similar condition in the full glare of television screens. WhatsApp news mainly indicated that the relaxation of the lockdown for a day was done to encourage people to leave the city to their hometowns and villages, along with the understanding that the closure would last as long as three months. Inputs from social media also suggested that the supply of electricity was likely to be cut and rations would soon be exhausted [5]. Such misinformation caused a large number of migrants employed in NCR to panic and leave for their villages, hundreds of kilometers away, despite the lack of transport.

Despite the regular distribution of guidance from both state and central governments, it is clear that there were communication gaps at the level of the grassroots [9]. Citizens either did not receive the information or the information was given by the official agencies was ignored in favor of false information obtained via social media. Therefore, legitimate people's problems may become exacerbated by miscommunication or misinformation via social media. There is also a risk of spreading exaggerated descriptions, which with each point of transmission can be further intensified. The outcome can lead to civil instability and even serious internal security confrontations.

12 The Way Forward

Any plan designed to ensure social stability will require an efficient mechanism for disseminating knowledge. Information openness and its successful distribution remain the first and perhaps most critical aspect. In this regard, the government has remained cautious, following the policy of regular briefings to encourage the media to disseminate information. Aarogya Setu App, the My Gov Corona Newsdesk, frequent interactions between the prime minister, chief ministers and government spokespersons have helped to disseminate information at regular intervals.

Moreover, tracking social media, preventing the spread of rumors and disinformation would also be useful. To counteract the misinformation campaign, closer contact with social media companies may also be an important weapon. To include government handles and websites, it is necessary to regularly disseminate trusted sources of data. During regular briefings of spokespersons, these sources of information may also be promoted and information is given.

At the organizational end of the government's response, parts of the government such as the police and local agencies are under intense pressure. Contrasting steps to ensure the enforcement of laws and directions have been implemented. These ranged from the use of harsh punishments to creative police-accepted means. Not only did the above alternative have a salutary impact within the limited reach of a case, but it also gained the police respect and appreciation for its circulation via social media. When rumors always spread faster than reality, the task of disseminating such incidents is an effective instrument in the hands of the government to improve the confidence of the people in the efforts of their representatives and officials.

13 Social Unrest Management

The migrant movement is a significant concern about the unregulated spread of COVID-19. At the same time, it has been recognized that the potential for disharmony remains a possible problem unless the immediate and mid-term concerns of individuals who do not have convenient access to medical, financial and social security needs are addressed. The solution may lie in providing help at the grassroots level, as the government has envisaged. The central and state governments in India have already introduced a large number of initiatives.

These include allocating additional financial expenditure to the announced support initiatives, increasing the direct transfer of financial support and rationing to the vulnerable and strengthening the infrastructure and capability of medical support across all government agencies, including the armed forces, police organizations and the railways. At the same time, it is also possible to explore the possibility of controlled movement of individuals, thus maintaining safety measures during intercity transfers. This will ensure that pressure cooker conditions have a safety valve as a result of protracted closures.

This is where the Indian Army's experience can be brought into force. There are two main events coordinated by the army. Next, marches for recruitment involving thousands of volunteers. And second, the movement of convoys through the country's length and breadth. It is possible to organize a combination of these elements with additional medical checks before assembly, protection of social distance in assembly areas and movement in an organized manner. By special trains, a similar exercise may be attempted, once again a practice perfected by the army over the decades.

Before allowing people into their villages, it is recommended that interim quarantine facilities be built. It would guarantee that the infection will not spread to a wider section of society. For health and hygiene practices, however, this will need to be controlled. In this respect, the world-class camping facility built for the Kumbh Mela by the Uttar Pradesh Government indicates a rich experience that can be replicated.

Given the size of the COVID-19 challenge, it is important to envisage the graduate jobs of uniformed forces to assist civil authorities. Although their medical capability and assistance are already being used, any additional involvement must remain available at the same time in terms of both men and material. However, this must be achieved by ensuring that safety equipment is used scrupulously and that protocols are followed to ensure that the risk of transmitting the virus among support staff employed close to the infected individuals is minimized. It should also be kept in mind that security forces that are prepared to support Humanitarian Assistance and Disaster Relief (HADR) may need more time to plan for contingencies such as the establishment of makeshift hospitals, optimal levels of protective equipment and the assignment of training in various geographical areas for potential support roles.

While the COVID-19 spread is global, the subject of response has remained largely domestic and local. There is no question that the pace of the spread of the disease and the subsequent social and economic disruptions have shown that attempts to curb biological weapons need to be improved further. There could be a variety of incidents of civil unrest coming from all over the world. Sharing and evaluating their causes to encourage better handling of problems will also be useful. It is important to exchange experiences and best practices to reinforce the collective fight against the current challenge presented by COVID-19.

14 Completion

The COVID-19 pandemic has necessitated holistic attention to the underserved and vulnerable communities to avoid long-lasting adverse health consequences. Economic stressors on the population as a whole will require mitigation, and rapid policy changes will help. Finally, communicable National Health Services and NCDs need to be revitalized and improved. The COVID-19 pandemic brought one of the most severe humanitarian problems the world has experienced in its aftermath. As a consequence, there are likely to be far-reaching implications of social and economic upheaval. From the viewpoint of disruption caused in the lives of urban migrant workers, this brief evaluates the same thing. At a time when social media has become

one of the most common sources of information, this is also exacerbated by misinformation. This can lead to instability, undermining the ongoing attempts to minimize the pandemic's adverse effects. Furthermore, the brief recommends steps to strengthen migrant movement management and the chain of information dissemination.

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Economic Impact and Measures of Corona Regime

Yogesh Garg and Rajinder Rawat

Abstract The eruption of the COVID-19 in later part of 2019 came as an extraordinary shock to an already struggling global economy. The spread of pandemic led to a phase of the prolonged countrywide lockdown in most of the countries. All this resulted in unwanted disruption of global demand and supply chains eventually resulting in inevitable slump of the world economy. Several studies fear that the estimated loss to global economic growth in 2020 could be in range of −4.5 to −6.0% and possibilities of any revival can only be visible in the later part of 2021. However, the recent reappearance of contagious cases in some parts of Europe and the United States could further weaken or delay any chances of early economic recovery. The report presents a summary of the financial impact caused because of the pandemic and steps taken by various governments to revive it through necessary fiscal measures to boost liquidity.

Keywords Employment generation · Fiscal measures · Globalization · Atmanirbhar Abhiyan · Opportunities

1 Introduction

As per WHO, "Corona viruses are a large group of viruses that are known to infect both humans and animals and in humans cause a respiratory illness that ranges from common colds to much more serious infections." In the recent history, two other corona viruses have infected humans, first being the epidemic of SARS in 2002 and other was the MERS epidemic in year 2012. The WHO stated present coronavirus as COVID-19, here "co" and "vi" stands for coronavirus, "d" is to indicate disease, and "19" to denote the year disease has appeared.

In the first wave which started in the early part of the year, the weekly deaths attributed to the virus tired in the second week of April 2020, at just over 51,000.

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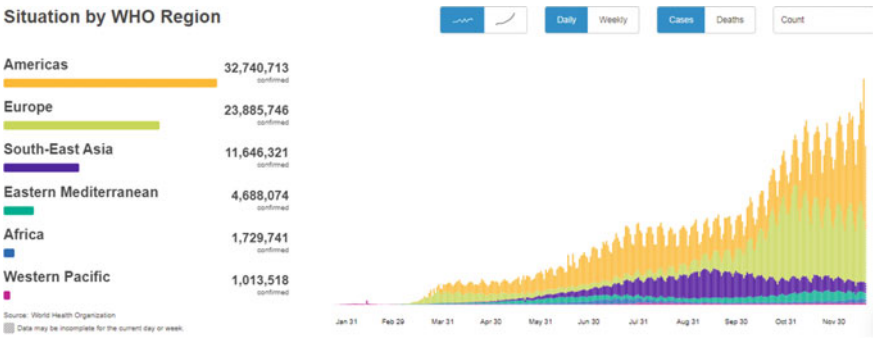

Fig. 1 World Health Organization, COVID-19 dashboard (as of December 22, 2020)

This number further plunged down in later part of May 2020 and everyone expected things to improve for the world economy. But as the cases instigated to increase the countries started taking stringent actions to curb its pace. A medical emergency was imposed and steps like complete lockdown and testing of the larger population started. By mid-September 2020, things started to get worse as the number of deaths per week increased again to above 30,000. The Americas itself records for around 50% of all cases globally and 53% of all deaths recorded while Europe accounted for nearly 20% of confirmed cases and around 24% of deaths, making it second largest region affected due to the virus. Though a sudden spike in number of cases and deaths recently in regions of South-East Asia and Americas giving fear of another lockdown in some of the major economies.

As per the website of WHO, the present numbers of confirmed infected cases are more than 75 million people and almost 1,500,000 deaths globally as on December 22, 2020 (Fig. 1). At the present pace, the numbers of confirmed cases are doubling up generally in every nine weeks and by the early part of February 2021 are likely to surpass 150 million marks.

2 Beginning of Economic Slowdown

Most of the major economies were already struggling before the outbreak of pandemic and any efforts made to recuperate an international recovery was further delayed because of several factors already surfacing on ground. The issues included: the enduring impact of growing trade protectionism; no near term solution to trade altercations between China and US, the key trading allies at various levels; prices of energy and commodities falling at the global level due to slow demand; and rising doubts in Europe over the possible economic impacts of the withdrawal of UK from the EURO zone. Independently, each of these problems were solvable but jointly each of them destabilized the financial institutions globally and impacted the freedom on hand to policymakers concerning the flexibility of decision making.

The occurrence of pandemic was first diagnosed in China in November 2019. Since its outbreak the pandemic has brought an unprecedented shock to the already struggling world economy with lower GDP growth rates and substantially rising unemployment rates. The countrywide lockdowns in combination with an economic slowdown and considerable disruption in the demand-supply chain have dented every economy extremely. The current disaster has toppled lives of people in numerous ways. It is not just the tragic losses of lives, rather millions lost their jobs, means of income, and years of savings in order just to survive and remained locked at homes, and many even have to be concerned about their rents and bills unpaid for the period.

Enormity and alacrity of the financial system crush was unseen before, quite unparallel to any of the financial crisis happened before. The calamity has opened up the world economies and destabilized economic stability at all levels. A big section of the global economy has been brought to an idle position, which even includes a large part of Latin America and Africa mainly in Sub-Saharan region, the so-called unorganized economies of the world. Swift action was required and to save lives, governments in all economies focused on providing additional financial resources to develop necessary medical services, some to be better-prepared others just to ensure survival. At places where conditions were conducive and there was room in the budget to allow some sort of fiscal stimulus, various governments also intervened to stop the fall of economic growth by bringing much needed fiscal stimulus. The estimated value of these fiscal and monetary supports by September 2020 sums up to around $11.5 trillion. These measures were needed to extend the support to various sections of people and businesses till things are brought to some sort of normalcy. More than one million deaths have been recorded worldwide since the eruption of the coronavirus disease. Globally, the financial system have suffered huge setbacks and economies are expected to squeeze by astounding 4.3% globally in 2020 resulting in millions of jobs losses, which has put livelihoods of many at risk and has brought new challenges like forcing millions of people into severe paucity.

As the things are becoming clearer and financial effects of the pandemic are more visible, going forward how various organizations choose to the respond can have a considerable impact. The changes are visible in the manner various businesses are organizing their workforces that can have long lasting impacts on global supply chains. Although, a large part of this economic recovery depends on the effectiveness of vaccines developed and how well they are distributed to the larger population. Most of the health experts believe that the first pandemic wave has begun to recede, and most of the nations have improved their capacity for further testing, tracing and have prepared new provisions of equipment to respond in a better way to check on reoccurrence of virus. In the second half of the year, many countries have already started relaxing the conditions of lockdown. Although, experts' fear such steps are untimely as some parts of European countries are facing new threats of the second wave that may prove to be more severe and could lengthen the process of normalcy anytime soon.

As per UNCTAD data in 2020, the global GDP can see a possible contraction of 4.3% and a sluggish recovery of around 4.1% only by the second half of the year 2021. From Fig. 2, it can be stated that pandemic has affected the developed economies

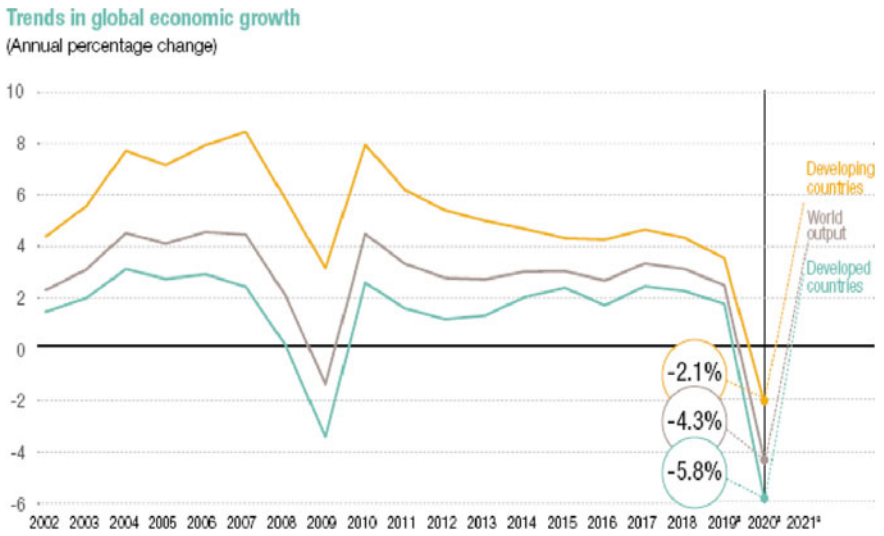

Fig. 2 Trends in global economic growth: UNCTAD (2020)

more severely compared to the other developing countries. Developed countries are expected to record a fall in their GDP's at −5.8% compared to −2.1% for developing economies, respectively, and expect a slower and weaker recovery in 2021. As per UNCTAD, recovery for developed economies is pegged at +3.1% compared with +5.7% for other developing economies. Many economists have compared this slowdown with the Subprime crisis of 2008/09, but unlike the global financial crisis of 2008/09, developing countries are expected to experience a negative effect and a growth rate in a negative trajectory. On the other hand, developed economies are expected to experience a much deeper fall in output mainly due to the lockdowns experienced in most of the countries, i.e., at −3.4 in 2009 weighing against −5.8 in percentage terms in 2020.

3 International Trade Plunged as the Virus Spread and Projections by Various Agencies

The impact of COVID-19 on global trade was unprecedented, spreading over all segments of businesses and services. The struggling global economy found it hard and every major economy has to suffer and was forced to close down all economic and social activities leading to further slowness. To date, the impact of epidemic has been quite broad, impacting global economical and trading activities. The major sectors that are impacted harshly are the ones catering to tourism and hospitality sectors. Apart them, a large number of other businesses whether related to supplies of medical goods, consumer electronics, financial services, logistics, goods value

chains, food, energy and many others catering to social activities suffered huge stress. The economic stress caused due to pandemic has left the economies of developing countries in a vulnerable position. To combat the health crisis and to develop health-care system with their limited financial resources has overburdened their economies. As per the estimates of IMF, in October 2020 there is high risk that pandemic could force a large population of some of these developing economies especially in Sub-Saharan regions of Africa and some parts of South Asia into extreme poverty. Such situation could hamper the gains made in last decades to fight poverty and upbringing of people in these regions.

It is not that the present economic slowdown is only due to pandemic, in fact the global economy was already going through a phase of downturn which started becoming visible between later part of 2019 and mid of 2020. The initial forecast by various organizations like IMF, OECD, and World Bank does reflect on that projecting decline in global economic growth rates. Some of the major industries like merchandise, automotive, entertainment, tourism, and machinery faced the fear of completely shutting down leading to negative growth.

Going forward in the month of September, an updated forecast for global growth rate in 2020 was released by the OECD. It estimated that things are looking slightly better than its June forecast when it projected a decline of 6.9%, though the decline in economic growth is inevitable, but it could be marginally better at 4.5%.

Around the same time in October, IMF also gave its updated growth projection terming the phase of lockdowns as "Great Lockdown" comparing it to economic crisis of "Great Depression." In its report, it concluded that the present crisis could see the worst phase of recession and could be more prolonged than the Great Depression period, surpassing even the subprime crisis that world witnessed a decade ago. It also revised its June projections of −4.9% shrinkage of global economy to slightly better −4.4%. It also projected that the world could see positive growth of 5.2% in 2021 if things get better. On the global trade front, it estimates a fall of 10.4% in 2020 and expects oil prices to decline as much as 32% due to slow economic recovery in some of the major economies.

As per the October report of WTO, global trade volumes can see a rebound in 2021 and a fall of 9.2% estimated for 2020 can turnaround drastically to an annual growth rate of 7.2% in 2021. These projections imitate a positive change from its April 2020 stand when it estimated a decline in global trade volumes somewhere in between 13 and 32% due to the disease. The recent WTO updates indicate that the recovery could be noticeably slower in global trade in 2021 principally suggesting a phase of shower GDP growth for global economies.

All global agencies believe the economic impact of crisis would be worst for emerging economies. The economies those are highly dependent on commodities exports, foreign remittances and tourism will remain in negative growth trajectory for a longer period. The demand for commodities is going to be negatively affected mainly due to a reduction in remittances, weakness in global currencies, and stiffer financial conditions. As governments are forced to spend more on social welfare, many of these developing countries especially the ones dependent on agricultural and mining sector may foresee a phase of slow recovery.

From the data provided by UNCTAD as shown in Figs. 3 and 4, in the first quarter of 2020 there is a visible decline in the growth of goods and services trade. That was also the period when fear of disease started surfacing for the first time. But the real decline in terms of trade of goods and services was witnessed in second quarter as per reports of UNCTAD. The decline was much more dramatic in nature compared to first quarter. During the period, values of merchandise business fell by 18% and trades in services fell by 21%. In the first quarter of 2020, the value of total trade in

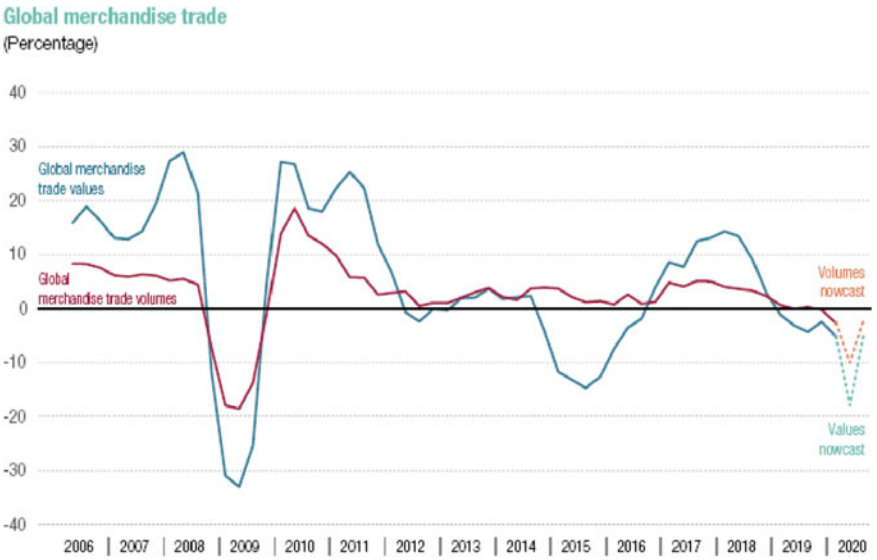

Fig. 3 Global merchandise trade: UNCTAD

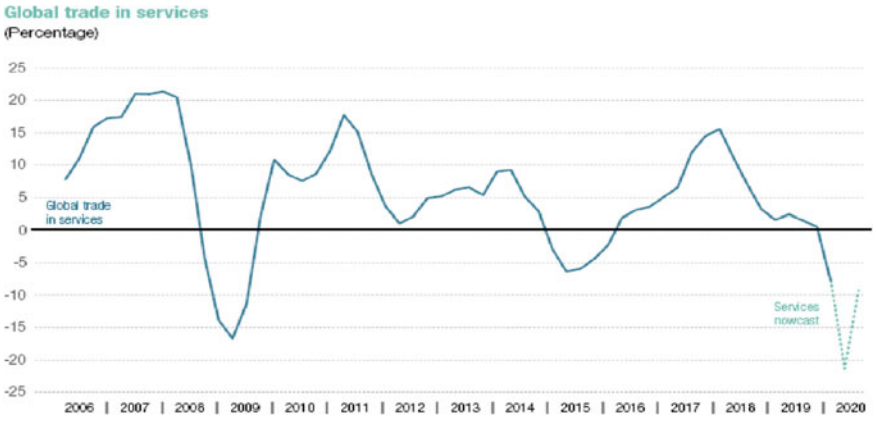

Fig. 4 Global trade in services: UNCTAD

services fell by 7.6%, and travel services fall by more than 24% with chances of no recovery for the sector anytime soon.

Another fact to be seen over here is the fall in activities compared with the economic crisis of 2008/09, although this time the decline is not that steep but due to no trade activities mainly because of lockdown in most of the countries the recovery is expected to be far slower. Although the outlook for third quarter looks promising and as per data available, the growth forecast year-on-year basis is −5% for goods and −9% for services. As the year ends, things are now far enough past the initial blitz to lift our gaze to the future, even if the pandemic's course remains uncertain.

4 Growth in Trade of Medical Products

In the first half of 2020, the world has seen a significant decline in global trade compared to same period of 2019. The decline was as much as 14% comparatively to the period a year ago. Although there were areas of positive growth as well, as the impacts of pandemic became visible, the demand for medical goods saw a massive change. The import and exports of medical related goods witnessed a growth of 16% that is around US $1200 billion in value terms. Government bodies increased their spending on health care facilities and as focus on personal hygiene improved the spending on medical facilities grew and continued to remain robust throughout the period. It can be seen in Figs. 1 and 2, as the spread of the virus increased, there was a sudden demand in the trade of medical goods. Comparing to the period of first half of 2019 when the demand saw a growth of just 2%, it grew as much as 15.8% in first half of 2020, showing a massive growth year-on-year basis.

In the first half of 2020, trade related to medical products in all categories witnessed a spike comparatively to same period of year 2019. Products related to personal hygiene grew by a massive 50.3% which was followed by medicines in all categories by around 12%, the supplies of medical products and various equipments also saw positive growth by, respectively, 9.6% and 5.5%. In the second quarter around May, a growth of 186% was recorded, showing a huge spike in demand for medical products related to COVID-19 especially products like ventilators, thermometers, sanitizers and other personal hygiene products compared to same period of 2019. The enforced lockdown in most of the countries also boosted the demand of various non-medical related products. As people shifted their office premises to home demand for home office equipments like Wi-Fi routers, laptops, and other portable devices also witnessed a growth. This growth of non-medical items though slowed down in the later part after the initial pick-up in demand (Fig. 5).

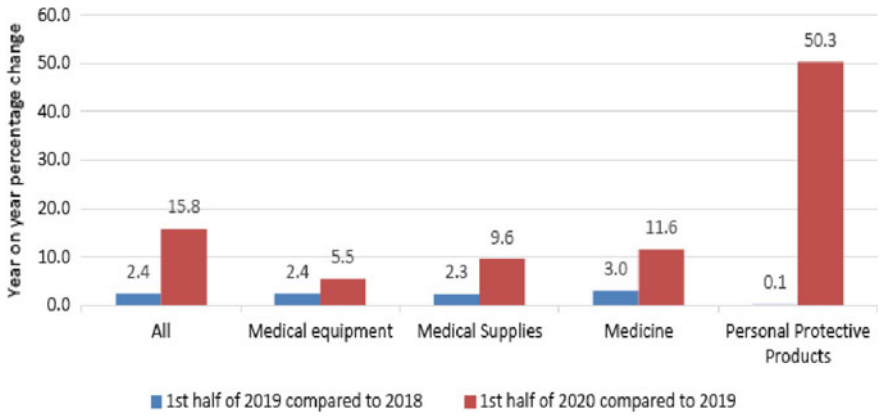

Fig. 5 Comparative data of trade in medical goods during the period of first halves of 2019 and 2020 with respect to same period of previous year (WTO). https://www.wto.org/english/tratop_e/covid19_e/medical_goods_update_e.pdf

5 Impact on Major Economies During the Period

Most of the major economies witnessed a contraction in financial development. Economies of China, the United States, and the European Union witnessed a steep fall. Figure 6 shows that significant declines are evident in the sectors like automotive and chemicals industries which are highly cyclical. For some industries that were related to the manufacturing of medical equipment witnessed a slight escalation led by China itself. The impact of COVID-19 on different industrial sectors also witnessed uneven growth. The industries which remain less impacted were the ones

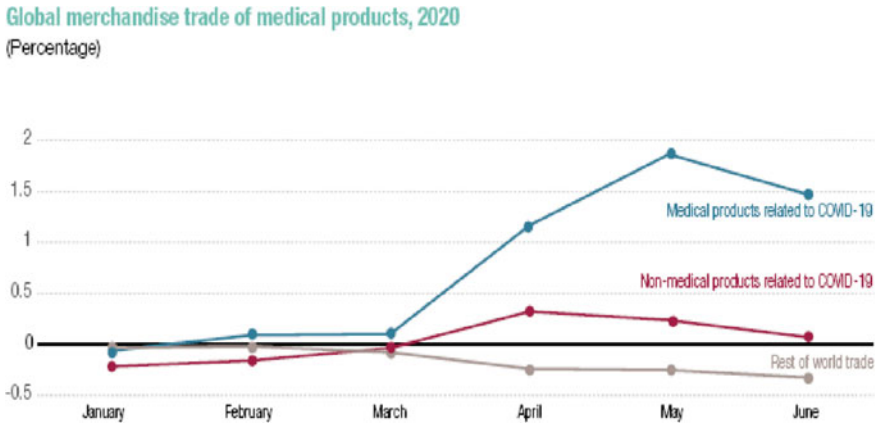

Fig. 6 UNCTAD Secretariat calculations based on the National Statistics of China, the United States of America, and the European Union (2020)

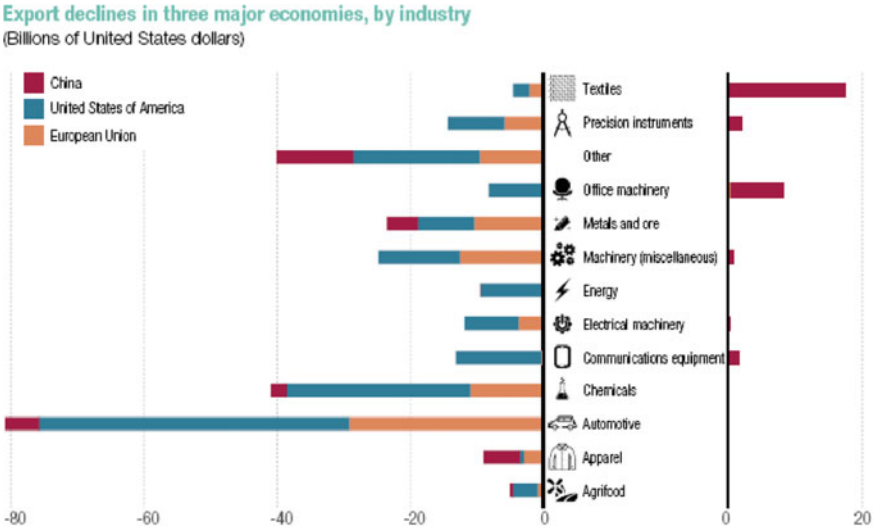

Fig. 7 UNCTAD Secretariat calculations, based on the National Statistics of China, the United States of America, and the European Union (2020). https://unctad.org/system/files/official-document/ditcinf2021d1_en.pdf

involved in food or pharmaceutical product production. The production of basic pharmaceuticals recorded moderate growth in the second quarter of 2020 globally while the sectors like motor vehicles, textiles, and apparel witnessed major declines. During the second quarter of 2020, the first signs of revival started coming from China. Its domestic markets started witnessing a revival of growth as the impact of COVID-19 slowed down. As the whole world still struggling to cope up with the impacts of pandemic, the signs of positive growth in China signal a positive change for global economy suggesting its recovering faster than the other major economies across various industrial sections (Fig. 7).

6 Turbulence in Global Financial Markets

The global financial markets whether it was equity or bond faced turmoil and witnessed falls up to 30% from their highs in the early part of the year. All the major indexes NASDAQ, Nikkei, Dow Jones, Nifty, FTSE, and others faced a mass selloff. Credit markets also witnessed a series of fall in rates leading to huge financial debts of businesses as well as countries which are highly depending on foreign funds. This further deteriorated the financial system and economic feasibility.

7 Impact of COVID-19 on Indian Economy

The pandemic has impacted the Indian economy just like every other economy. Although the exact estimations of its actual effects are yet to be unfolded, the lockdown period of close to two months has left many sectors in a dire state. To curb the impacts, government did announce various fiscal stimulus packages at different stages to ease the situation and to pump up the liquidity into the market through all means.

Indian MSME's sector is considered to be the backbone of the Indian Economy and contributes more than 40% of India's exports and 30% of GDP was hit the hardest. In the short term, severe liquidity problems will put more pressure to operate and survive in the market as they are the most labor-intensive sector and any prolonged slowdown phase could deter any chances of recovery soon. A study by the All India Manufacturers Organization (AIMO) analyzed that 25% of MSMEs are facing closure due to various issues that involve lack of demand, dependency on other sectors, financial issues, and need immediate steps by the government.

The two sectors that have faced the maximum burn are the Entertainment Industry and Tourism/Hospitality sectors. A study by CRISIL suggests that revenues from the Indian Media and Entertainment Industry in the Current Financial Year are expected to reduce by 16% or Rs. 25,000 crores to Rs. 1.3 lakh crores. The impact on both the sectors would be severe as they will be last to see the demand pick up. A study by Credit Ratings predicts that the revenue from tourism would be 40% less than the revenue earned in 2019 and are estimated to incur huge losses.

Automobile Sector witnessed the same thing; the sector was already under huge stress for some time and was reporting a 20–25% downturn due to new emission norms. A Recent Report by Fitch Ratings forecasted that in 2020, the vehicle production in India would probably contract by 8.3% which will put the automobile industry under huge debt. Industry experts fear the Indian Automobile sector could be pushed back by four to five years.

The Indian Banking Sector over the past few years has been experiencing a major slowdown due to an increase in the number of Bad debts and NPA's. Reserve Bank of India in its Financial Stability Report released in December 2019, found that under the benchmark framework, the ratio of gross bad loans in September quarter of 2020 may raise around 9.9% compare to 9.3% recorded in 2019. With the outburst of pandemic, Banks, and Financial Institutions are facing another risk of bad loans as the moratorium period gets over. After this Pandemic, Central Banks expect an increase in Non-performing assets to 10.2–10.5%.

Drugs and Pharmaceutical Industry of India is the third-largest Producer of drugs (in volume) worldwide and is manufacturing approximately 60% of the world's vaccines. This pandemic affected this sector as well and exposed India's weakness and dependency on imports as it imports 85% of the active pharmaceuticals ingredients (API) from China for producing vaccines. The outbreak of COVID-19 affected the supply chain of china, resulted in a shortage of API and a high jump in the prices of commonly used medicines like paracetamol and other vitamin tablets in

India. However, the pharmacy sector has recovered sooner than the other sectors as the Indian Government has extended is its full support by introducing the incentive package of 13.76 billion INR for domestic manufacturing of essential drugs, medicines, and API devices. On the other hand, the resumption of businesses in china also ensured the continuous supply of necessary medical ingredients.

The logistic sector faced the biggest disruption due to lockdown. Over the last few years, the Indian Logistics sector has experienced growth resulting in the consolidation of large amounts and a substantial increase in market share. As per the Report of India Ratings, the size of Inland logistics is projected to fall up to 15% in the current financial year 2020–21. The report also suggests that the logistics player would be under great stress due to high leverage levels. The recovery of this would be gradual rather than V-shaped because of lower disposable income and heightened risk aversion.

As per the press release by the Ministry of Commerce and Industry in December 2020, overall Indian exports that include service as well as merchandise are set for a decline in period April–November 2020–21, as can be seen in Chart 2. The exports are estimated to show a negative growth during the same period last year and could be around USD 304.25 billion, a fall by (−) 14.03%. There is an estimated negative growth of (−) 29.96% in the overall imports in April–November 2020–21. The value of total imports is estimated to be USD 290.66 billion (Fig. 8).

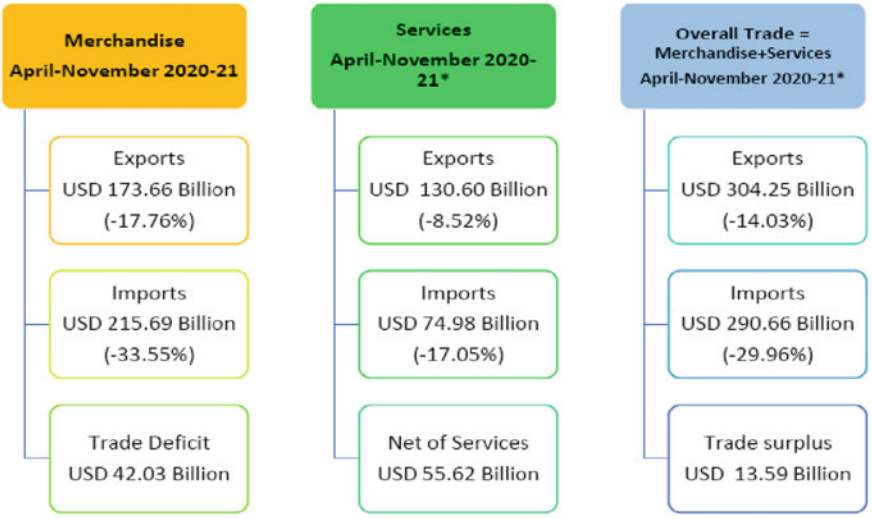

Fig. 8 India's foreign trade 2020–21 (RBI report of October 2020). https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1672676

8 Policy Responses Taken so Far

With the rise in the number of cases and all economic activities turning to almost zero levels, many of the countries preferred to infuse liquidity into the financial system. To counter the impacts of pandemic, it was a necessary step not just to keep the flow of demand moving but also to stop a credit crunch and to control the deflationary debt coil. During the time, every government also realized the need to speed up the health facilities and to support that emergency funds were created. One of the benefits of this fund was to increase the ability to cope up with new challenges which otherwise would have struggled due to insufficient funds needed to deal with the magnitude of the problem.

The health system is a neglecting sector both in developed and developing countries and the lack of medical facilities in terms of structure, health staff, bed, and medicines forced many of the nations into a tight situation. This limitation created bottlenecks and rationing in health systems. The financial crisis faced by the global economy is different from the ones previously witnessed; the thing that makes present scenario an unparalleled incident is manner every government and global agencies has to respond to it. The decision by governments to shut down all sort of economic activity leaving many vulnerable to contain the impact of the disease, to defend their already heavily burdened healthcare facilities and lastly to safeguard people to avoid any further damage to the society and economy was never foreseen.

Most of the developed economies are consumers market, driven by the spending habits of their people. This sudden stoppage of all activities through lockdown triggered automatic spending stabilizers. Apart from these sudden measures to save lives, government had additional responsibility to bring the economy back on its feet. To prevent further damages to their people in terms of jobs losses or income losses and also to curb down the damage on corporate balance sheets, governments in all countries adopted measures ranging from monetary, fiscal, and financial initiatives. To further support businesses and families, fiscal targets were foregone to provide relief packages not just during period of lockdown rather even later when things start getting back to some sort of normalcy. The social spending also impacted the revenues of local administrations drastically, and the monetary measures by different agencies helped them in many ways.

9 Some of the Immediate Measures Included

- Every government realized the need to spend more on developing health care system, in India itself where the budget of health care system is roughly around 1.5% of GDP more government funds for healthcare were allocated to cope up with the situation. These funds were made available either from a reallocation of funds from other sectors or through higher expenditure from government by crossing their budgetary limits. These funds were used in strengthening the health care

system and to increase the budgetary allocation for research activities to develop vaccines.

- Another important initiative taken by governments was to allow a reduction in interest rates by central banks. Although, not all the countries lower down the rates in the same manner, but everyone was cleared about making the cuts. This change in policy by central banks was followed even in countries witnessing higher inflations like Turkey and Argentina. The cycle started with Federal Reserve, which was quite aggressive in its policy stance and started the process of rate cuts even before pandemic started impacting its economy in harsh manner. Every other economy followed it later and a sequence of substantial rate cuts in developing countries started to support their weakening economies and to counter the effects of soft global economy. Rates were brought down to almost zero levels in most of the developed economies for short term deposits. During the period, only few countries choose not to follow the rate cuts mainly because of already prevailing low levels of interest rates there, like in Japan. In developing economies, substantial rate cuts were noticed to pump up the liquidity in the market, countries like India, Brazil, and South Africa followed the same to support the local demands while China choose to keep its monetary policy moderate without any major rate cuts.
- In India, the phase of interest rate cuts that begins at the end of 2018 got further accelerated. RBI in its first monetary policy briefing to tackle the effects of pandemic reduced the repo rate by 75 basis points bringing the rates down to 4.4 from the earlier rate of 5.15. Reverse repo rates were also brought down by 90 basis points to make the rates at 4%. Present rates stands at 4% for repo rate and 3.3% for reverse repo.
- In the face of the pandemic and to boost up the liquidity, quantitative easing was required. "Quantitative easing is defined as an emergency increase in the balance sheets of central banks to avoid a collapse of asset prices in domestic currency." Most of the countries whether advanced or developing made efforts in this regard. Special facilities and programs were launched to buy private as well government bonds. Countries like United States, UK, and Japan were more active in this role.
- In India, to ease up the liquidity several synchronized sales as well as purchases of government securities from open market were made by RBI under the "Operation Twist" since March 2020. This program was first introduced in 1961 in US by Federal Reserve as a medium to administer market yields.
- To enable enough liquidity in the market and to ensure the smooth running of financial operations, some Regulatory easing by central banks is very much required. This involves relaxation in capital reserve requirements of financial institutions to cope up with tough economic conditions like these. This liquidity enables these institutes tackle the risk of credit crunch in case of a sudden spike in default cases and to prevail any sort of capital loss. RBI brought down its CRR to 3% during the period by 100 basis point reduction, and any excess funds with banks were made to deploy in various financial instruments like commercial papers, corporate bonds and non-convertible debentures. These steps are part of RBI's Long Term Repo Operations enabling enough liquidity with banks.

- In tougher economic conditions, the risk of higher financial defaults and assets turning into non-performing looms larger over the whole banking system. Relaxations with respect to provisioning of non-performing loans were made to support the stressed financial system. RBI also specified not to downgrade any of the assets under this category. Globally through its flagship programs targeting poorest and vulnerable member countries IMF under the Catastrophe Containment and Relief Trust (CCRT) provided debt relief services to over 29 nations.
- To provide relief to their citizens and corporate houses from rising debt burdens countries announced programs that involved either restructuring of debt payments or standstill of any dues for a limited period. In March 2020, RBI also announced measures on similar lines which were applicable to all lending institutions. An extended period of loan moratorium was announced to safeguard the middle class and other sections of society which were highly impacted due to job losses and rising financial burdens.
- Tax administrations across globe played a critical role in supporting economies by helping to mitigate cash flow difficulties and minimize compliance burdens on the citizens. Many important steps including easing of taxation norms, early tax refunds, easing of auditing norms, and providing facilities of either defer or cancellation of tax payments for the time being were taken. In some countries, higher rates of taxes were also imposed on high net worth individuals to raise funds to meet social expenses. That is to fight the pandemic through the ease of direct and indirect tax burdens although temporarily. Several countries adopted extension of tax filing period and facilities that enable flexible tax payment, e.g., Australia and New Zealand. Complete tax waiver was allowed only in few countries, specifically targeting a particular sector like tourism, e.g., Indonesia and Korea.
- Emergency cash and non-cash transfers to all the affected sections of the working-class that included formal workers, informal workers, and people at risk. Different measures targeting the larger part of the population that was impacted the most and remained out of the safety nets of most of the policies were made. Steps like food distribution, minimum income surety and insurances to safeguard the rights of people who went unemployed due to the crisis. The most common strategy adopted by developed countries was providing temporary stimulus packages to the people during the period to sustain their income. It was successfully adopted by US to keep the flow of demand moving or through "corona voucher" to unpaid workers as in Brazil, with an extra benefit for families with children. India did its bit in helping its underprivileged sections of society by providing free rations for an extended period and also by transferring a sum of Rs. 1000 to more than 30 million people. These programs played a major part in faster economic recovery and kept the demand flow intact to cope with economic disruptions caused by Covid-19.
- To revive the Indian economy and to provide relief to those affected by the pandemic, the Central Government persistently supported the State Governments towards a faster economic recovery. As a part of its Aatma Nirbhar Bharat Package, the Centre enhanced the borrowing limit for the States from 3 to 5% of GSDP for FY 2020–21. Up to 22nd November 2020, the State Governments had raised ₹4.73 lakh crores as gross market borrowings during the current fiscal, which is

approximately 50% higher than the states' gross borrowings of the same period in 2019–20.

- To compensate the states for the losses of GST revenue during FY 2020–21, Indian Central Government operationalized a Special Window, coordinated by its Ministry of Finance, to borrow the shortfall arising out of GST implementation through the issue of debt and pass it on to the States and UTs. The window is in operations since 23rd October 2020 and an amount of Rs. 24,000 crores on behalf of the States is already borrowed by the Government of India in four installments and its benefits are already passed on to the States and UTs opted for it.

10 How the Story Looks Like Now?

The combination of a weakening global growth that was alarming around 2.5% in 2019 after averaging around 3.0% growth over a period of three years, and the constant unwarranted tussle between the major economies in recent times has impacted global economic growth severely. For major part of the period, 2019 trade volumes remained in a negative growth trajectory. Most of the experts were hoping for a better 2020 but any hopes for a revival were rapidly darted. The spread and the impact of pandemic have brought the world to halt and the tougher times the global economy has witnessed during the financial crisis of 2008–09 began to resurface.

The big task of economic reconstruction after COVID-19 is not going to be a smooth one. It will require all governments to play an active role and policies should aim at reducing income inequality while ensuring the growth path sustain. The need for structural reforms to boost government spending in large projects to generate employment opportunities as well as to ensure smooth transition to new patterns of production and consumption. On the other hand, availability of sufficient funds for developing nations should be a priority for global agencies not just to strengthen their social system but also to cover the rising inequality gap globally. The most important aspect to understand is requirement of large public spending by economies for the time being to recover at a faster rate from shocks of pandemic, and to accomplish that they must work on finding fresh ways to manage fiscal constraints and imbalances, which remains an indisputable challenge in these times.

By studying the financial crisis of 2008–09, it can understand that though reduction in interest rates to lower values do help in a short time but to boost market sentiments are not enough in long period. It can boost up the investment cycle but to keep stimulation continue and to bring the economy back to full employment level again is a huge task. This will require combination of policies from governments' side targeting industrial, fiscal and labor issues simultaneously.

11 Debt Sustainability Issues

One of the major risks that the world is facing is there could be another rise of large financial defaults. The global debt levels are already high and are nearly $250 million even before the pandemic. This is approximately 320% of global GDP by the third quarter of 2019. The advanced economies hold about 70% of it. Majority of the global debt is held by nonfinancial corporations (29%), governments (27%), and financial corporation's (24%), trailed by households (19%). The interest rates are lowest at the moment in most of the countries whether it is developing or the developed ones. But these low rates come with a risk as the level of debts in most of the countries whether with government agencies or corporate houses is at the highest points. The circle of low-interest rates that is on for a long period has brought a situation of soaring financial risk. During the present crisis, most of the countries have to opt for measures for financial easing in their economies that have increased their vulnerabilities to this debt circle. The global financial debt has seen an increase by many folds and fiscal deficits of most of the nations are at levels higher than they were at times of subprime crisis. The risk of defaults in large numbers by borrowers and thereby affecting the profitability and balance sheets of banks loom large.

12 Rising Unemployment

As per estimates of ILO, the first three quarters of 2020 has recorded labor income losses of around $3.5 trillion that is approximately 5.5% of global GDP of 2019 of same period. The pandemic has resulted in a labor income decline of around 10.7% in 2020 compared to same period of 2019. The rising unemployment both in organized and unorganized sector has resulted in massive working hour and income losses for workforces. To counter it, stimulus packages announced by various governments have been effective to an extent. The employees in the organized sectors remains the major beneficiaries of social policies brought in by governments to support labor income losses. But the worst impact will be felt by employees of the unorganized sector employees which constitute around 60% of global workers. Most of the government schemes target the organized sector workforce as a result this section remains vulnerable and unprotected. In India itself rate of unemployment was hovering around six percent at the end of September 2020 which is better than the figures recorded in May 2020 when unemployment rate were as high as 24%.

Most of the sectors are still suffering from demand losses and working at underproduction levels. The decrease in demand and disruption of the workforce are the major issues faced by companies. Social distancing has also resulted in huge job losses, specifically to those who are in domestic help services, and constitutes a big part of the unorganized sector. The rising poverty and unemployment levels will

continue to trouble the policymakers as they required to be prepared for the challenges with necessary policy responses to minimize the risk. Biggest challenge will be to ensure the effectiveness of investments made in bringing these reforms.

13 China Leading the New Growth Phases

When the first case of the virus was noticed in China no one has predicted it to counter it so strongly and revive its economy faster than any other country. The progress made by China economically is significant especially at a time when most of the world including major powers struggling to cope up with challenges of pandemic. This is evident from its July–September GDP numbers that are showing a growth of 4.9% mainly after observing a contraction of 6.8% in first quarter of 2020. In the third-quarter, China has recorded an imposing growth in all sections that even include its foreign trade. The third quarter growth numbers are much more impressive than the 3.2% it recorded in second quarter while most of the world is still battling down lockdowns. September quarter also witnessed a rise of nearly 10% in export values and 13% rise in import values compared to same period of previous year. Certainly, strong economic buoyancy showed by the Chinese economy is highly appreciable.

While IMF predicts a contraction of 4.4% for global economy for China, it believes a positive GDP growth of 1.9% in 2020. It also expects it grow at an even faster rate of 8% next year. During the same period, it expects most of the major economies to contract sharply, for UK expected contraction is as low as 9.8% while for India, it is nearly 10%, stronger economies like Japan and US are also expected to record declines this year.

As China seems to be recovering at faster rate than most of the world, it is highly possible it will emerge as more dominant player in post COVID era. US will still remain a dominant force but to get back to its global supremacy may take time for a while.

14 Inequality of Income

The aftermath of the pandemic has left lots of questions on the table and has exposed and intensified inequalities between countries just as it has within their own countries. Job losses at a massive scale and change in working culture as work from home became a new trend the difference between different groups only expand, leaving the lower-income group much more vulnerable to the aftermath of the new calamity. The burden of disease has fallen disproportionately in the United States, impacting people of all religions, colors, and gender. In India, studies suggest that minority communities, Dalits and Adivasis have fallen deeper into debt and economic deprivation, disproportionately compared to others. The sectors like textiles, entertainment industry, tourism, and household workers have been hit hardest compared

to the people engaged in blue-collar jobs and are working from the comfort of home since the beginning of the pandemic. It is also going the impact the poorer countries lot harder as they have to spend more on health services than developmental activities and may push them into a cycle of the debt burden. To cater to this situation, it becomes more important that the International Monetary Fund, World Bank, and other development institutions can come together and create a platform of international cohesion to help out these countries. Possible solutions like writing off a part of their debt or restructure the payment cycle accordingly.

15 Slowdown of Globalization

The lockdowns of months disrupted the global supply chain leaving most of the economies vulnerable. Closure of borders and all the possible ways of transportations made the distribution of essential resources like medicine, health equipment, food, and other essential items difficult. As per WTO forecasts in 2020 itself, a possible fall of around 13–32% in global trade volumes is inevitable due to stringent lockdowns globally. This has made many of the countries to look into the resources internally, developing their capacities and slowly reducing their dependence on imports both in terms of technology as well as materials. Another important factor to consider is that even before the pandemic struck the global market, some of the major economies were already making efforts to decouple themselves from other markets thereby threatening the concept of globalization. As per WTO in the recent years for both emerging as well as developed economies a decline in the ratios of trade to GDP is visible. If we take into account the economies like India and China we can see similar trends. In 2008, ratio of trade to China's GDP was nearly 58%, but today it is hardly up to 40%. Data from India is very much similar to China; in 2012 India's trade to GDP ratio was 56% which at present has declined to 43%, showing a significant fall. Since the pandemic, the meaning of globalization itself has taken a different shape. Amidst the current crisis Japan has allocated a sum of nearly $2 billion for its companies to assist them in relocation from China to anywhere near Japanese region. Such shifts could hamper the pace of revival for the global economy and may also force the nations with limited capabilities further vulnerable.

16 Conclusion

After the precipitous decline into which the global economy is pushed in the second quarter of 2020, at present things look a lot better for the global economy. Most of the economies have opened up their economic activities although the threat of new COVID strain is still surfacing, to the relief of everyone development in finding vaccinations has smoothened things up. The next phase is an important one, till now the focus of every country was on survival by supporting its people through spending

on health care and other social welfare resources. Now things need to shift towards a bigger goal that is from containment to revival.

The third quarter has seen substantial growth in most of the economies. Improvement in manufacturing, labor markets, and retail sales powered strong recoveries in some countries boosted by investments due to liquidity available in the market pushed through various stimulus packages. The collaborated work done by all countries has prevented a deeper downslide. The massive policy supports by authorities has helped in employment generation at the grass-root level, support household incomes and struggling businesses. To boost the income and to create employment opportunities in rural areas Indian government has started job creation programs under its various policies like the MGNREGA.

Going forward, global leaders have a big task in their hands; they need to keep a balance among their policies and have to ensure they do not hurry up in taking back the financial stimulus' provided to the industries. For the time being, governments should keep their expenditure on developmental activities on to create the job as well as boosting the incomes of people in the lower-income group. Fiscal deficits and all the budgetary targets should be relaxed till the complete revival of economies.

Along with providing fiscal packages and job creation, governments has to ensure the developmental activities do not hamper due to rising burden of social welfare programs. Fiscal deficit targets should be managed in lighter manner and no major burden of taxes should be imposed on people to keep the necessary liquidity in the system to boost the sluggish demand cycle. Once the moratorium period ends chances of debt defaults are high, governments should be prepared for them and a system of restructuring should be placed accordingly to reduce the impact on financial system.

Globalization can play a key role in a faster global recovery, all the major agencies like OECD, IMF, WTO, and World Bank should work together to bring the trust back among economies. Rather than looking at growing inside countries should be supported to grow together. This will ensure the under developing countries are able to recover at a better rate and trade balance could be attained among emerging and advanced economies.

Every adversity brings new opportunity and the world needs a stronger vision to revive it.

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Modeling the Impact of Various Treatment and Prevention Tact's on COVID-19 Worldwide

Kamal Kumar, Meenu, Sheetal, and Abhishek Raj Singh

Abstract World Health Organization declared an epidemic on March 11, 2020 known as COVID-19. In the world, there are deceptive distinctions in prevalence and impermanence of COVID-19 cases in different areas. The COVID-19 first case in India was found on January 30, 2020. Presently, no remedy is available for COVID-19 treatment. The organs or the cells having ACE-2 expression are at higher risk of COVID-19, and in this manner, lymphocytes, which make a larger portion of the immune system, are the primary target of COVID-19 virus. Without authentic vaccines or treatment, there is a crucial need for the tactics of treatment and prevention for COVID-19 virus. Developing such tactics involves full understanding of how the virus is spreading in all over the world. Various treatment and prevention methods have been started worldwide such as BCG vaccination, plasma therapy, antiviral drugs, and immunoboosters to decrease the high death rate caused because of COVID-19 pandemic. Our motive is to compare various models (BHRP transmission model, SIR model, and SEIR model) and then put on different control factors to understand the results of recovery from COVID-19 virus.

Keywords COVID-19 · ACE-2 · Mathematical modeling · Immunoboosters

1 Introduction

COVID-19 is an acronym and it is an infection caused by the severe acute respiratory syndrome coronavirus 2 (SARS-COV2). China country office informed about death cases to WHO on December 31, 2019, which were susceptible of an unknown disease

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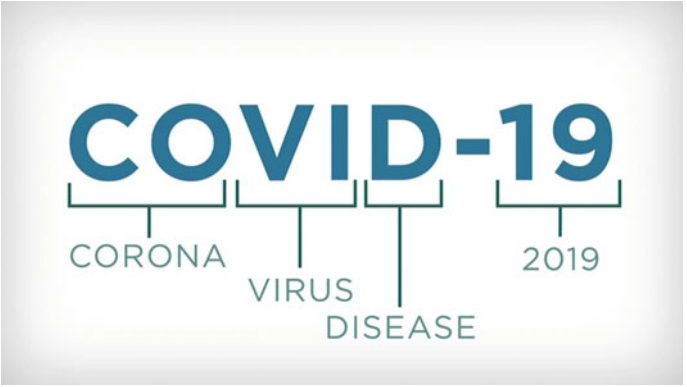
in the Wuhan city, Hubei province China, then WHO announced that as novel coronavirus. SARS-COV-2 was named by International committee on taxonomy of viruses on February 11, 2020. First, it is found that virus transmitted from bats to humans. Therefore, the spreading of virus was linked to seafood market. After this epidemic, COVID-19 grabbed severe attention across the world. WHO declared the COVID-19 as a universal epidemic in March 2020. The main reason of radiate COVID-19 was the unavailability of data and awareness regarding causative agent during its foremost stage of infection. The virus spread in the crowning through respiring droplet during sneezing or coughing from the infected person. An earlier healthy inhabitance may become infected when they breathe in contaminated area or touch the infected surface. COVID-19 symptoms develop in 2–10 days. The prime symptoms involved dry cough, difficulty in breathing, and high fever. In beginning stage of infection, we isolate the infected person.

Angiotensin-Converting Enzyme: Angiotensin-converting Enzyme is a zinc-dependent carboxypeptidase which has two catalytic domains. ACE imparts an important role in regulation of blood pressure by conversion of angiotensin I to angiotensin II. This enzyme also has a role in immunity response focusing on innate and adaptive responses by modifying functions of macrophage and neutrophil cells. These effects are increased when expression of ACE is over-expressed in these types of cells. Over-expression of ACE in macrophages is more effective in managing tumors and infections. Discovery of ACE was coming into light in 1953 in the course of rennin-angiotensin system (RAS), on cell membrane present which is attached through a transmembrane domain having carboxy terminal. In various treatment strategies of different types of diseases, ACE or kininase II inhibitors are widely used as therapeutic agents. The pharmacological effects of ACE-2 have been reported as it increases constriction in blood vessels, alleviates oxidative stress, and results in fibrosis. It also stimulates to angiotensin II due to which concentration of water and salt is increased in blood plasma. ACE-2 has well-known vasoconstrictive, proinflammatory, and fibrotic effects. In various studies, it has been proved that activity of ACE is found in an alleviated amount and downregulation of ACE-2 also reported in patients suffering from various diseases as diabetes, hypertension, and other cardiovascular disorders.

Lymphocytes: Innate immunity is the first line of defense against viral infection which is important in providing immunity to viruses. Al-Shura [1] discussed that in blood, white blood cells are one of the types of blood cells which have lymphocytes. Omman and Kini [2] discussed on lymphocytes that they are found in the immune system of vertebrates and are composed of different types of cells as natural killer cells, T and B lymphocytes cells, etc. Total lymphocyte counts decreased in the first two weeks of illness in COVID. It also has reported that patients who have immune dysregulation, due to infection of COVID-19, had decreased counts of different types of lymphocytes cells specially counts of CD3+, CD4+, CD45+, CD8+, CD45+, CD16+, and CD56+ cells than those individuals who has an intermediate immune state.



There is no established medicine and vaccine for the treatment of COVID-19. The drug chloroquine and antibiotic azithromycin which is used as antimalarial exposed some promise against COVID-19 but its effectiveness has been debated lately [3]. Only strong immunity of humans can decrease the spread of disease [4]. Some researches such as Chen et al. [5], Hung et al. [6], Ko et al. [7], and Zhou et al. [8] showed successfully the safety results of CP therapy during pandemic in their studies. The disease recognized as COVID-19 dated back its origin in December 2019 at Wuhan city, China. Jain et al. [9] explored an inventory model the learning impact on best policy with preservation technology for decline goods under in COVID-19 pandemic. Koutsakos et al. [10] and Althaus [11] also discussed on COVID-19 transmission in humans. Mittal et al. [12] discussed the measures of predictive and preventive for pandemic COVID-19. Mittal [13] explored a statistical modeling approach related to the factors affecting digital education during pandemic. Goyal et al. [14] discussed that COVID-19 is another way of natural disaster. Mittal et al. [15] explored the impact of air quality on the COVID-19 fatalities in Delhi, India, by using machine learning techniques.

The spread of the disease is similar to the spread of other airborne diseases such as influenza and tuberculosis via direct contact with the person infected by the virus through respiratory droplets. As there is no defined treatment or a vaccine which is effective for controlling the transmission of the disease, it is a crucial need to develop much more effective methods to deal with the increasing spread of the disease. Vaccines are responsible for providing protection against particular pathogens by making effective mechanisms that work directly toward the pathogens. The BGC vaccine is a live attenuated vaccine which improves the immunity against not only single bacteria but also to several other microorganisms which are present with acute respiratory tract infections.

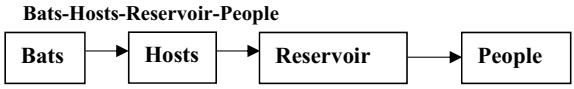


Fig. 1 Diagram of BHRP transmission model

1.1 Bats-Hosts-Reservoir-People

BHRP spreading network model was formulated on January 19, 2020. Here, we consider that the virus circulated among the bats and then transferred to an unspecified host. The host was the most purchased food in the market of seafood which was identified as the reservoir of the virus. People went to the market for food and became infected (Fig. 1).

Bats are divided into four parts susceptible, exposed, infected, and removed bats. After waste spreading of bats and hosts was disregarded, then reservoir-people spreading models come because we consider that COVID-19 might be carried from the market of seafood in a short time among many people.

1.2 SIR Model

SIR model was first developed by Kermack and Mckendrick [16] in 1927. This was the first continual varying projection model considering epidemic population dynamics. In this model, constant populations are distinguished in three circumstances which include susceptible, infected, and removed. Three possible parts of transitions are susceptible $S(t)$, infected $I(t)$, and removed $R(t)$. The portion of interconnection between $S(t)$ and $I(t)$ which taken as the rise to infection per unit time is ϕ. The portion of infected people that recover with exemption or pass away from disease per unit time is φ.

The mathematical formulation of SIR model is as follows:

$$\frac{\mathrm{d}S}{\mathrm{d}t} = -\phi S(t)I(t),$$
$$\frac{\mathrm{d}I}{\mathrm{d}t} = \phi S(t)I(t) - \varphi I(t),$$
$$\frac{\mathrm{d}R}{\mathrm{d}t} = \varphi I(t).$$

1.3 SEIR Model

The SEIR model includes four parts: susceptible (S), exposed (E), infected (I), and removed (R). Let α be the infection rate between susceptible (S) and exposed (E)

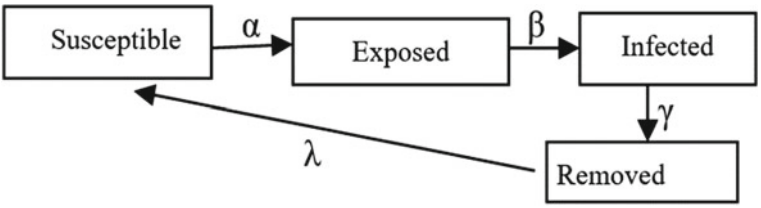


Fig. 2 Diagram of SEIR transmission model

which expresses the chance of disease transferring to susceptible people to exposed people; β is the growth rate which expresses the inactive rate at which one becomes infectious; γ is the recovery rate and λ is the rate at which recovered people become susceptible again because of health issues (Fig. 2).

The mathematical formulation of SEIR model is as follows:

$$\frac{dS}{dt} = -\alpha \frac{SI}{N} + \lambda R \tag{1}$$

$$\frac{dE}{dt} = -\alpha \frac{SI}{N} - \beta E \tag{2}$$

$$\frac{dI}{dt} = \beta E - \gamma I \tag{3}$$

$$\frac{dR}{dt} = \gamma I - \lambda R \tag{4}$$

Here N shows the sum of susceptible, exposed, infected, and removed.

The function of SEIR model is to find the value of R_0 where R_0 shows basic reproduction number. R_0 denotes an average of people affected by an infected person in a limited time. Here, three cases arise:

(1) If $R_0 < 1$, then the stage of disease is controllable.
(2) If $R_0 = 1$, then the stage of disease is endemic.
(3) If $R_0 > 1$, then the stage of disease is uncontrollable (or increasing).
$R_0 = \frac{\alpha_0 \beta}{(\mu+\beta)(\mu+\gamma)}$, where μ is the proportionately birth rate. The α, β, λ, and γ value can be found from Eqs. (1–4).

Chen et al. [17] derived a model on novel coronavirus for reproducing the phase-based transmission from the source of infection to the people. Pal et al. [18] used a different model to study and forecast the increase of virus disease. Shah et al. [19] introduced the idea to control COVID-19. In model, they assumed all feasible cases of transmission of this virus. To examine the accurate transmission of the virus, a basic reproduction number is derived. They devised the plan to show control of disease numerically as well as graphically. Transmission model is divided into five compartments. Shah et al. [20] derived a model for the recovery of infected people

of COVID-19. They calculate the basic reproduction number and applied different parameters to see the impact of recovery from disease. Plasma therapy shows the better result for a long term. From the studies of COVID-19, Leung et al. [21] developed a method to evaluate the pandemic which is spreading globally. Shah et al. [22] derived the mathematical model by using the different parameters to control the COVID-19 and also agreed that better results can be seen by using plasma therapy.

2 Formulation of Mathematical Model

Here, a model for COVID-19 transmission among the people is formed. Model is divided into eight parts:

1. Exposed people
2. Infected people
3. Symptomatically infected people
4. Non-symptomatically infected people
5. Quarantined people
6. Hospitalized people
7. Critical stage people
8. Recovered people.

First part is the category of exposed people to COVID-19 denoted as E. From these, some people are transferred into the stage of infection denoted as I, some infected people that have symptoms of COVID-19 denoted as S, and some people do have any symptoms of COVID-19 denoted as N_S. From these class of people, some get quarantine denoted as Q and others get hospitalized denoted as H. From these hospitalized people, some shift to quarantine and other go to critical stage denoted as C, another some people recovered also denoted as R. From these critical stage people, some people also recovered (Fig. 3).

By using Fig. 4 and Table 1, the nonlinear differential equations are formulated as:

$$\frac{\mathrm{d}E}{\mathrm{d}t} = B - B_1 E I \tag{5}$$

$$\frac{\mathrm{d}I}{\mathrm{d}t} = B_1 E I - B_2 I S - B_3 I N_S \tag{6}$$

$$\frac{\mathrm{d}S}{\mathrm{d}t} = B_3 I S + B_4 N_S - B_5 S - B_8 S - B_9 S \tag{7}$$

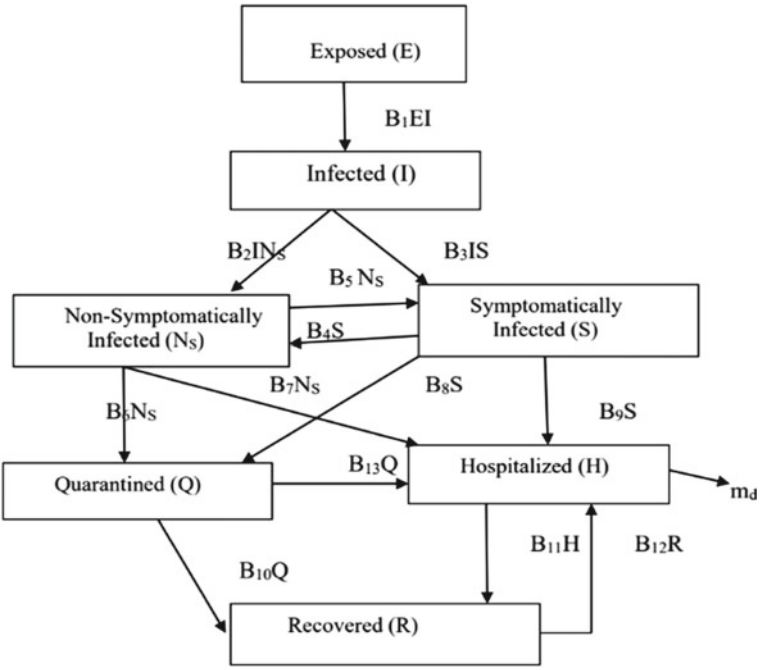


Fig. 3 Diagram of COVID-19 transmission model

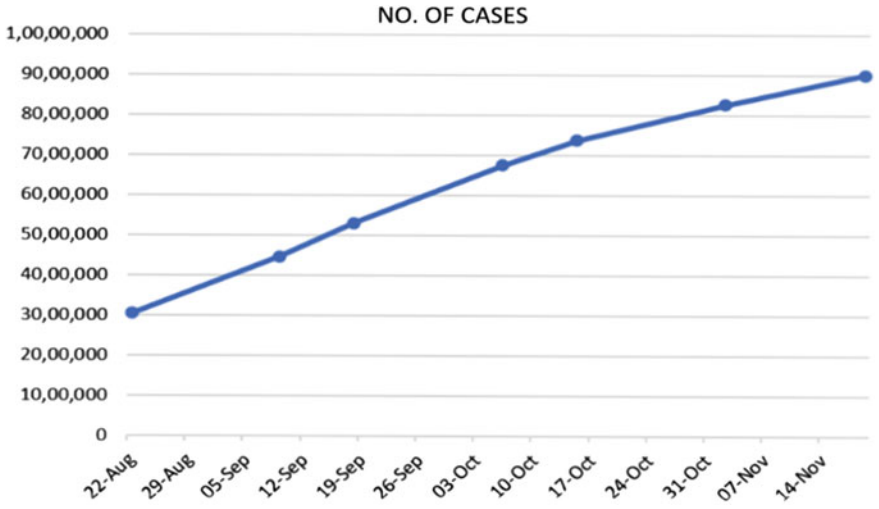


Fig. 4 Graph of India's total coronavirus cases

Table 1 Notation and its description

B	Birth rate of exposed people
B_1	Rate of infected people
B_2	Rate of infected people who does not show symptoms
B_3	Rate of infected people who show symptoms
B_4	Rate of infected people lose symptoms
B_5	Rate of symptomatically infected people now show symptoms
B_6	Rate of non-symptomatically infected people getting quarantine
B_7	Rate of non-symptomatically infected people who get hospitalized
B_8	Rate of symptomatically infected people who get quarantined
B_9	Rate of symptomatically infected people getting hospitalized
B_{10}	Rate of recovered people who get quarantined
B_{11}	Recovery rate of hospitalized people
B_{12}	Rate of recovered people who get hospitalized
B_{13}	Rate of quarantined people who get hospitalized
m_{d}	Rate of death due to disease

$$\frac{\mathrm{d}N_{\mathrm{S}}}{\mathrm{d}t} = B_2 I N_{\mathrm{S}} - B_4 N_{\mathrm{S}} + B_5 S - B_6 N_{\mathrm{S}} - B_7 N_{\mathrm{S}} \tag{8}$$

$$\frac{\mathrm{d}H}{\mathrm{d}t} = B_9 S + B_7 N_{\mathrm{S}} - B_{11} H + B_{12} R + B_{13} Q - m_{\mathrm{d}} H \tag{9}$$

$$\frac{\mathrm{d}Q}{\mathrm{d}t} = B_6 N_{\mathrm{S}} - B_{13} Q - B_{10} Q + B_8 S \tag{10}$$

$$\frac{\mathrm{d}R}{\mathrm{d}t} = B_{11} H + B_{10} Q - B_{12} R \tag{11}$$

With $E > 0$; $I, S, N_{\mathrm{S}}, H, Q, R \geq 0$.

3 Basic Reproduction Number

The solution of Eqs. (5–11),
$E^* = (E^*, I^*, S^*, N_{\mathrm{S}}^*, H^*, Q^*, R^*)$ is

$$E^* = \frac{B}{x B_1}, \quad I^* = x, \quad S^* = -\frac{B B_4}{y},$$

$$N_S^* = \frac{B(B_3x - B_5 - B_8 - B_9)}{y}, \quad H^* = \frac{B}{m_d},$$

$$Q^* = \frac{B((B_3x - B_5)B_6 - B_6(B_8 + B_9) - B_4B_8)}{y(B_{10} + B_{13})},$$

$$R^* = \frac{zB}{y(B_{10} + B_{13})m_dB_{12}}$$

where $z = m_dB_{10}B_6(B_3x - B_5) - m_dB_{10}B_4B_8 + B_{11}(B_6 + B_7)(B_3x - B_5)\ (B_{10} + B_{13}) + (B_8 + B_9)(B_{11}(B_6 + B_7)(B_{10} + B_{13}) + B_{11}B_4(B_{10} + B_{13}) + m_dB_{10}B_6)$ and $y = (B_6 + B_7)(B_3x - B_5) - (B_8 + B_9)(B_4 + B_6 + B_7)$, x is the highest root of the polynomial

$$m(P) = B_2B_3P^2 - B_2(B_5 + B_8 + B_9) + B_3(B_4 + B_6 + B_7)P + B_5(B_6 + B_7) + (B_8 + B_9)(B_4 + B_6 + B_7)$$

By using next generation matrix method, we calculate endemic equilibrium point. Now

$$f = \begin{pmatrix} B_1EI \\ B_2IN_S \\ B_3IS \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix},$$

$$v = \begin{pmatrix} B_2IN_S + B_3IS \\ B_4N_S - B_5S + B_6N_S + B_7N_S \\ -B_4N_S + B_3S + B_8S + B_9S \\ -B + B_1EI \\ -B_6N_S - B_8S + B_{10}Q + B_{13}Q \\ -B_7N_S - B_9S + B_{11}H - B_{12}R - B_{13}Q + m_dH \\ -B_{10}Q - B_{11}H + B_{12}R \end{pmatrix}$$

$$\text{Again, } F = \begin{pmatrix} B_1E^* & 0 & 0 & B_1I^* & 0\,0\,0 \\ B_2N_S^* & B_3I^* & 0 & 0 & 0\,0\,0 \\ B_3S^* & 0 & B_3I^* & 0 & 0\,0\,0 \\ 0 & 0 & 0 & 0 & 0\,0\,0 \\ 0 & 0 & 0 & 0 & 0\,0\,0 \\ 0 & 0 & 0 & 0 & 0\,0\,0 \\ 0 & 0 & 0 & 0 & 0\,0\,0 \end{pmatrix},$$

$$V = \begin{pmatrix} B_2N_S^* + B_3S^* & B_2I^* & B_3I^* & 0 & 0 & 0 & 0 \\ 0 & B_4 + B_6 + B_7 & -B_5 & 0 & 0 & 0 & 0 \\ 0 & -B_4 & B_5 + B_8 + B_9 & 0 & 0 & 0 & 0 \\ B_1E^* & 0 & 0 & B_1I^* & 0 & 0 & 0 \\ 0 & -B_6 & -B_8 & 0 & B_{10} + B_{13} & 0 & 0 \\ 0 & -B_7 & -B_9 & 0 & -B_{13} & B_{11} + m_d & -B_{12} \\ 0 & 0 & 0 & 0 & -B_{10} & -B_{11} & B_{12} \end{pmatrix}$$

Hence $R_0 = \rho(FV^{-1})$

$$= \frac{B_2B_3x((B_6 + B_7)(B_3x - B_5) - (B_8 + B_9)(B_4 + B_6 + B_7))}{\begin{pmatrix} (B_6 + B_7)(B_2B_5(B_3x - B_5) - B_3B_4B_5) + (B_8 + B_9) \\ (B_3B_4(B_2x - B_4) - B_2B_4B_5 - B_2(B_8 + B_9)(B_4 + B_6 + B_7) \\ +(B_6 + B_7)(B_2B_3x - 2B_2B_5 - B_3B_4)) \end{pmatrix}} \tag{12}$$

where ρ is the eigenvalue of the matrix FV^{-1} (Figs. 5, 6, 7 and Tables 2, 3, 4, 5).

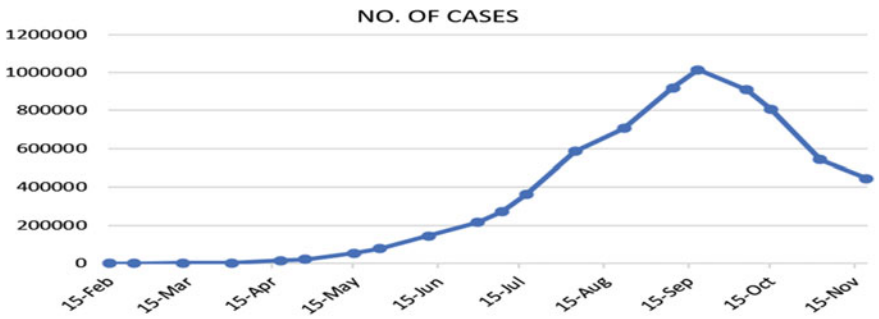


Fig. 5 Graph of coronavirus active cases in India

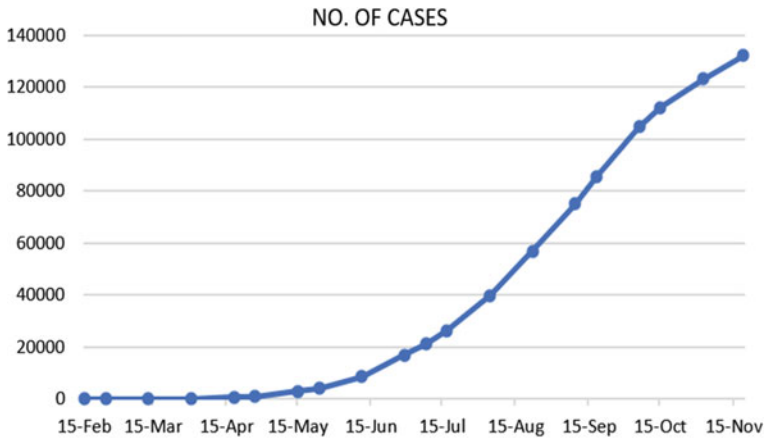


Fig. 6 Graph of total deaths due to coronavirus in India

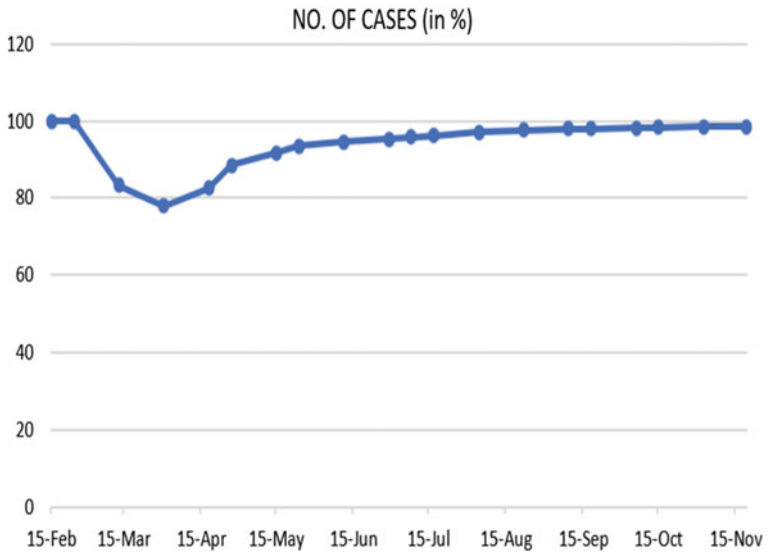


Fig. 7 Graph of total recovery rate of coronavirus in India

4 Summary and Conclusion

Coronavirus cases include a large family of viruses which causes illnesses like mild cold to severe respiratory disorders. The novel COVID-19 is one such strain that had not been identified in the past. In this chapter, SIR, SEIR, BHRP, and RP models were utilized to survey and forecast the extent of disease, and a compartmentalized model is proposed to find the transmission of COVID-19 in the human population class.

Table 2 Total coronavirus cases in India

Date	No. of cases
15 February	3
24 February	3
13 March	82
31 March	1397
18 April	16,385
27 April	29,451
15 May	85,784
24 May	138,536
11 June	298,283
29 June	567,536
8 July	769,052
17 July	1,040,457
4 August	1,906,613
22 August	3,043,436
9 September	4,462,965
18 September	5,305,475
6 October	6,754,179
15 October	7,365,509
2 November	8,266,914
19 November	9,004,325

Table 3 Coronavirus active cases in India

Date	No. of cases
15 February	0
24 February	0
13 March	70
31 March	1239
18 April	13,381
27 April	21,375
15 May	52,773
24 May	76,820
11 June	142,810
29 June	215,361
8 July	271,354
17 July	360,094
4 August	585,133
22 August	706,690

(continued)

Table 3 (continued)

Date	No. of cases
9 September	918,790
18 September	1,014,649
6 October	908,335
15 October	804,705
2 November	542,346
19 November	445,107

Table 4 Total deaths due to coronavirus in India

Date	No. of cases
15 February	0
24 February	0
13 March	2
31 March	35
18 April	521
27 April	939
15 May	2753
24 May	4024
11 June	8501
29 June	16,904
8 July	21,144
17 July	26,285
4 August	39,820
22 August	56,846
9 September	75,091
18 September	85,625
6 October	104,591
15 October	112,146
2 November	123,139
19 November	132,202

Table 5 Total recovery rate of coronavirus in India

Date	No. of cases (in %)
15 February	100
24 February	100
13 March	83.33
31 March	77.85

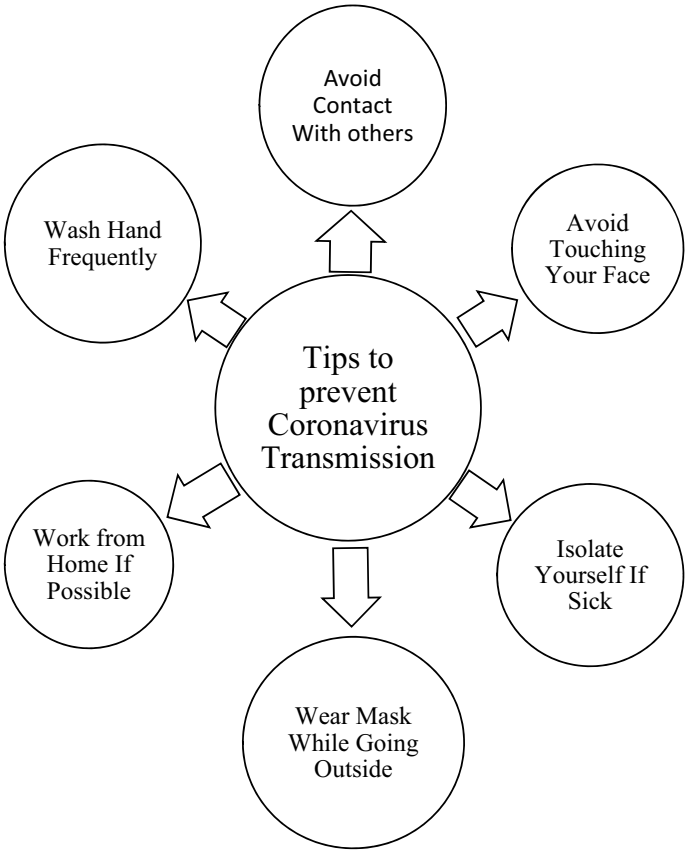
(continued)

Table 5 (continued)

Date	No. of cases (in %)
18 April	82.54
27 April	88.37
15 May	91.66
24 May	93.48
11 June	94.53
29 June	95.20
8 July	95.75
17 July	96.14
4 August	96.99
22 August	97.57
9 September	97.88
18 September	98.00
6 October	98.20
15 October	98.29
2 November	98.41
19 November	98.46

Furthermore, basic reproduction number is found to find the origin value of spread of COVID-19. In this model, seven control variables are established to control tactics the spread of COVID-19. These tactics involve symptomatic and non-symptomatic of infected peoples, quarantine and hospitalization of infected people to reduce the case of COVID-19. It has not only possessed harm to the health of people but has also hampered the economy, trade, and relations between various countries at a noticeable stage. But, the long-term effects of this epidemic are still to be felt which cannot be predicted at such an early stage. The increasing cases of COVID-19 and deaths due to COVID-19 across the world also add to its seriousness. We all have heard that prevention is better than cure. Thus, we must take the desired steps to distance ourselves from the ever-growing COVID-19. These steps include:

- Use of masks
- Avoid to be in congested places
- Wash or sanitize your hands frequently
- Maintain considerable distance from people
- Do not touch your face often.



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Understanding Emotional Health Sustainability Amidst COVID-19 Imposed Lockdown

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Abstract Considering the COVID-19 outbreak, comprehending the psychological state is a major concern across the world. Sentiments and their emotions can be accessed via diverse social media platforms. Most prominently, Twitter plays a vital role in understanding the emotions of netizens, regardless of their origin. In this chapter, we study emotional health during the lockdown phases, taking India as a case study. Varied emotions over time derive their possible existence from the reported, deceased, and recovered cases, or a number of unanticipated situations. This study's empirical findings are based upon eight emotions: Anger, Anticipation, Disgust, Fear, Joy, Sadness, Surprise, and Trust. We also describe how every lockdown impacted the emotions among people in worst hit Indian states towards COVID-19 cases by analyzing how a particular lockdown comes to be associated with distress and relief. For better understanding, we developed an automated tool to pictorially represent emotions, URL: https://emotiontrackerindia.herokuapp.com/. Understanding the emotional and mental health of the masses makes the nations proactive and future-ready. Adoption of suitable sustainability measures at the right time mitigates such crisis-like situations. This chapter puts forth an emotion analysis mechanism using social media and recommendations for upcoming emergencies.

Keywords COVID-19 · Lockdown · Emotion analysis · Twitter · India

1 Introduction

Since the second half of the year 2019, COVID-19 has been sorely hitting the world. The seriousness of this pandemic can be determined by the uninterruptedly growing COVID-19 cases around the world. As per the current situation, countries like the USA, Russia, Brazil, and India have been severely affected by this virus [1]. Several lockdowns were imposed worldwide in different countries to minimize the outspread of the disease. Due to these unprecedented situations in the lives of all human beings

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alive today, the behavior and emotions of human beings have been greatly affected [2]. As one could expect at this time of total lockdown, it is but natural for a person to have different sorts of emotional swings. A lot was happening within a fraction of days, that there were mixed emotions [3]. The physical movement of people came to a halt to maintain social distancing. The sudden outbreak of the disease made the authorities put in a tough situation to handle the medical facilities for treating the deadly virus [4] as well as the psychological disorders that were caused by the imposed lockdown. Understanding the emotional and mental wellbeing of the citizens of the country plays a major role in sustaining these kinds of pandemic situations. The World Health Organisation (WHO) [5] also issued several guidelines to maintain the healthy mental state of people throughout the pandemic. While some people were dealing with the emotional trauma, fighting with the negative psychological effects while other people were finding ways to entertain themselves and getting more and more creative in these times of home confinement [6, 7]. To assist numerous administrations and organizations, it is extremely necessary to comprehend the emotional state of people of the country so that they can be helped in overcoming the psychological imbalance that has occurred throughout this time [8]. Moreover, technology has grown by leaps and bounds in today's modern world [9]. The whole tedious process of writing and publishing news articles has been simplified using social media [10]. Immense amount of data is produced every day every minute [11]. Nowadays, online social media websites are frequently used as a source of analyzing and investigating the emotional state of people. Social media platforms play a vital role in the time of trouble to evaluate the mental and emotional health of people around the world [12]. Particularly, social media platform Twitter provides a handy mechanism to express one's viewpoint in short and crisp messages. The challenge is to identify, process, and combine various data sources to reach intelligent decisions [13].

When it comes to highly populous[1] countries like India, COVID-19 cases have significantly escalated. Owing to the heterogeneous demographics of India, it took just three months for the number of cases to reach almost thousand times the cases that were at the commencement of the spread. Furthermore, living in the largest democracy [14], people are free to express their feelings and thoughts on all the incidents happening around them. Every individual has the right to convey their opinion on political, social, economic, and cultural matters.

Taking into account the seriousness of the pandemic, it is very essential to persuade the public to reduction of the spread of COVID-19 and adoption of sustainable measures. Several initiatives were taken, not only by the Government of India but also by the citizens. The government has set up helpline centers to help people (telephonically) with emotional issues during the pandemic. The adoption of these sustainable measures helps to mitigate such crisis situation and make the public future-ready. During COVID-19 also, people took healthy participation in spreading awareness about the disease not only in cities but also in village areas. In order to minimize the outbreak of the disease, the Indian government gave several instructions to people from wearing masks to maintaining social distancing among each other.

[1] https://www.worldometers.info/world-population/population-by-country/.

Table 1 shows the major events that caused a havoc of emotions amongst the people. These events played a key-role in triggering emotional outbursts on Twitter.

In this chapter, we present an internet portal visualizing the eight-pointer emotional spread amongst the people of different states of India during different phases of lockdown. Our application does real-time monitoring of tweets and displays the tweets of people related to various hashtags as mentioned. The internet portal

Table 1 Major events that took place in India during the lockdown period

Timeline	Major events
30th January	First reported case
6th March	International passenger screening at the airport
11th March	COVID-19 declared as pandemic by WHO
12th March	First reported death
13th March	Suspension of non-essential traveler visas
15th March	100 reported cases Maharashtra overtook Kerala
16th March	Land border crossing suspended
22nd March	Nation-wide Janta Curfew, suspended air travel
25th March	Nation-wide lockdown imposed till 14th April
28th March	1000 reported cases
30th March	100 reported recoveries
31st March	Tablighi Jamaat cluster identified in Delhi
5th April	100 reported deaths
14th April	Lockdown extended till 3rd May
19th April	500 reported deaths and Goa became Corona free
20th April	Manipur becomes Corona free
22nd April	20,000 reported cases
25th April	5000 reported recoveries
29th April	1000 reported deaths
1st May	Lockdown extended till 17th May
2nd May	10,000 reported recoveries
7th May	50,000 reported cases
10th May	2000 reported deaths
11th May	20,000 reported recoveries
17th May	Lockdown extended till 31st May
19th May	100,000 reported cases
23rd May	50,000 reported recoveries
27th May	150,000 reported cases

(continued)

Table 1 (continued)

Timeline	Major events
31st May	5000 reported deaths
8th June	Phased reopening begins after 75 lockdown days Around 250,000 reported cases and 7200 deaths
12th June	10,000 new cases reported
17th June	Delhi and Maharashtra report backlog fatalities India registered the highest ever spike
27th June	India reports 390,459 cases, 681 deaths, and 22,664 recoveries

allows to select the state as well as particular lockdown for which the emotional spread is to be visualized. The analysis conducted considers textual information contained in the tweets while exploiting the linguistic features. Subsequently, emotion lexicon (NRC Word-Emotion Association Lexicon[2] [15]) has been utilized to understand state-wise and lockdown-wise emotion. This emotion analysis has been conducted on the tweets posted by people during different lockdown stages. In this analysis, information has been extracted from Twitter using Twitter API.[3] The tweets associated with hashtags #CoronaVirus, #LockdownDiaries, #Lockdown, #Covid-19 that were posted on Twitter in different states of India in the duration March 2020–June 2020, have been analyzed and categorized into one of the eight emotion categories—Anger, Anticipation, Disgust, Fear, Joy, Sadness, Surprise and Trust [16].

The rest of the chapter is organized in the following manner: Sect. 2 describes the related work completed in the field of emotion analysis during COVID-19 attack. Section 3 describes the proposed methodology and gives insight into the approach used to analyze the tweets of the dataset. Section 4 presents the results obtained through the analysis and a brief discussion. Section 5 concludes the chapter and throws light on the future scope of the project.

2 Related Works

Understanding the emotional state of people in such difficult times of crisis, not just pushes the public authorities to survey old guidelines, yet in addition, helps in forming new rules and undertake measures that can propel the masses and re-establish their physical and emotional wellbeing. Consequently, to examine the public feelings on different occasions during this pandemic, a few investigations have been led.

[2] http://saifmohammad.com/WebPages/NRC-Emotion-Lexicon.htm.

[3] https://developer.twitter.com/en.

There are a few models proposed for dissecting the public feeling during COVID-19 pandemic.

In [17], the proposed approach examines the emotions of Weibo users in China—gender wise and age-wise. The outcomes additionally showed that the expressions of concern like "Wellbeing", "Family" and "Demise" expanded fundamentally demonstrating that with sitting back, individuals were getting more worried about their family and wellbeing. Another work [18] examines the mental health of individuals during lockdown stage 2 and lockdown stage 3 on Twitter dataset and investigated the assessment on web-based businesses (e-commerce) during this pandemic. There was a sure plunge in the level of joy, fear, and trust in lockdown stage 3 when contrasted with that of lockdown 2 while there was a sure ascent in level of disgust, anger, and anticipation. Analysts have likewise broken down the news-headline features of Coronavirus and performed sentiment and emotion association [19].

Cao et al. [20] contemplates the effect of Coronavirus on students in China. The study uncovered that approximately 25% of students have encountered tension in view of this COVID-19 episode. The outcomes inferred that the danger factor and the postponements in scholastics were the fundamental explanations behind expanding tension while factors like living with family and having consistent family earnings were defensive variables against experienced nervousness during the COVID-19 flare-up.

Landicho-Pastor [21] discussed the students' sentiment on online schooling strategy dependent on an open-ended poll. Their investigation uncovered that many students were not ready for the online method of training and were stressed over the elements like the network issues at their place.

As the pandemic began, numerous analysts were interested to gain understanding of major worries of Twiterrati on COVID-19. Abd-Alrazaq et al. [22] examined 2.8 million tweets found out twelve concepts. Heffner et al. [23] considered the public readiness to self-isolate by breaking down the conclusions on two kinds of self-isolation rules, either undermining or written in convincing language. Their outcomes showed that despite the fact that individuals evoked negative supposition for government-imposed rules, they showed readiness toward social distancing.

3 Data and Methodology

The methodology used in this chapter includes a set of major tasks performed to achieve the desired visualizations. Figure 1 shows the methodology used in the analysis.

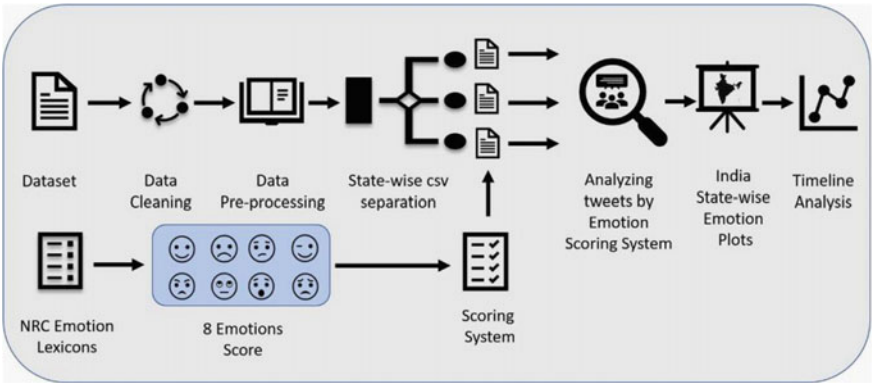


Fig. 1 Methodology

3.1 Dataset

The dataset has been curated from Twitter using public streaming API (see footnote 3) on India—specific tweets to perform analysis. The Twitter API facilitates fetching of real-time data by providing certain hashtags and specifying locations. The hashtags used for this analysis are #CoronaVirus, #LockdownDiaries, #Lockdown, and #Covid-19. The final dataset is taken into account for analysis, mainly consisted of tweets, date, time, and their locations from where the tweets were posted. The considered duration is 01-03-2020 to 09-06-2020. The word—emotion association was performed through NRC emotion lexicon (see footnote 2) which consist of scores for eight emotions: anger, fear, anticipation, trust, surprise, sadness, joy, and disgust [15]. The dataset was cleaned by removing the tuples of incorrect data and 'Not a number' values. The tweets were pre-processed using Natural Language Processing techniques [24]. Application of machine learning to explore the Impact of Air Quality on the COVID-19 Fatalities is also studied [25, 26].

The text of tweets in the form of a string was first word tokenized into individual words. Then, as a step towards cleaning of tweets—slang, misspelled words, hashtags, URLs, and emoticons have been removed [27]. Additionally, the tweets have been converted to lowercase. User mentions along with re-tweets were removed, followed by elimination of punctuations, special symbol characters (except a–z, A–Z). A list of English stop words has been imported from NLTK library which is used to remove the stop words present in tweets.

3.2 Two-Way Emotion Characterization

In this chapter, a two-way emotion characterization of tweets has been presented state-wise and lockdown-wise:

(a) State-Wise Emotion Analysis—In this analysis, tweets of the people from different states of India have been collected, cleaned, and analyzed. The approach processes each tweet and categorizes it into one of the eight emotions. The results of this analysis are visualized on the map of India, with each state depicting the intensity of a particular emotion.
(b) Lockdown-Wise Emotion Analysis—In this analysis, tweets posted during four lockdown phases observed in India have been taken and dissociated according to different states. Tweets have been cleaned, analyzed, and categorized into one of the eight emotions. The results were analyzed using stacked bar charts for different states of India.

3.2.1 State-Wise Analysis

The dataset is dissociated according to different states. The tweets are POS tagged to help identify adjectives and adverbs. The state-wise emotions are given a score based on the most frequent words found in tweets and NRC emotion lexicon list. A 'state-wise-emotion-count-dictionary' dictionary is formed which contains words with their occurrence frequency. This dictionary is used to calculate the sum total of eight emotions. With these scores, the heat maps of India have been created depicting respective state-wise emotion intensity levels (ref. Sect. 4, Fig. 3). The heat maps of India for different emotions have been developed using boundary shape file "Indian states.shp". The shape file included features: state name and geometry. The merged data frame was formed by combining state emotion count with the Indian state shape file (.shp file). The plots of separate emotions were created by using Matplotlib's subplot and plot function in Seaborn style.

3.2.2 Lockdown-Wise Analysis

The lockdown-wise analysis is carried out with the help of dates extracted from tweets in the dataset. The same has been presented through stacked bar charts (ref. Sect. 4, Fig. 4). This lockdown-wise analysis has been carried out for lockdown 1, lockdown 2, lockdown 3, and lockdown 4 during COVID-19 pandemic. The lockdown phases are listed in Table 2.

Table 2 depicts the dates of lockdown issued by the Indian government. The lockdown-wise emotion analysis was conducted for separate states of India. A word

Table 2 Lockdown phases

Lockdown	Dates
Lockdown 1	25-03-2020 to 14-04-2020
Lockdown 2	15-04-2020 to 03-05-2020
Lockdown 3	04-05-2020 to 17-05-2020
Lockdown 4	18-05-2020 to 31-05-2020

count dictionary was created containing words with frequency segregated according to four lockdown phases. This was then categorized into different emotions based on the NRC emotion lexicon list. Stacked bar plots were obtained for top 12 states and are depicted in Sect. 4, Fig. 4, using Matplotlib.

3.3 Internet Portal

An internet portal has also been launched as an outcome of this analysis, as shown in Fig. 2. It depicts graphical figures that quantify public emotions during COVID-19. The portal provides the users with two menus—based on the states and the emotions.

4 Results and Discussion

The pandemic caused by coronavirus has been one of the most unexpected and grave casualties for the whole world. This section presents visual analysis depicting a tremendous downpour of public emotions expressed towards the lockdown on an eight-pointer scale of emotions: anger, fear, joy, disgust, anticipation, surprise, sadness, and trust. Figure 3 presents the state-wise emotion wise analysis.

Despite massive amounts of efforts by the government, Maharashtra, Delhi, Haryana, Uttar Pradesh, Karnataka, Madhya Pradesh, Tamil Nadu, and Rajasthan have been worst affected. Figure 3 depicts this analysis. There is an apparent relationship between the states where more cases were reported, and huge mix of emotions were also reported from those states only.

Some states like Goa and Manipur have managed the pandemic situation commendable as depicted in Table 3. People have been quite enthusiastic about the lockdown time. They have considered it a time for personal productivity and growth. Some are also happy spending time with their families. While others who have lost their jobs have been really worried and upset. Economy of the nation has been completely shattered by the situation. This has been depicted in Sect. 1, Table 1.

Being the capital of the nation, Delhi has had huge responsibilities of catering to everyone's healthcare needs. Many people have been moving to Delhi for their treatment as it is considered to have the best medical facilities. This has been a reason for chaos and worry amongst the people and has caused a shortage of hospital beds and other medical facilities like ventilators and oxygen cylinders.

Another issue that has been an area of concern throughout was public gatherings like Tablighi Jamaat and mismanaged movement of people who lost their jobs across state borders. There was a shortage of food and a lack of facilities for these laborers to go back home. These people had to walk back home covering hundreds of kilometers all by themselves. This has been the major cause of anger throughout the nation as these people were highly susceptible to catching infection. During the lockdown phases, international travel had completely stopped. This was another cause of stress

for the Indian citizens stuck outside and for their families. The government played a very positive role in resolving this issue by trying to get all the people back to their country. This gave people relief.

Figure 4 and Table 4 depict lockdown-wise emotion analysis of states. In the case of Maharashtra, it can be clearly observed that there was a sharp rise in anticipation and sadness amongst the citizens. This has been the general pattern in almost all the states like Delhi, Gujarat, West Bengal, Rajasthan, Punjab, Goa, and Karnataka.

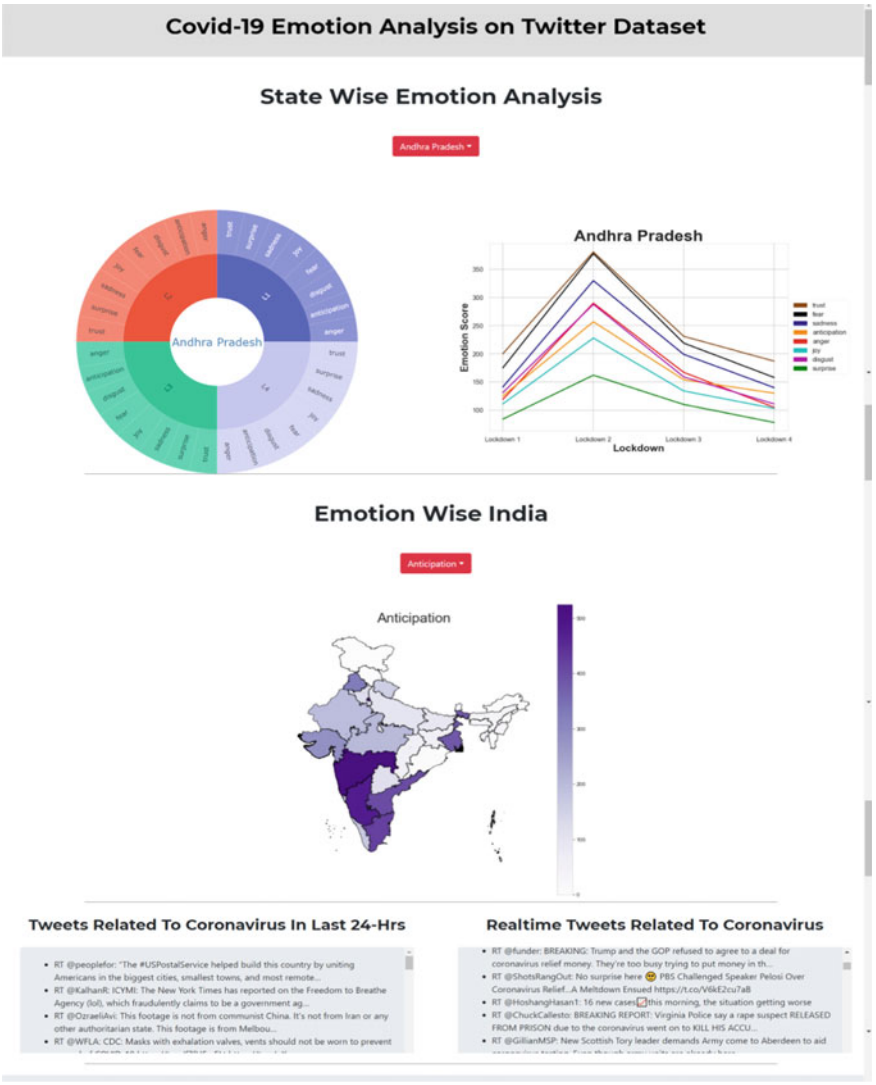
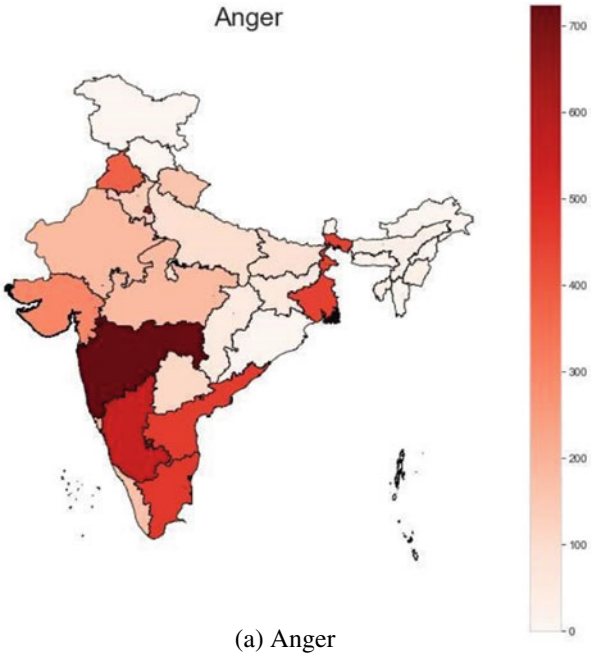
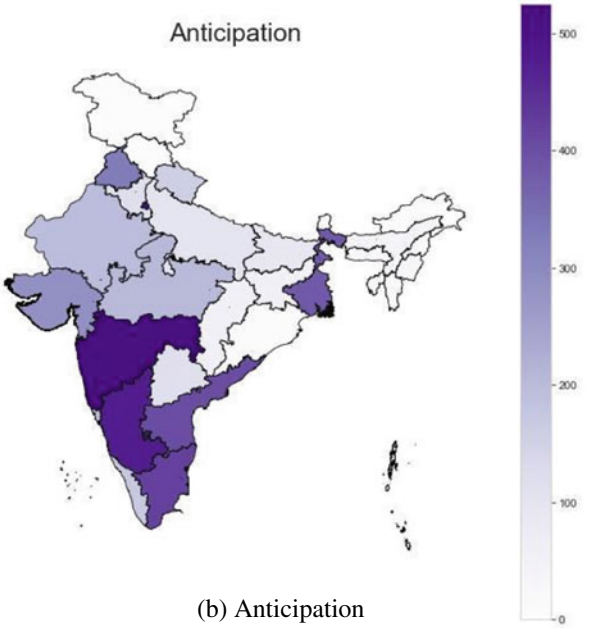


Fig. 2 Internet portal. https://emotiontrackerindia.herokuapp.com/

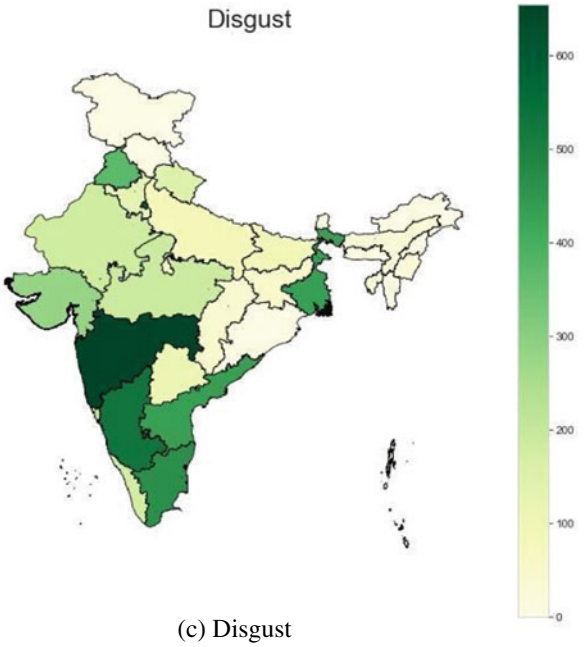


(a) Anger

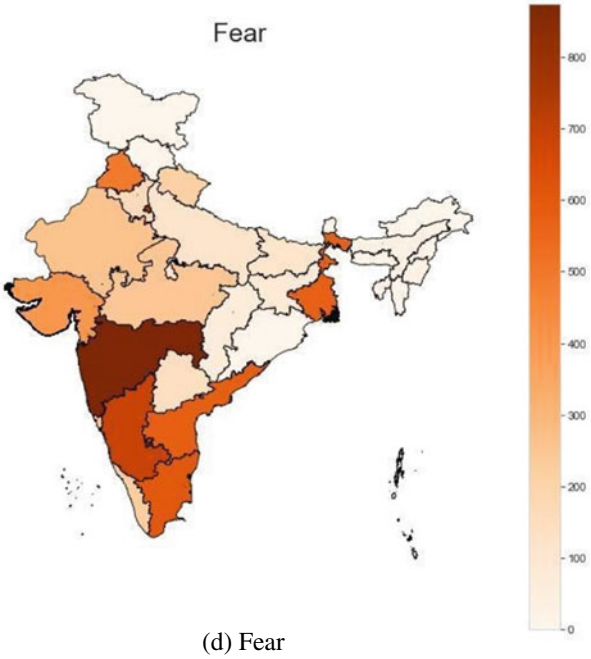


(b) Anticipation

Fig. 3 **a**–**h** Country-wide heat map of all emotions

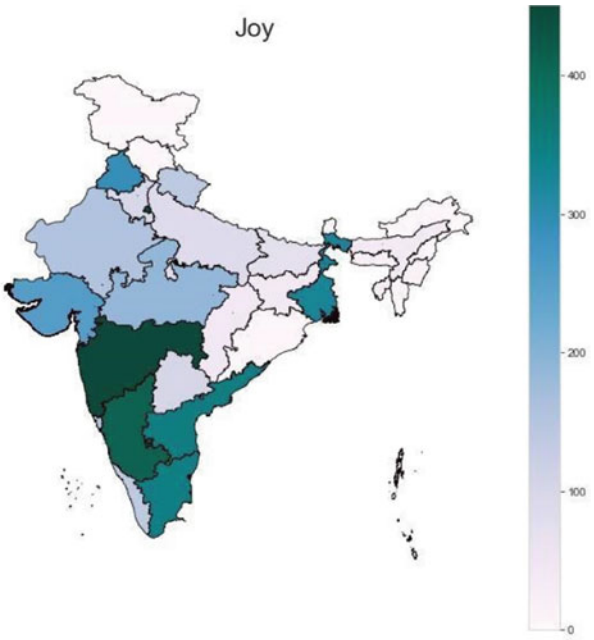


(c) Disgust

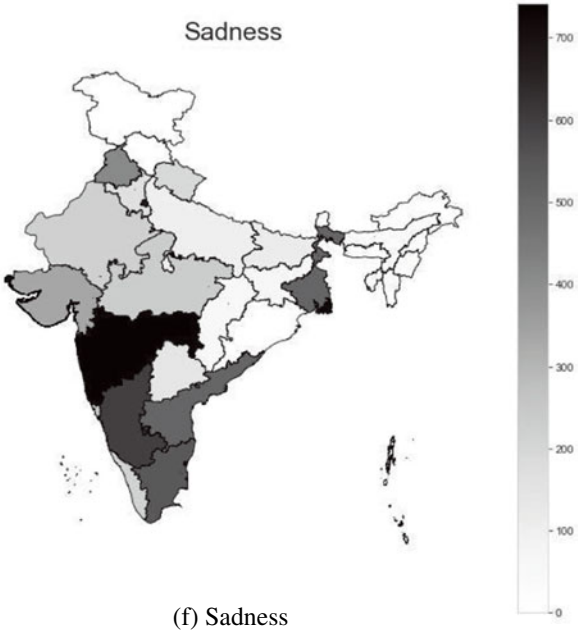


(d) Fear

Fig. 3 (continued)

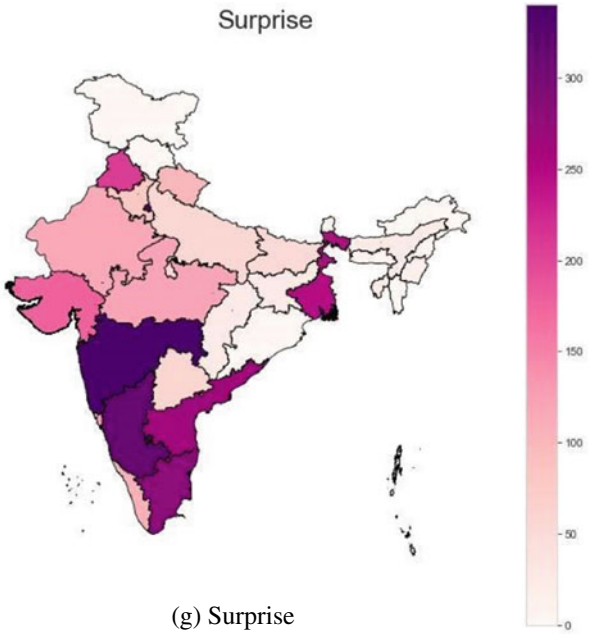


(e) Joy

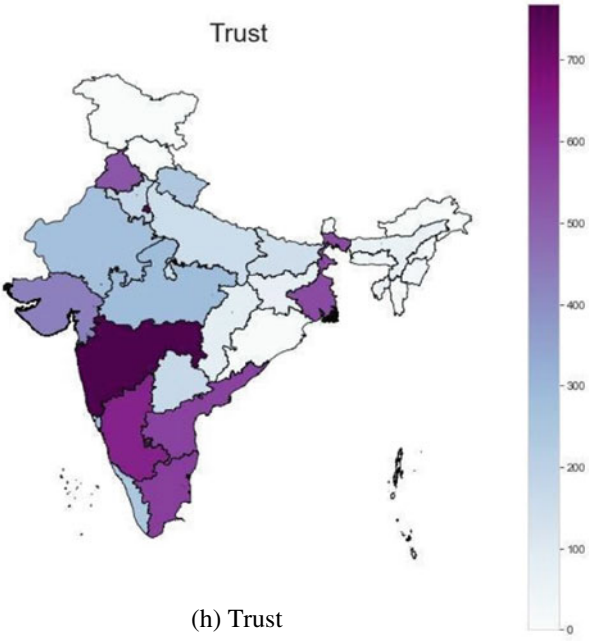


(f) Sadness

Fig. 3 (continued)



(g) Surprise



(h) Trust

Fig. 3 (continued)

Table 3 Reported, recovered, and deceased cases of worst hit Indian states

States/lockdown	Cases	Lockdown 1 (25th March to 14th April)	Lockdown 2 (15th April to 3rd May)	Lockdown 3 (4th May to 17th May)	Lockdown 4 (18th May to 31st May)
Maharashtra	Reported	2558	10,294	20,079	34,602
	Recovered	259	1856	5573	21,641
	Deceased	178	370	650	1088
Tamil Nadu	Reported	1178	1819	8201	11,109
	Recovered	81	1298	2793	8585
	Deceased	12	18	49	97
Delhi	Reported	1526	2988	5206	10,089
	Recovered	31	1331	2840	4276
	Deceased	30	34	84	325
Karnataka	Reported	209	353	533	2074
	Recovered	68	222	216	709
	Deceased	9	15	12	12
Andhra Pradesh	Reported	474	1099	797	1191
	Recovered	16	472	968	884
	Deceased	11	22	17	12
Uttar Pradesh	Reported	622	1985	1819	3611
	Recovered	50	704	1882	2207
	Deceased	8	35	69	105
Gujarat	Reported	612	4778	5952	5414
	Recovered	59	983	3457	5420
	Deceased	28	262	369	379
West Bengal	Reported	181	1008	1479	2824
	Recovered	36	96	827	1198
	Deceased	7	115	116	79
Rajasthan	Reported	967	1881	2316	3629
	Recovered	147	1209	1699	2977
	Deceased	11	60	60	63
Madhya Pradesh	Reported	726	2126	2110	3112
	Recovered	64	734	1605	2439
	Deceased	53	103	92	102
Punjab	Reported	153	918	862	299
	Recovered	27	90	1249	621
	Deceased	13	8	14	10
Goa	Reported	4	0	22	42
	Recovered	5	2	0	37

(continued)

Table 3 (continued)

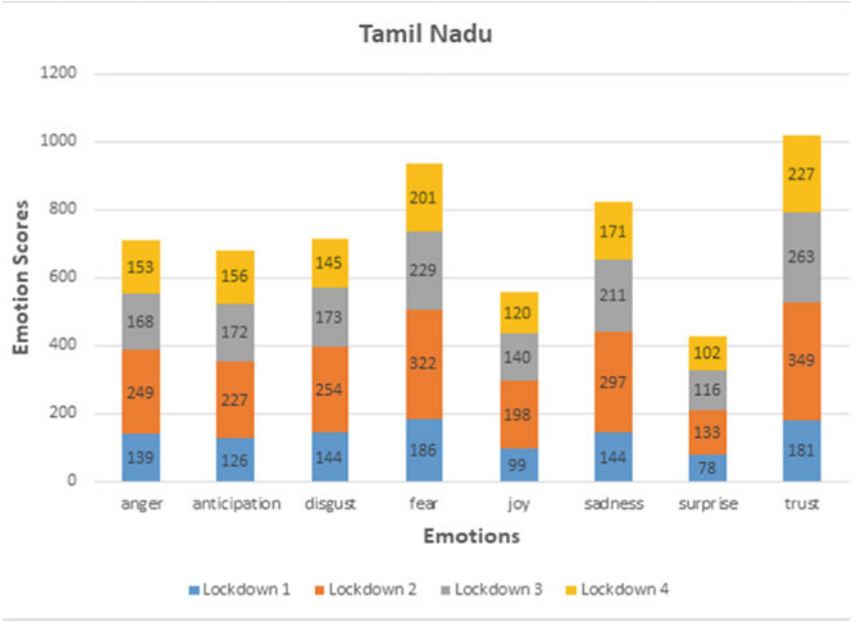
States/lockdown	Cases	Lockdown 1 (25th March to 14th April)	Lockdown 2 (15th April to 3rd May)	Lockdown 3 (4th May to 17th May)	Lockdown 4 (18th May to 31st May)
	Deceased	0	0	0	0

These states have seen massive growth in Coronavirus cases even after following the strict rules of the first lockdown. These emotions tend to lower down during lockdowns 3 and 4 which may be due to the increase in recovery rates. On the other hand, cases in Uttar Pradesh reduced in the second lockdown, and hence the counts somewhat decreased there. The same decreasing pattern was observed for the 3rd and 4th lockdowns. The number of Corona cases in Madhya Pradesh was not very high during lockdowns 1 and 2 but the people there were shocked by the growth during lockdowns 3 and 4. This led to an emotional upheaval amongst the people. Observing the general trend, it can be quoted that lockdown 2 had shown the maximum rise in the number of COVID-19 cases which decreased down during lockdown phases 3 and 4. The emotional pattern of the people was widely linked to the number of reported cases, recovered cases, and deceased cases during different lockdown stages.

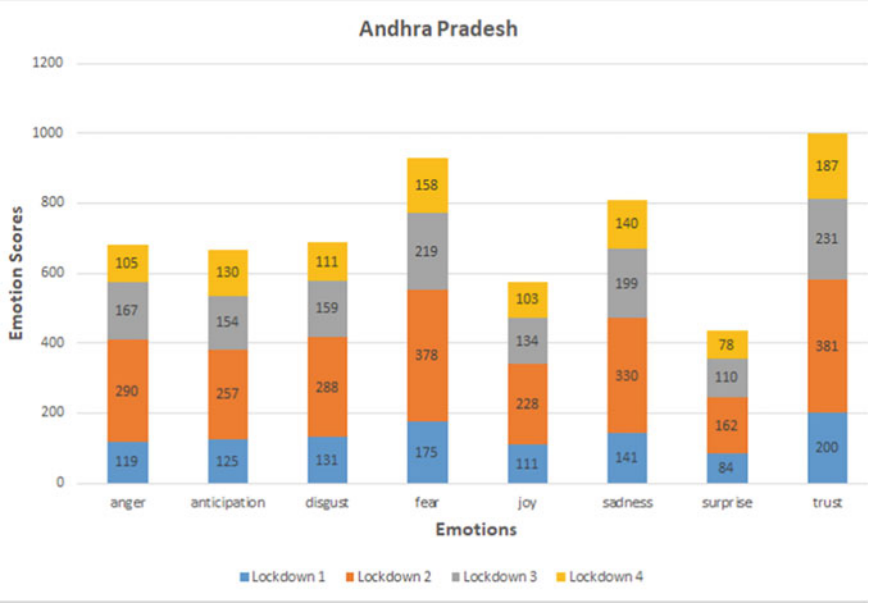
Overall, pandemic time has been stressful as expected. But at the same time it has brought the people of India together, fighting for one mission—to keep the nation safe and healthy. India has again proved that there is unity in diversity. People of India, under all circumstances, stand strong together.

5 Reflections

This chapter studies the social consequences of COVID-19. The pandemic posed unusual challenges to human behavior and mental health [27]. In this study, tweets posted across India during different lockdown phases have been analyzed to gain an understanding of the psychological health of the people. Heat maps have been plotted on the map of India, denoting the intensity of emotion in different states. This kind of analysis can help policy makers to conduct psychosomatic assessments of people in order to provide support in times of crisis. The notion of sustainability somewhere lies in settling the recent concerns and also parallelly focusing on long haul answers for battling with comparative issues in future. With everything taken into account, lockdown would not have been forced in the event that we would have been ready for such pandemic circumstances physically, intellectually, emotionally, and financially. Undertaking right sustainability measures at the perfect time fortifies the system alltogether. These proactive measures likewise search for long haul help habitats for individuals worldwide. We should recognize the issues deeply and afterward work on them. A nation leads by its residents, and it is similarly imperative to keep up sanity and psychological wellbeing of individuals. This chapter also puts forward an

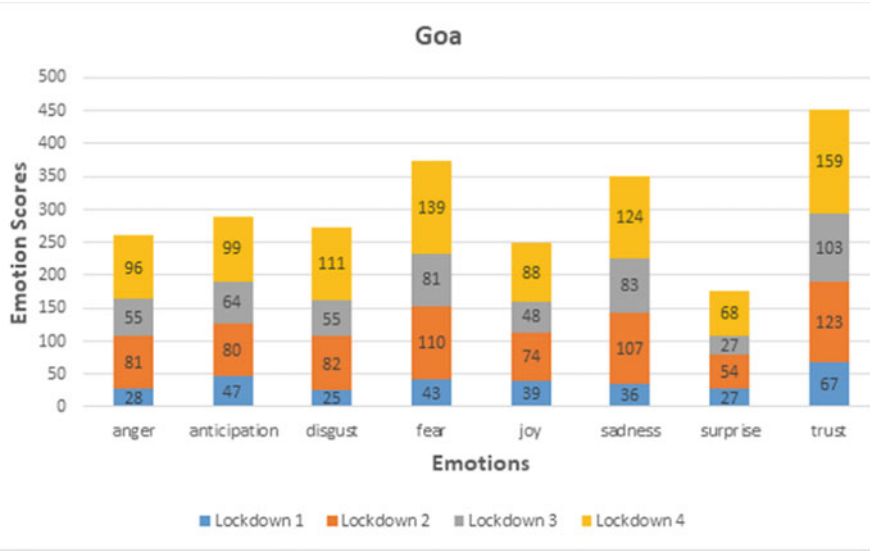


(a) Tamil Nadu

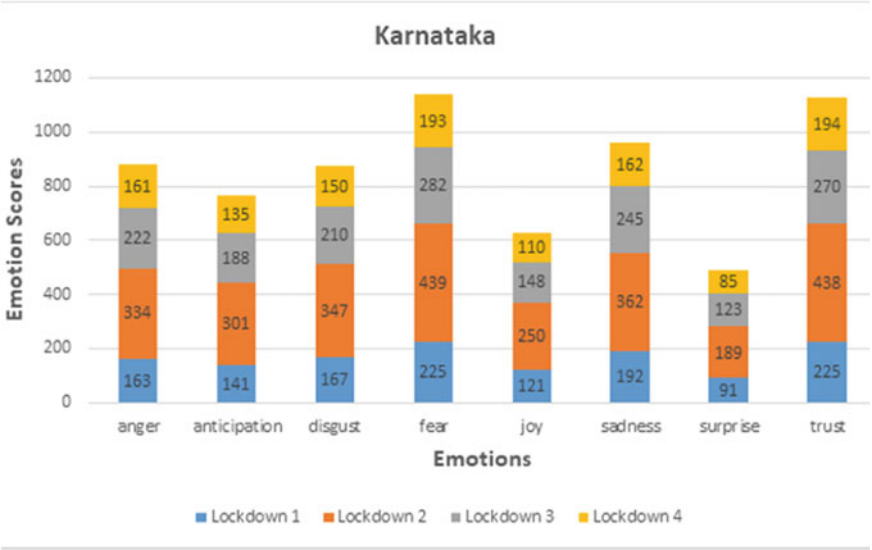


(b) Andhra Pradesh

Fig. 4 **a–l** Lockdown-wise analysis of emotions in 12 states

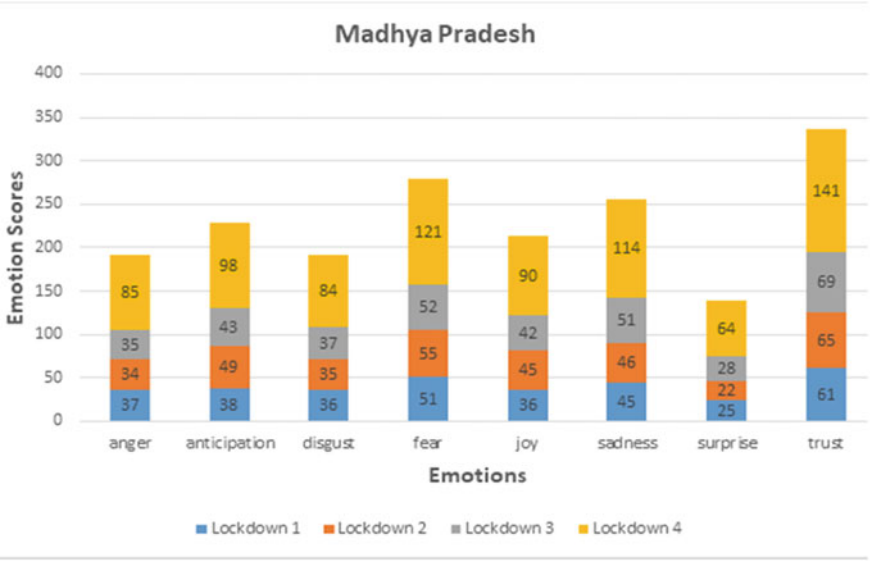


(c) Goa

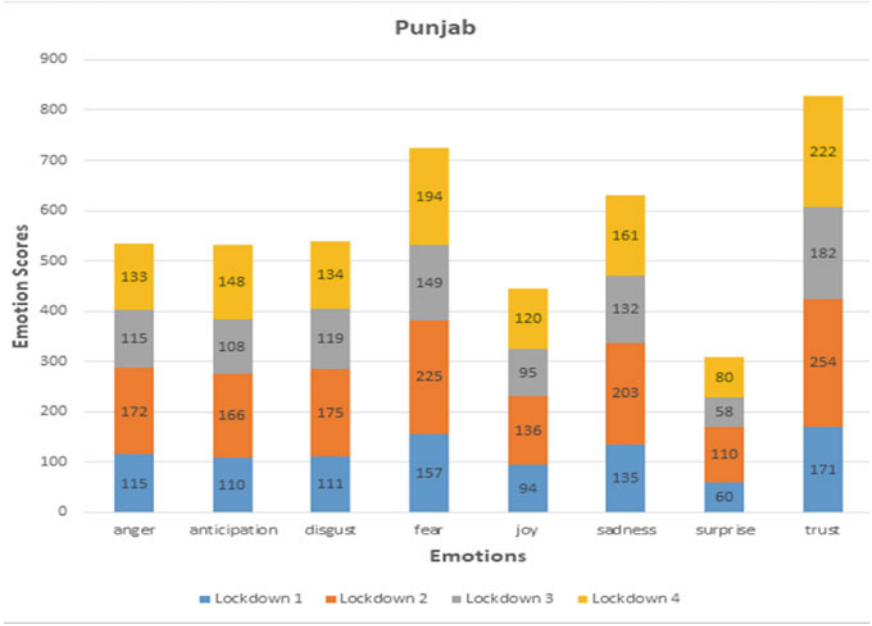


(d) Karnataka

Fig. 4 (continued)

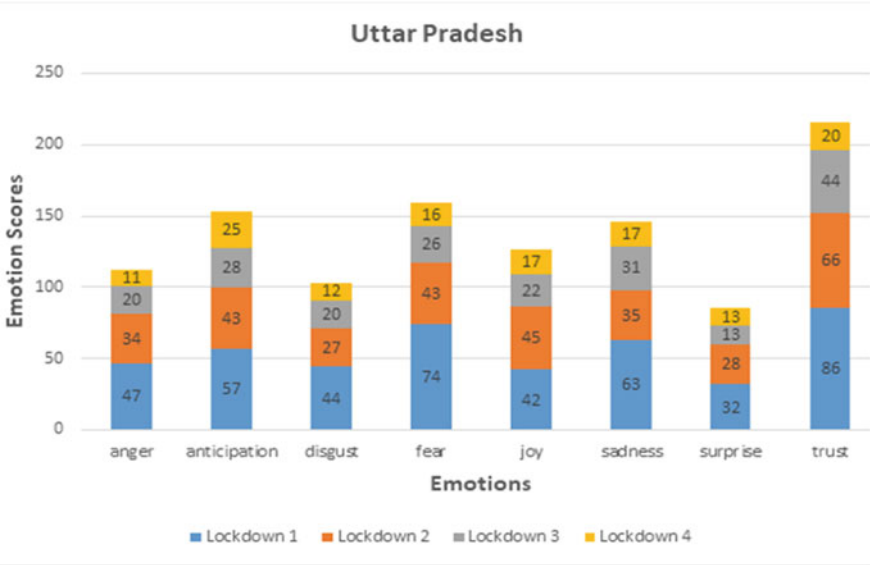


(e) Madhya Pradesh

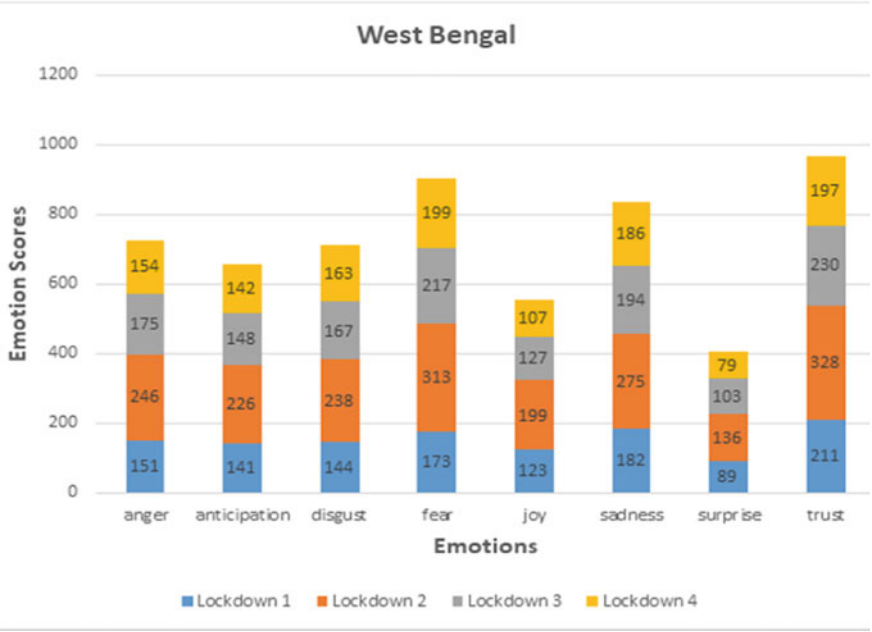


(f) Punjab

Fig. 4 (continued)

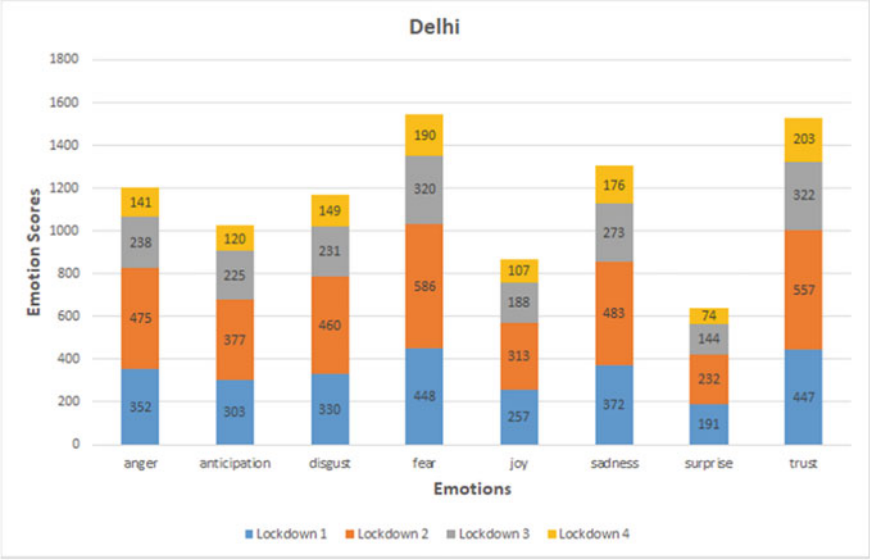


(g) Uttar Pradesh

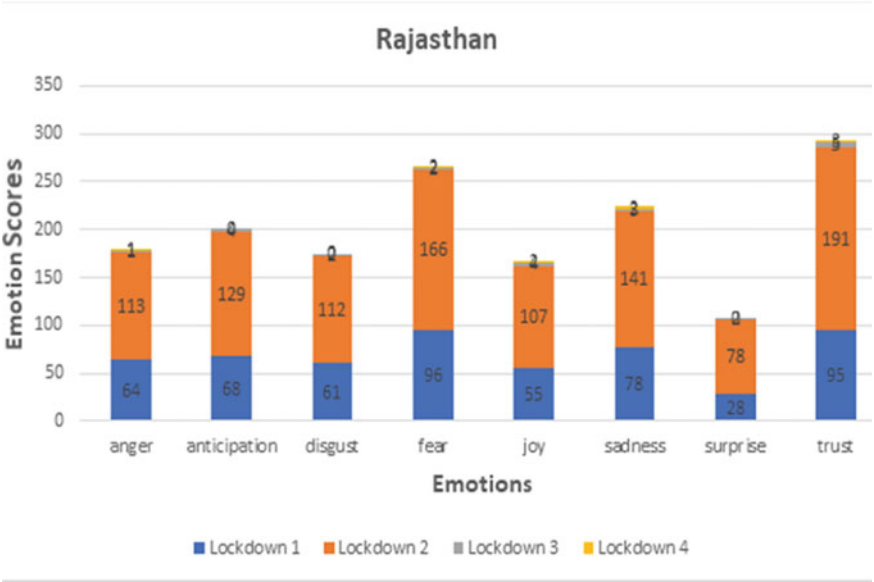


(h) West Bengal

Fig. 4 (continued)

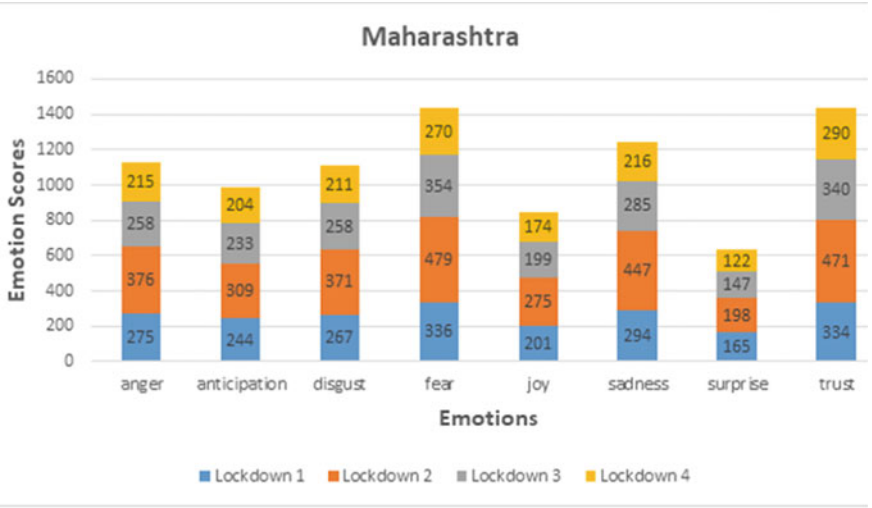


(i) Delhi

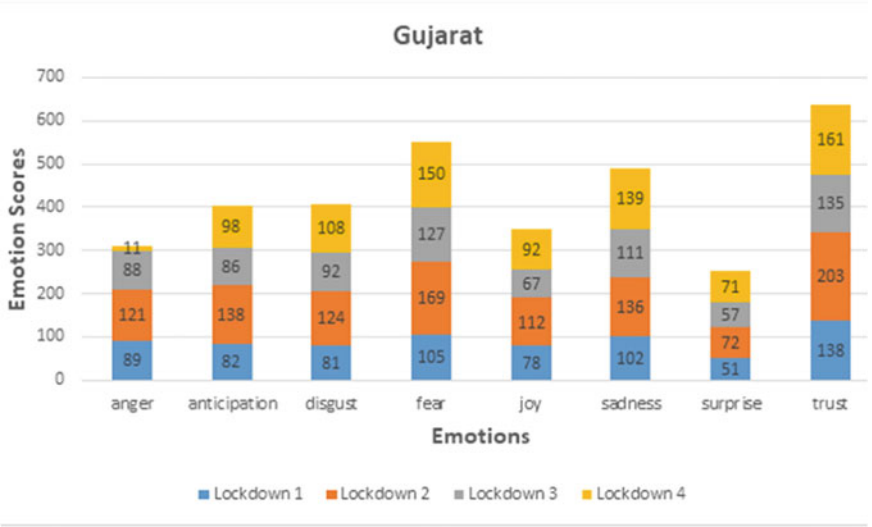


(j) Rajasthan

Fig. 4 (continued)



(k) Maharashtra



(l) Gujarat

Fig. 4 (continued)

internet portal, as a by-product that can show intensity levels of different emotions in different states of India alongwith different timelines.

Table 4 Emotion depicted by Indian states during different lockdown stages

States	Lockdown phases[a]	Emotions[b]							
									
Maharashtra	L1	275	244	267	336	201	294	165	334
	L2	376	309	371	479	275	447	198	471
	L3	258	233	258	354	199	285	147	340
	L4	215	204	211	270	174	216	122	290
Tamil Nadu	L1	139	126	144	186	99	144	78	181
	L2	249	227	254	322	198	297	133	349
	L3	168	172	173	229	140	211	116	263
	L4	153	156	145	201	120	171	102	227
Delhi	L1	352	303	330	448	257	372	191	447
	L2	475	377	460	586	313	483	232	557
	L3	238	225	231	320	188	273	144	322
	L4	141	120	149	190	107	176	74	203
Karnataka	L1	163	141	167	225	121	192	91	225
	L2	334	301	347	439	250	362	189	438
	L3	222	188	210	282	148	245	123	270
	L4	161	135	150	193	110	162	85	194
Andhra Pradesh	L1	119	125	131	175	111	141	84	200
	L2	290	257	288	378	228	330	162	381
	L3	167	154	159	219	134	199	110	231
	L4	105	130	111	158	103	140	78	187
Uttar Pradesh	L1	47	57	44	74	42	63	32	86
	L2	34	43	27	43	45	35	28	66
	L3	20	28	20	26	22	31	13	44
	L4	11	25	12	16	17	17	13	20
Gujarat	L1	89	82	81	105	78	102	51	138
	L2	121	138	124	169	112	136	72	203
	L3	88	86	92	127	67	111	57	135
	L4	11	98	108	150	92	139	71	161
West Bengal	L1	151	141	144	173	123	182	89	211
	L2	246	226	238	313	199	275	136	328
	L3	175	148	167	217	127	194	103	230
	L4	154	142	163	199	107	186	79	197
Rajasthan	L1	64	68	61	96	55	78	28	95
	L2	113	129	112	166	107	141	78	191

(continued)

Table 4 (continued)

States	Lockdown phases[a]	Emotions[b]							
		😠	😟	😫	😰	🥳	😔	😲	😌
	L3	1	4	2	2	4	3	2	5
	L4	1	0	0	2	2	2	0	3
Madhya Pradesh	L1	37	38	36	51	36	45	25	61
	L2	34	49	35	55	45	46	22	65
	L3	35	43	37	52	42	51	28	69
	L4	85	98	84	121	90	114	64	141
Punjab	L1	115	110	111	157	94	135	60	171
	L2	172	166	175	225	136	203	110	254
	L3	115	108	119	149	95	132	58	182
	L4	133	148	134	194	120	161	80	222
Goa	L1	28	47	25	43	39	36	27	67
	L2	81	80	82	110	74	107	54	123
	L3	55	64	55	81	48	83	27	103
	L4	96	99	111	139	88	124	68	159

[a]Lockdowns are represented as L1—lockdown 1, L2—lockdown 2, L3—lockdown 3, and L4—lockdown 4

[b]The emotions are represented by 😠—anger, 😟—anticipation, 😫—disgust, 😰—fear, 🥳—joy, 😔—sadness, 😲—surprise, 😌—trust

The scope of this chapter is not only limited to the tweets on Twitter. The analysis can be broadened if we move to other social media platforms such as Facebook, Mastodon, Gab, and Peeks. The work presented in this chapter can be extended to aspect-based emotion analysis on the dataset. Furthermore, this analysis can be scaled to encompass different countries with different native languages.

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Industry 4.0 Technologies and Their Applications in Fighting COVID-19

Sushila Palwe and Sumedha Sirsikar

Abstract Industry 4.0 represents the revolution of the fourth industry. Cyber-physical systems form the backbone of Industry 4.0. Cyber-physical systems use modern control systems with embedded software connected through IoT. Basically, cyber-physical systems build the facilities required in recent industries. Industry 4.0 is a blend of automations and data exchanges in various technologies like manufacturing industries, retail industries, and public services like hospitals and schools. With Industry 4.0, it is possible to develop smart applications to fight with the uncommon situation like COVID-19. Pandemics are the sudden attacks on public health, due to which the public services like hospitals collapse. Such situations demand the requirement of a medical facility in a nonlinear way which is hard to handle with traditional demand–supply strategy. This may lead to insufficient occupancy of services, etc. This insufficient occupancy leads to big losses in public health and lives. These scenarios can be handled by promoting the usage of advanced technology as a substitute for many services. Industry 4.0 revolutions are capable of handling such sudden situations like COVID-19 wherein social distancing plays a key role in stopping the spread of this. In a pandemic situation like COVID-19, the manpower requirement can be replaced with automated devices and cyber-physical systems, which will assist and substitute humans in providing the various services like real-time assistance, observation, medication, and sanitization. This chapter discusses the Industry 4.0 applications, methods, and case studies in various applications, which are essential to handle the sudden pandemic like COVID-19.

Keywords COVID-19 · Industry 4.0 · Lock phase · Unlock phase · Machine learning

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1 Introduction

COVID-19 pandemic affected every aspect of human life across many parts of the world. The World Health Organization declared this disease as the global pandemic as its impact on the health crisis crossed all the national and international boundaries. The main precautionary and preventive measure suggested to prevent the virus spreading is "lockdown" to maintain social distancing. Almost every country across the world adopted this measure. But, the "social distancing" method, which proved as the perfect preventive measure, impacted the lives of many people. It directly affected the day-to-day lifestyle of not only the urban personnel but also the personnel of rural regions. School, offices, industries, transport, and many more get closed all of sudden and enforced everyone to identify the way-out to deal with the situation [1–4] (Fig. 1).

Also, this pandemic enforced us to think about the innovative use of technology in the public sectors where technology can be used effectively to assist and the personnel.

Industry 4.0 is the latest technology and trends which is adaptive, scalable, compatible, and intelligent enough to help in the fighting the challenges raised due to pandemic. Personal reachability is restricted due to lockdown and social distancing, but the Industry 4.0 technologies are proving its equivalent support to overcome many of the issues and problems which are raised due to this pandemic.

1.1 Industry 4.0 Overview

Industry 4.0 is a collection of the latest technologies to support the recent social and economic changes.

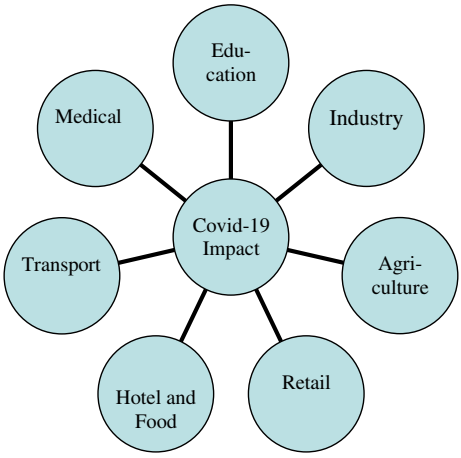

Fig. 1 Industrial revolution

First revolution of the industries started in mid-decade of eighteenth century, which was targeted on cotton production using water-wheeled machines. These revolutions made the increase in productivity of workers drastically. With this revolution, the handcrafting manufacturing era shifted to machine manufacturing segment [1–5].

In the second industrial revolution, i.e., Industry 2.0 which started in the last decade of eighteenth century till first decade of nineteenth century. The real electrification, automobile exploitation, and use of petroleum industries were the theme of this revolution. Private industries with massive work processes and workforce were initiated as a trend in this era.

Third industrial revolution initiated after the World War II, which was known for the evolution of atomic energy and resources. This revolution also introduced the digital era. Semiconductor industry, introduction to computer and network technologies, and Internet were the core aspects of this revolution. This era is also known as information era due to advancement of information transfer and exchanges using computer and network technologies. Industry 4.0 is the next revolution in industry, one step ahead of Internet, information, and computing era. It is related with smart factories and automated industries with extended digitization. All the mentioned aspects are possible with the latest technologies which are the main foundation of Industry 4.0 revolution. Industry 4.0 is the cyber-physical systems of physically and logically connected components. There are few important design aspects if Industry 4.0 like inter-operability which explains the compatibility of latest devices and their workability interconnected manner (Fig. 2).

Information availability is the next important principle of Industry 4.0, which explains the various types of data like virtual data, sensor data, structured and unstructured data, and big data, due to its quick and easy availability across the cyber-physical systems. Next principle of Industry 4.0 explains the capacity of the cyber-physical

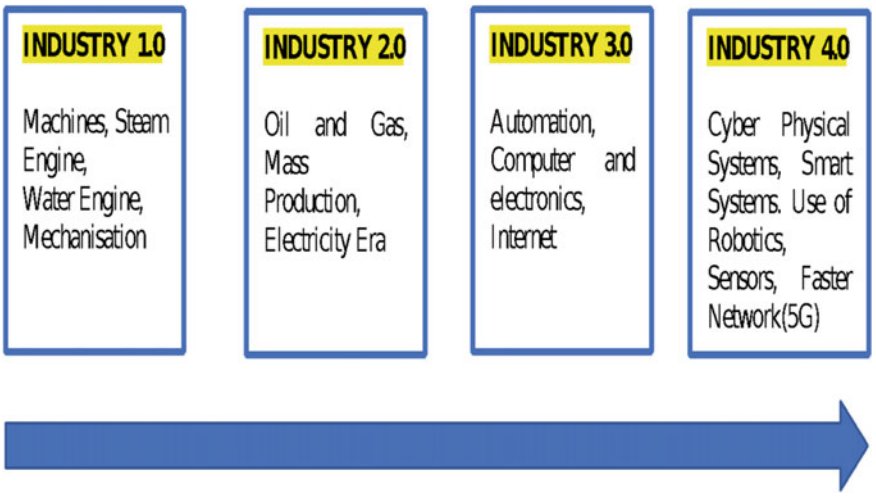

Fig. 2 Industrial revolution

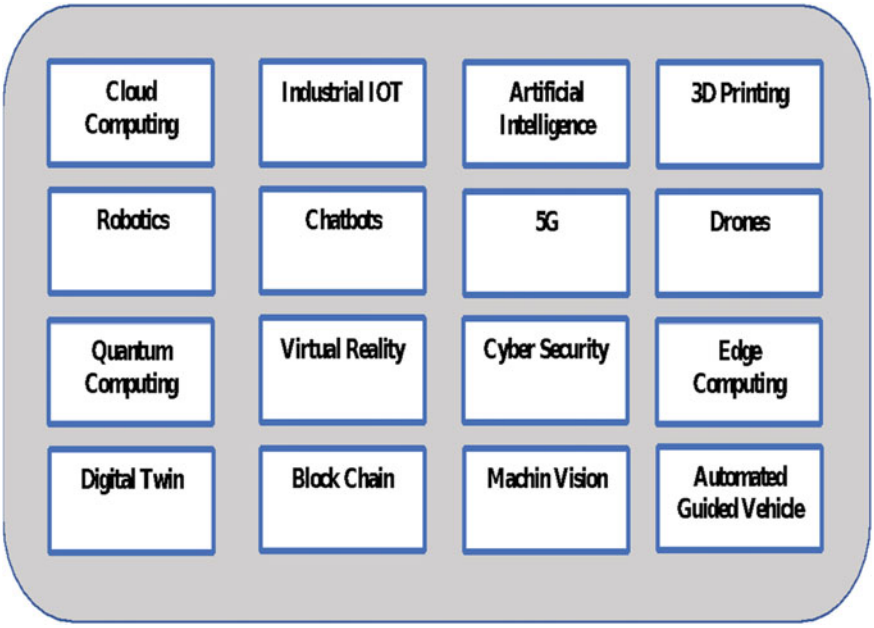

Fig. 3 Industrial revolution

systems to replace, assist, and mimic the human being with maximum accuracy for making the system smart and automated.

1.2 Industry 4.0 Technologies

Industry 4.0 always proves the stated principles with the use of the latest technologies. These latest technologies are shown in Fig. 3.

All these latest technologies are useful for implementing the Industry 4.0 applications, which make the applications as smart application and make the use of it for COVID-19 challenges.

2 COVID-19 Challenges

COVID-19 is declared as a pandemic by WHO as it crossed national and international boundaries. Such pandemic creates the panic and emergency public situations which is not thought prior [5]. It is actually difficult to handle such situations in population-dense countries especially in case of COVID-19, where social distancing

is the precautionary measure. Different COVID-19 challenges are classified in two ways,

- Challenges in lockdown scenario.
- Challenges in unlock phase.

In both scenarios, Industry 4.0 applications are capable to handle the challenges using smart and innovative technologies and cyber-physical systems.

Major precautionary measure suggested by WHO for COVID-19 prevention is social distancing. To follow this measure on immediate basis, sudden lockdown was announced by almost all countries. Due to this sudden lockdown, most of the social and public processes got hampered and created the panic situations. It was a big challenge to keep the social and public processes running smoothly. COVID-19 challenges in lockdown phase as well techniques that can be used are listed here [6–17].

2.1 Review of Literature

COVID-19 challenges are discussed in many research papers and articles in the middle of 2020. Most of the literatures are related to discussion of COVID-19 challenges, remedies, and techniques to overcome those challenges.

Article [18–20] discusses the COVID-19 challenges like dense population, urban–rural areas in the country, ratio of health facility with respect to population, nutrition, and social health. Authors also discussed three various steps considered by government to overcome this outbreak challenges: like improve on health care providers; education program to make people aware of the situation and precautionary measures; and to promote surveillance system to reduce the spread.

Riva et al. [21], De et al. [22], Qi et al. [23], and Xu et al. [24] discussed various technologies to overcome the COVID-19 outbreak. These technologies, named as positive technologies, suggested to enhance the existing strategies for generating psychological health, public health, reduced fear, and panic conditions, and help old-age people. These technologies vary from smartphone-based health apps, smart devices to support sanitization, social distancing, basic health symptoms, etc. Paper [22] discusses a very different aspect as COVID-19 challenges has increase in fraud ratio and workforce management challenges. It also discusses the blockchain technology approach to overcome these challenges.

Qi et al. [23], Xu et al. [24], Wang et al. [25], Mittal et al. [26], Singh et al. [27], Sethi and Mittal [28, 29], and Chhetri et al. [30] discussed various intelligent methods like IoT, machine learning, and big data to collect and handle data with ease, to predict the impact of outbreak, need of resources and to forecast the requirement of workforce, to detect the symptoms of COVID-19, to identify the relation between COVID-19 with other diseases, etc.

With this literature review, summarized COVID-19 challenges are discussed in upcoming section in two section as challenges in lockdown phase and challenges in unlock phase.

2.2 COVID-19 Challenges in Lockdown Phase

Keep Track COVID-19 Positive Patient
As COVID-19 gets spread fast, in case of contact of COVID-19 positive personnel [18–26], it was a big challenge to track the COVID-19 personnel and trace the roaming record of that personnel. It was really challenging as most of the time, COVID-19 symptoms get recognized late and not on an immediate basis. To prevent spreading of the COVID-19, it was the first and foremost challenge to keep track of the COVID-19 patient, so that the nearby personnel will get alerted about it.

COVID-19 Patient Data Analysis
Another important challenge in COVID-19 is to collect big data related to COVID-19 patients and perform its deep analysis like descriptive analysis, predictive analysis, and prescriptive analysis for smart decision-making on COVID-19 prevention. Descriptive analysis is useful in observing the COVID-19 patient summary with respect to various dimensions like age, gender, medical history, and region.

Product Supply and Distribution
Due to sudden lockdown, most boundaries got locked. This stopped the transportation completely. Blocked transportation raised the issue of smooth supply as per the demands. This demand-supply challenge is raised in many industries with production of essential products like agri-products, medical products, grocery, diary products, and petroleum. Smooth supply of these products to the exact needy location and personnel without hampering social distancing is the major challenge.

Panic Buying
Panic buying is the situation that occurs due to customer fear and uncertainty of product supply. Such situation occurred in start phase of COVID-19. Such panic buying causes the shortage of the product supply which is not real occurred due to mass purchasing of products in huge quantities in advance in the fear of shortage.

To handle this panic buying, Industry 4.0 smart applications are useful and effective.

Care of Old-Age People
Lockdown and social distancing cause the personnel working as caretakers and helpers to leave the job and step out to their natives. Such a situation caused real challenges in case of old-age personnel health and safety. Persons who were under observation needed the personal attention in need of help to perform outdoor tasks

were helpless in this scenario. Industry 4.0 technologies are really helpful to solve this challenge, with support of robotics and chatbots.

Teaching Learning
COVID-19 and lockdown also affected the teaching–learning domain. With the lockdown situation, schools, colleges, and training centers got closed, which impacted the teaching–learning process tremendously. It was a major challenge to continue the teaching–learning process to avoid the educational losses. Challenge here was to make teaching–learning assessment continued without hampering the quality of education.

Medical Treatment to COVID-19 Patient
COVID-19 caused sudden increase in patient numbers. There were many hurdles; challenge here was to treat patients with social distancing. Forecasted requirements of COVID-19 centers, medical treatment, and supporting staff are essential in this case and became very much essential. Industry 4.0 technologies help to forecast these essentials. Also, the latest technologies like AI, ML, robotics, and cloud made it possible to create smart applications which help medical professionals to deal with the panic situation like COVID-19 pandemic. It was important to analyze various symptoms of COVID-19 at initial level by using big data of COVID-19 samples. Industry 4.0 made this analysis possible with the help of the latest data analytics and visualization techniques.

Track the Quarantine Personnel
For those who traveled across boundaries of countries, cities, states, or across the contaminated zones of region, it was important to keep such traveler quarantined for few days, so as to stop the spread of the COVID-19. It became important to trace these personnel and avoid the quarantine escape. Industry 4.0 made it possible to solve this challenge with the help of the latest technologies in Industry 4.0.

Detecting Basic Symptoms (Fever and Oxygen Level) of COVID-19
Detecting and tracing the general symptoms of COVID-19 in a crowd are a real challenge. Unless people visit hospital, detection of these symptoms is really hard. Industry 4.0 technologies made this possible to provide the solution to this challenge.

2.3 After Lockdown: Unlock 5.0

After the lockdown for few days or months, step–by-step unlock phase was initiated in many regions, following some precautionary measures like compulsion on face mask, frequent use of sanitizer, and social distancing [11–15].

With these conditions of unlock 5.0, it became essential to track that people are following the said rules. These challenges are mentioned in following sections.

Maintain Social Distancing
Maintaining the social distancing was easy in lockdown phase but became challenging in unlock phase of COVID-19. With Industry 4.0 smart applications, the observing of the social distancing and alarming when not followed are possible.

Surveillance of Mask usage
With unlock phase, surveillance of mask usage is unavoidable for preventing the spread of COVID-19. It is then essential to have smart system which assists human for such surveillance.

3 Industry 4.0 Applications in COVID-19 Challenges

Above mentioned challenges are solved by many smart applications created using Industry 4.0. Industry 4.0 is the collection of cyber-physical systems with the latest technologies so as to support smart applications which suit requirements of current scenario and solve the challenges of COVID-19 [11–17].

3.1 Face Mask Detection System for COVID-19

Face mask is being a must precautionary measure taken to prevent the COVID-19. Forgetting and avoidance of such measures are the tendency of human being. Face mask detection application became useful and important to assist the surveillance of face mask usage. This application detects the personnel with and without face mask. Such outputs are important to alert the personnel for wearing face mask or to deny the entry of personnel without face mask. With new and advent technologies of Industry 4.0, it became easy to implement such application. In face mask detection system, computer vision, machine learning, and IIoT play important role (Fig. 4).

Machine learning model, particularly classification model, gets trained with labeled training data. Image feature extraction algorithm extracts the image features for training and inputs face images. Input face image is processed for feature extraction and submitted as input to machine learning model. This machine learning model outputs the class label as with face/without face. Upon receipt of these labels, IIoT model reacts with access/deny the access to personnel.

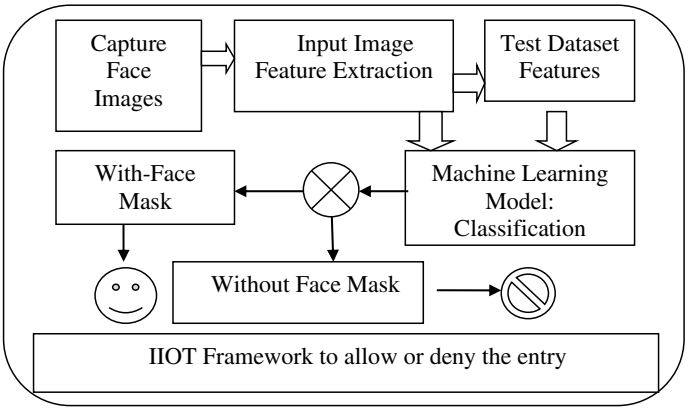

Fig. 4 Mask on face detection

3.2 COVID-19 Self-test Software

In the pandemic of COVID-19, it was overburden on the medical services, to test every patient, for preliminary symptoms assessment and then final COVID-19 test. Limitation of resources like COVID-19 test kits, COVID-19 test centers, and force of medical practitioners was the major problem. So, the smart system, like COVID-19 self-test software, is an innovative idea to fight such situation of COVID-19 challenge. This software helps in assessing the preliminary symptoms of COVID-19, when end-user inputs their health data into the software. Industry 4.0 with the latest technologies like machine learning and natural language processing contributes in implementation of this software (Fig. 5).

For implementation of this system, COVID-19 patients health data are collected and treated as training data. These training data are used to build the classification model for preliminary screening of COVID-19. Various parameters like, temperature, cough, cold, and headache are considered for preliminary screening of COVID-19.

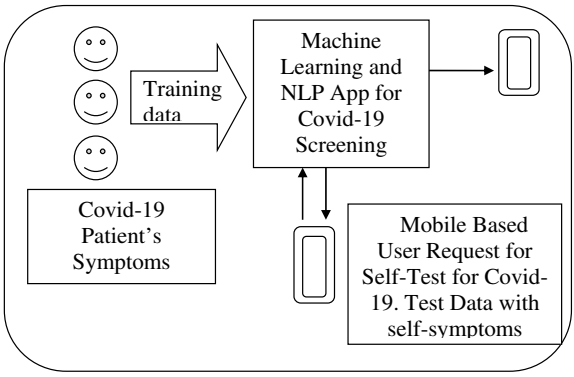

Fig. 5 COVID-19 self-test software

Machine learning techniques like predictive and descriptive analytics are used for the prediction of COVID-19 presence in end-user data.

Natural language processing module helps in understanding the end-user queries posted in linguistic way. Those queries are analyzed and processed to provide the requested data about the screening. This module made this system user-friendly, ease of use, and maximum outreach to public.

3.3 Keep Track COVID-19 Positive Patient

Social distancing and keeping trace of positive patients became important to prevent the spread of COVID-19 disease. With Industry 4.0, smart applications to keep track of positive patients and making nearby public alert of this were made easy. This is proved as an important innovation in this situation.

Industry 4.0 technologies like IIoT, machine learning, natural language processing, and networking contributed in the development of this application. Mobile application for tracing and tracking COVID-19 patients uses the network-based contact-tracing mechanism to record the details of all persons came in contact with end user. This app keeps the record of COVID-19 patients too. It detects the other devices with same app and exchanges some secure information like time, geospatial location, and hot spots. With the help of such collected records like COVID-19 positive patient and person contact history, this software suggests and alters the end user about their contact status and in case some COVID-19 positive patients came in contact. Also, this system alerts the end user about any person who contacted within past 14 days and now found COVID-19 positive. With such alerts, this app suggests some precautionary measures to end users. This system also uses natural language processing to provide the support in regional languages. It also shows the current statistics of COVID-19 link recovery, patient count, and COVID-19 test centers in nearby locality.

3.4 Social Distancing Analysis System for COVID-19

Detecting social distance, i.e., safe distance proposed for COVID-19 prevention and alarming the end-user in case of violation are the main objectives of social distancing analysis system. Such apps are developed using various approaches that includes the latest Industry 4.0 technologies like computer vision, sensors, and IIoT. This app is presented in various ways as such sensor-based wrist band or mobile app or cloud-based surveillance systems. With computer vision, surrounding-captured images are analyzed to detect and measure the distance between nearby person. Calculated distance is then considered to take further action. In case the distance is too small, then alarm gets generated to notify the user about the risk. In other approach, sensors are used to detect the distance among nearby persons. Threshold level of these sensors

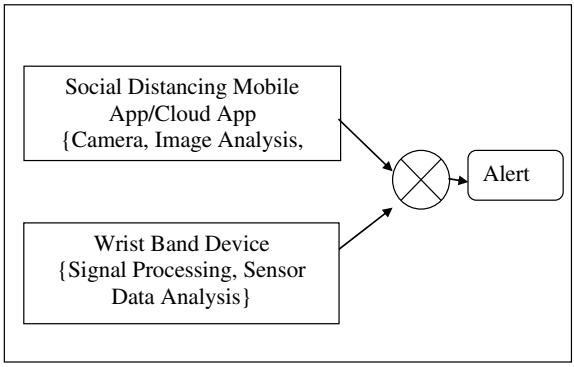

Fig. 6 Social distancing analysis software for COVID-19

decides the distance of the user with surrounded person. In cloud-based surveillance system, end-user location is traced and public crowd-related real-time data at that location is analyzed to alter the end user (Fig. 6).

3.5 Care of Old Age

Follow-up of health, wellness, and social connection is crucial for old-age people, but same social connection was announced as a great risk in case of pandemic of COVID-19. In such a contradictory phase, the advance Industry 4.0 technology can provide the great assistance to deal with this situation. The cyber-physical tools and apps which support the old-age people's care could support the mental and physical health of old-age personnel in a way to improve the quality of their life. These apps help the old-age personnel in various fronts like to take medical advice, to get connected to hobby groups, to order online medicine, and to order online groceries and food products. All these apps provide contactless and distant support. Major technologies which contributed in implementation of these systems are networking, communication, natural language processing, machine learning, cognitive computing, etc. (Fig. 7).

3.6 COVID-19 Data Analysis

Lots of related data are collected during this pandemic time of COVID-19. This huge amount of big data are effectively used for prediction and planning of COVID-19-related strategies to overcome, prevent, and deal with the sudden unexpected challenges (Fig. 8).

COVID-19 data analysis is carried out using various techniques like exploratory data analytics and predictive analytics which are used further for critical decision-making about the sudden situation of COVID-19 pandemic.

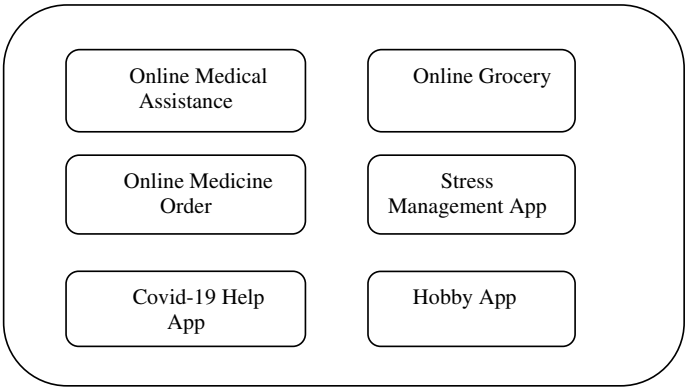

Fig. 7 Various applications for old-age care

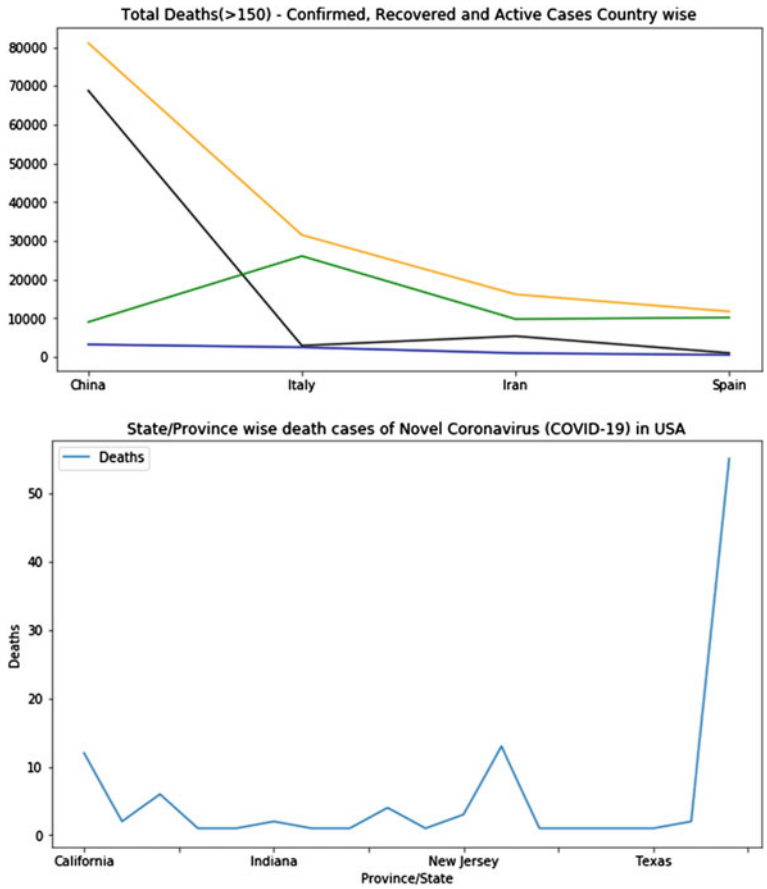

Fig. 8 Exploratory data analysis on COVID-19 data

- Exploratory data analytics like data Visualization attempts to showcase meaningful patterns which are useful to extract important insights from the COVID-19 dataset. Different dimensions of COVID-19 dataset can be explored to do exploratory analysis like which part of the city have maximum COVID-19 cases (hot spot, containment zone), which age group is most suffering from COVID-19, what are the symptoms that most of the COVID-19 patients suffering from, what is the timeline of treatment, and various categories of COVID-19 treatment.
- Predictive data analytics attempts to propose some intelligence predictions on COVID-19 dataset. Supervised and unsupervised machine learning models like classification, clustering, and association rule mining could be used effectively to understand hidden patterns and relationship in data and predict the important clues. These predictions are identifying the COVID-19 positive and negative cases based on symptoms, COVID-19 risk analysis, predicting containment zone, and resource requirement based on region density and crowd, etc.

4 Conclusion

This chapter discussed various COVID-19 challenges and the Industry 4.0 applications as a solution to those challenges. COVID-19 pandemic was a sudden and uneven situation arose in 2020 and impacted a lot to many aspects of our lives and lifestyle. Some aspects were so impacted that those situations lead to birth of smart, intelligent Industry 4.0 applications. Industry 4.0 applications proved as substitute of human being which was real need of this pandemic situation. Industry 4.0 applications discussed in this chapter provided contactless service to solve the challenges of this pandemic. These applications also proved as substitute to manual surveillance in case of face mask checking, patient tracing, and social distancing.

With Industry 4.0 applications, it was made possible to provide contactless medical services too which was very essential in this scenario. Applications like smart COVID-19 analysis system and apps to help the old-age people are some of the applications which proved very useful to end user.

Cognitive computing, machine learning, networking, IIoT, and artificial intelligence are the recent techniques of Industry 4.0 contributed much to provide all way round assistance in fighting these COVID-19 challenges.

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Internet of Medical Things (IoMT) Enabled TeleCOVID System for Diagnosis of COVID-19 Patients

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Abstract The emerging global threat of the COVID-19 pandemic has crossed provincial, radical, philosophical, spiritual, social, and educational boundaries. The Internet of Things (IoT) is a well-developed scheme of integrated computational tactics, digital and mechanical machines capable of distributing data over a defined network without any human intervention at any stage. Since pandemic has spread worldwide, limited healthcare facilities may lead to a shortage of diagnoses of patients. Moreover, most positive cases of COVID-19 are quarantined in the home, which triggers a lack of diagnosis of patients from home. This chapter aims to develop a TeleCOVID diagnostic system for monitoring COVID-19 patients with body temperature, oxygen saturation level, heart rate, throat, and patient's behaviour. A web platform was developed to monitor the patient's symptoms, and a smartphone application was developed and used to detect the patient's activities. The accuracy of the activity detection system was reached 81.82% at 0.82 precision. The overall system showed promising results for several test trials.

Keywords COVID-19 · Global pandemic · Internet of Medical Things (IoMT) · Real-time monitoring · Smart healthcare · TeleCOVID

1 Introduction

Coronavirus disease 2019, also known as COVID-19, is an acute respiratory disease that originated in Wuhan, China. In December 2019, COVID-19, caused by Severe Acute Respiratory Syndrome Coronavirus 2 or SARS-CoV-2, was initially identified. SARS-CoV-2 is a new strain virus that is part of the coronavirus family and the Sarbecovirus subgenus (beta-CoV lineage B) [1–3], distinct from Severe Acute Respiratory Syndrome (SARS-CoV) and Middle East Respiratory Syndrome (MERS-CoV). In China, the prevalence of COVID-19 has risen significantly and, since late February 2020, the virus has spread exponentially to more than 200 countries across the world.

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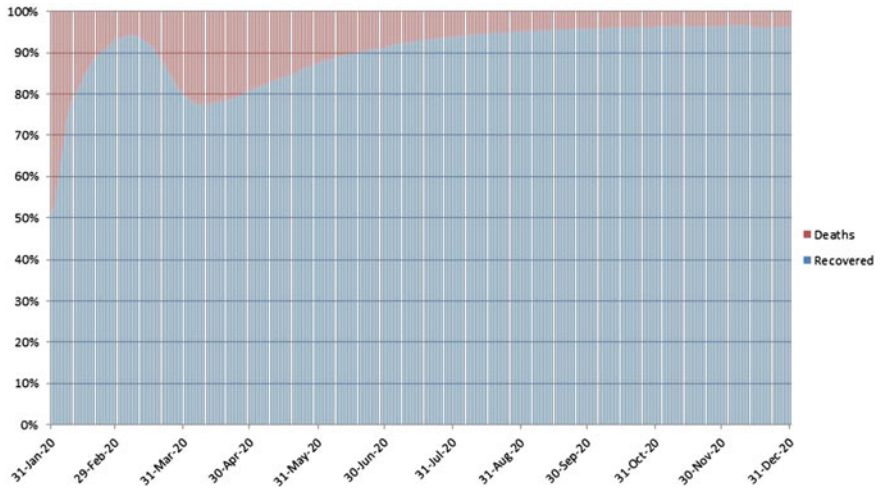

Fig. 1 COVID-19 global death and recovered cases as of 31st December, 2020

The World Health Organization (WHO) states that, as of December 2020, more than 75.5 million confirmed cases (Fig. 1) of COVID-19 had been reported [4] worldwide. Moreover, the WHO reported that approximately 1.67 million infected people have died with a 2.21% global death-to-cases ratio.

The latest coronavirus primarily spreads by respiratory gout, overt or indirect contact, and aerosol. A variety of reports have found that human-to-human transmission of a modern coronavirus happened in households, clinics, or towns. Recently, remote health monitoring has been encouraged owing to the recent COVID-19 pandemic. Telehealth [5] is the offering of medical facilities through healthcare professionals by the usage of ICTs for the sharing of reliable and precise data where the major element is the distance [6]. Most households have at least one wireless device, such as smartphones and webcams that allow patient's accessibility and healthcare providers to extend mobile device growth [7]. The sensors and sensor network can capture several biomedical signals including ECG and pulse. The use of smartphones as a network portal to capture, process sensor signals, and store them on related medical repositories [8] or data processing facilities is an advantage of the traditional remote medical tracking approach [9, 10].

In recent decades, mobile computing and networking have been essential to smartphones or tablet computers throughout our daily lives. Along with the advent of multiple advanced sensor technologies, smartphones have enhanced functionality and innovations that soon are projected to revitalize several social and economic fields. Social networking, environmental regulation, oversight, healthcare, and logistics are also part of this. Several sensor systems, including accelerometers, light sensors, GPS modules, microphones, optical compasses, gyroscopes, and cameras have been mounted in modern intelligent devices. Wi-Fi, 3G, 4G, 5G, Bluetooth, and other communication protocols are integrated for networking and knowledge

exchange. In recent years, research on smartphone-based healthcare systems [11] has attracted greater interest, and various applications have been developed.

Many integrated wearable sensing systems are composed of the Body Area Network (BAN) to gather various biomedical data [12], such as heartbeat, brain activity, patient's blood pressure, and body temperature. COVID-19 is correlated with many physiological changes and other viral diseases, which can be tracked using wearable sensors. Via numerous networking protocols, including ZigBee, Bluetooth, and Wi-Fi, such sensor nodes are interconnected. However, sensor nodes are mostly equipped with minimal memory and computational power, so sensor data is usually sent to another processing server where cell phones are often used [10]. Table 1 shows the data utilized from sensors, mobile devices, and medical records for building the Internet of Medical Things (IoMT) designs.

Since COVID-19 waves have caused harm to civilization and people's wellbeing, there is a strong need for a Telehealth support system. Cities like Singapore and Seoul are spending more money to mitigate the COVID-19 pandemic on remote health monitoring systems. According to the WHO, 25% of responding countries were reported that there had been an evaluation of a government-sponsored Telehealth

Table 1 Health parameters gathered from sensors, smart devices, and medical records

Resource	Parameter	Description
Sensors [13]	Blood sugar	Measure blood glucose (mg/dL)
	Temperature	Measure body temperature (°C)
	Pressure	Measure systolic and diastolic blood pressure (mmHg)
	Oxygen saturation	SpO_2 consumption (mmHg)
	Heart rate	Measure heart rate (bpm)
	ECG	Measure electrocardiography (ECG) wave behaviour
	EEG	Measure electroencephalography (EEG) wave behaviour
Smartphone [13]	Age	Age of the patient in days
	Height	Height of the patient (cm)
	BMI	Body mass index (BMI) of the patient (kg/m^{-2})
	Gender	Gender of the patient (male/female)
Medical records [13]	Smoking	Smoking history
	Drinking	Drinking history
	Cholesterol	From a blood test of the patient
	Diseases	Diseases history of the patient
	Blood sugar	Blood testing history of the patient
	Virus	EVD, SARS, MERS, COVID-19 etc.
	Haemoglobin	Glycated haemoglobin (A1c) of the patient (%)

program. This chapter aims to develop a TeleCOVID diagnostic system to monitor COVID-19 patients using wearable sensor technologies and smartphone sensors.

The related work of the current proposal is reviewed in the Sect. 2 of this chapter, and the materials and methods of the proposed design are set out in Sect. 3. The results and analysis section (Sect. 4) consists of the experiment's observations and the research outcomes (activity detection and TeleCOVID system). Finally, the proposed system is concluded in Sect. 5.

2 Related Works

The novel coronavirus is a new strain that has not been identified in the human body previously. The clusters have now been left undetected by several nations, which poses the enormous problem of transmitting the virus. Telehealth services have recently become more prominent due to the COVID-19 pandemic, and many government bodies and medical institutions are demanding remote monitoring facilities for COVID-19 patients to be diagnosed. This chapter aims to develop a TeleCOVID diagnostic system based on wearable sensor technology to monitor COVID-19 patients. In order to achieve the research objectives, previous research of activity detection systems for healthcare applications, IoT frameworks for cloud-based applications [5, 14], and reliable network protocols used in smart cities were mainly focused.

Al-Khafajiy et al. [15] have proposed developing a smart monitoring system for healthcare purposes capable of remotely monitoring older people. They also reflected on the ability to monitor an individual's physiological details to classify particular conditions that may assist with early detection activities. The result has indicated that clinical decision-making can be strengthened by the proposed development when promoting early intervention procedures. In terms of data collection and manipulation, they have found that the system works reliably and cost-effectively.

Patel et al. [16] have outlined recent advances in wearable devices and applications specific to the field of healthcare. Applications for evaluating treatment effectiveness, safety, home rehabilitation, fitness and wellness, and early diagnosis of disorders have been examined and identified.

Aljehani et al. [17], who have created an Apple smart-watch application that supports the Arabic language, also introduced a novel feature in the application's language. The software has monitored and located the patient's heart rhythms, demonstrating over 94% satisfaction with using it.

A sensor network that measures heartbeat, acceleration, blood pressure and body temperature has been built by Bose [18]. Its data has been safely transmitted through developed wireless mesh network architecture to the remote-control station. They have observed wireless signal identification, effective data collection and delivery, low power consumption, and efficient channel allocation.

Yang et al. [19] have introduced an IoT-cloud-dependent ECG monitoring framework, where sensed data is transmitted directly to the cloud server through Wi-Fi. The data has been accessed by the patients, physicians, and family members through

either the web or a mobile application. Table 2 depicts the different IoT technologies [20] used by previous researchers and their outcomes.

In a careful analysis conducted through Google Scholar and ResearchGate, at the time of this writing, we have found no new development in terms of TeleCOVID. As it is new, the authors aim to develop a TeleCOVID system to diagnose COVID-19 patients. The next section of this chapter discusses the materials and methods used for the proposed system.

3 Materials and Methods

This section introduces the materials and methodology of the proposed system. Proposed system composed of sensor layer, connectivity layer, cloud computing layer, and administrative actions. Figure 2 illustrates the proposed IoT architecture of the TeleCOVID diagnostic system.

Google Firebase is a Backend-as-a-Service, also known as "Baas" that was developed by Google LLC. It offers several tools and resources for developers to design various software, expand their user base, and earn profits. Firebase is categorized as a database program called NoSQL, which stores data in records identical to JSON. Since our system collects a large amount of sensor data and is required to access it remotely, the Google Firebase platform was used to store and access data on the cloud database. Table 3 depicts the description of components used for the development of the proposed TeleCOVID diagnostic system.

Table 2 Review studies of internet of medical things (IoMT) and its aspects

Reference	Year	IoT technology	Research outcomes
Ienca et al. [21]	2017	Wearable sensors	Efficiency
		Smartphones	High performance
		Robotics	High clinical values
Talboom and Huentelman [22]	2018	Wearable sensors	Ease of use
			Efficiency
			Invasiveness and esthetics
Li et al. [23]	2015	Smart home	Efficiency
			Ease of use

(continued)

Table 2 (continued)

Reference	Year	IoT technology	Research outcomes
Al-Shaqi et al. [24]	2016	Biometric sensors	Efficiency
		Smart home	Ease of use
		Environmental sensors	Cost-effective
Patel et al. [16]	2012	Wearable sensors	Energy consumption
		Biometric sensors	Cost-effective
		Microphones	
		Indoor positioning	
Cedillo et al. [25]	2018	Wearable sensors	Reliable networking
		Smart applications	
Baig et al. [26]	2019	Wearable sensors	Ease of use
			Energy consumption
Peetoom et al. [27]	2015	Wearable sensors	Various sensor types used
		Microphones	Efficiency
		Cameras	
Rashid and Mihailidis [28]	2013	Wearable sensors	Different sensor type used
		Biometric sensors	Different data types used
		Environmental sensors	
		Indoor positioning	
Wang et al. [29]	2017	Indoor positioning	High accuracy
			Availability of security
			Cost-effective
			Ease of use
Piwek et al. [30]	2016	Wearable sensors	Robustness
		Smartphones	Security features
		Smart applications	

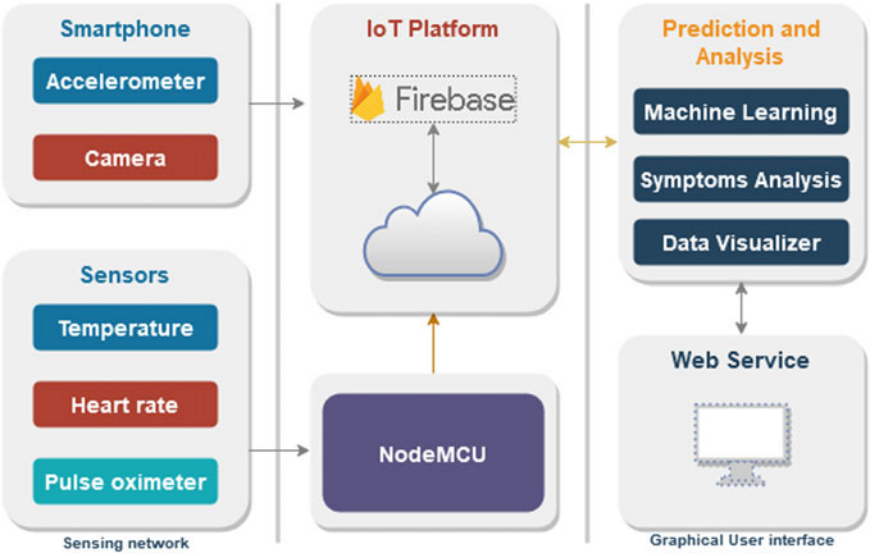

Fig. 2 Proposed IoT architecture of the TeleCOVID diagnostic system

Table 3 Components used for the development of the TeleCOVID diagnostic system

Component	Parameter	Sensor/Device	Unit
Temperature sensor	Body temperature	LM75A high-speed temperature sensor module I2C	°C
Accelerometer sensor	3D acceleration	Huawei MediaPad *T*1 7.0 Android tablet	ms^{-2}
Camera	Image of the sore throat		binary
SpO2 sensor	Oxygen saturation level	MAX30100 pulse oximeter SpO2 and heart-rate sensor module	%
Heart-rate sensor	Heart rate		bpm

3.1 Dataset

The MotionSense Dataset that is publicly available in the Queen Mary University of London repository [31] was used to train and test the Artificial Neural Network (ANN) model. The data collection includes time-series data generated by the accelerometer and gyroscope sensors of the smartphone. We extracted data from the accelerometer sensor for five separate activities (walking, downstairs, upstairs, sitting, and resting) for this study.

3.2 Proposed Design

The proposed design of this chapter is composed of two sub-sections. The first sub-section outlines the development of the activity recognition system. We developed an Android application to acquire accelerometer sensor data and determine the user's activities in real-time. Moreover, we proposed an ANN model to predict the activities based on the data acquired. The second sub-section describes the development of the TeleCOVID diagnostic system. We proposed and developed a Web-based application to monitor and predict COVID-19 status based on the data acquired. Biomedical data such as heart rate, body temperature, and oxygen saturation were collected through the aid of wearable sensor technologies. Both designs proposed here were linked with the IoT network and functioned as a single operation.

3.2.1 Development of the Activity Recognition System

The idea of implementing sensors and sensor networks for activity monitoring and recognition [32] has been popular over the last two decades. Human behaviour detection is a significant and demanding area of study with many uses in wellness, smart environments, and safety [33]. One of the early behaviour recognition frameworks is to mount several accelerometers to the human body to monitor the specifics of acceleration of different areas of the human body [34, 35] and therefore identify the gestures of the body of the consumer. The development of an Android application for measuring acceleration in three orthogonal directions is presented in this section, and user activities were predicted using the Artificial Neural Network (ANN) technique. For data collection, we used a triaxial accelerometer on the Android smart devices. Linear acceleration along the *X*-axis, *Y*-axis, and *Z*-axis are respectively required for accelerometer results. The horizontal/sideway motion (*X*-axis), up/down motion (*Y*-axis), and forward/backward motion (*Z*-axis) of the consumer is captured by these axes. The proposed design used a built-in mobile accelerometer to measure the linear acceleration (ACC_x, ACC_y, ACC_z) in the direction of x, y, z and labeled them according to user activities performed by the user. For the Artificial Neural Network (ANN) model's training and testing, the MotionSense dataset that is publicly available in the Queen Mary University of London repository was used.

Biologically motivated computer networks are Artificial Neural Networks (ANNs). This chapter focuses on Multilayer Perceptrons (MLPs) with back-propagation learning algorithm among the various forms of ANNs. The MLPs, depending on the controlled process, are more intensively used for a broad variety of problems and consist of three layers defined as the input, hidden, and output. The proposed ANN architecture was developed with 3 nodes (ACC_x, ACC_y, and ACC_z) for the input layer, a single node for the output layer, 10 nodes for the first hidden layer, and 5 nodes for the second hidden layer. Figure 3 illustrates the architecture of the proposed ANN model to predict user activities based on the accelerometer reading.

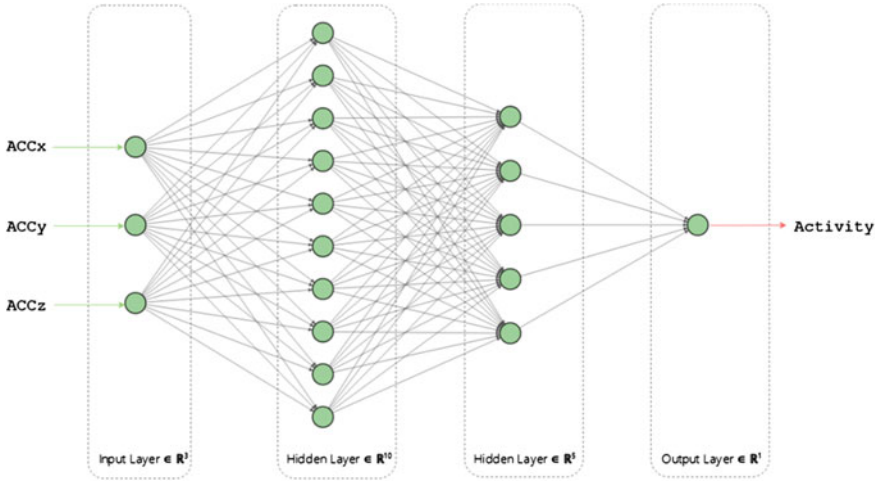

Fig. 3 The architecture of the proposed ANN model of the activity prediction process

The neural network's activation functions are considered a crucial part of deep learning. Activation functions determine the efficiency, accuracy, and statistical viability of training a model that can make or break a large-scale neural network. The performance of a deep learning algorithm is calculated by activation functions. As the activation function for the neural network's hidden layer, the hyperbolic tangent sigmoid transfer function (Tansig function) is widely used. The activation function is associated with each neuron and determines the state of activation, whether the neuron should fire or not. This activation status is based on the neuron's input state relevant to the prediction of the model. For input to output transformation, the S-shaped anti-symmetric function was used [36]. This transition allowed each neuron's output to remain within the interval between -1 and $+1$. The hyperbolic tangent sigmoid function is defined by Eq. (1). In this research, we used the Tansig activation function to activate the neurons.

$$a = \text{Tansig}(n) = \frac{2}{1 + \text{e}^{-2n}} - 1 \tag{1}$$

The accelerometer sensor was initialized to read the data from the sensor when the program begins. Initially, the availability of internet access was verified by the program. Then, accelerometer data (ACC_x, ACC_y, and ACC_z) was obtained to predict user activities. Preprocessing procedures were carried out to remove noise from the collected data. To predict activities using the ANN algorithm, the activity prediction (P_{act}) process was used. For each operation in 0 to 4 indices, the system then checked the P_{act} ($0 \leq P_{\text{act}} < 5$) (0—Sitting, 1—Walking, 2—Resting, 3—Stairs up, 4—Stairs down). Finally predicted activity was sent to the Google Firebase and refreshed the operation itself. Figure 4 shows the user activity detection system's program flow chart.

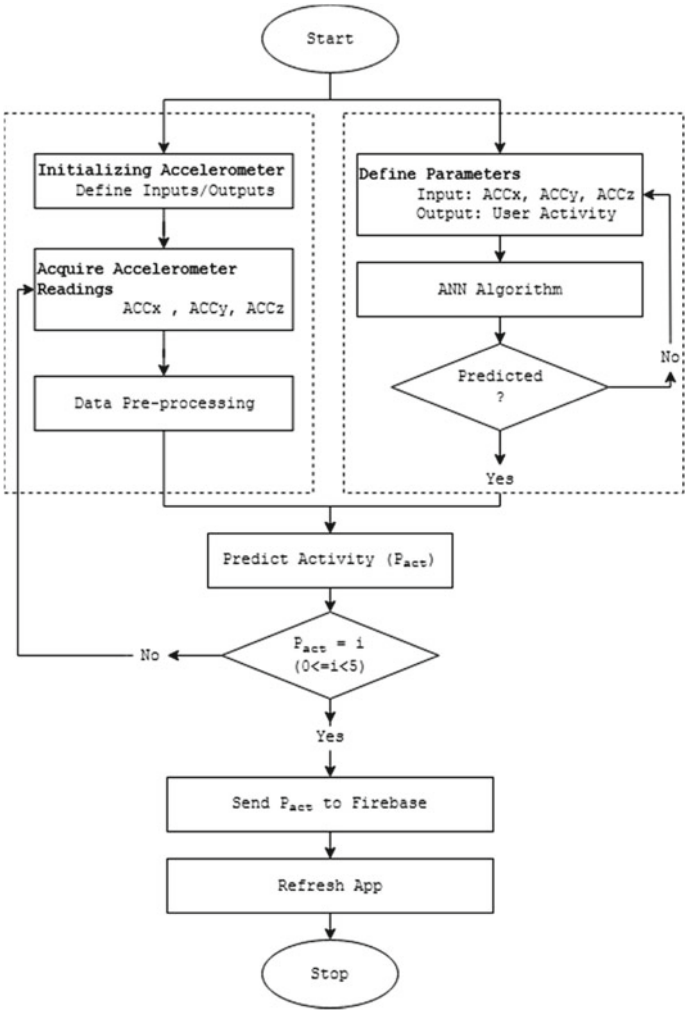

Fig. 4 Program flowchart of the patient's activity detection system

3.2.2 Development of the TeleCOVID Diagnostic System

This section introduces the development, using wearable sensors and IoT technologies, of a web-based TeleCOVID framework. An IoT cloud is vital to ensure that sensitive information is quickly preserved in a cloud database and viewed after a large volume of sensor data that has been obtained from the sensor node, where appropriate. Temperature analysis is extremely important for the diagnosis of COVID-19. It has been widely used by many nations as an instant examination to determine if COVID-19 may be infected by travellers or individuals. Although quarantining

individuals with fever will prevent transmission to some degree, temperature regulation is necessary because COVID-19 can be transmitted before a fever develops. We also used heart rate and oxygen saturation of the patient's blood for the diagnosis of the patient. Figure 5 displays the attached pulse rate, SpO2, and temperature sensors after wearing the subject's hand when conducting the experiments. We have connected sensors to a fabric material for reliable readings, as seen in the figure.

Figure 6 illustrates the schematic diagram of the proposed wearable sensor unit. The sensor unit is composed of Pulse Oximeter SpO2 (MAX30100), heart-rate (MAX30100), and temperature sensor (LM75A). The NodeMCU (NMCU1) was used to connect with the server and send acquired data to the Google Firebase. Centred on the traditional '*REQUEST*' and '*RESPONSE*' procedure, the HTTP server was configured to acknowledge user responses and reply accordingly. To access the sensor information, the user had to submit a '*GET*' request to the IoT

Fig. 5 Sensors attached to the subject's hand while performing the experiment

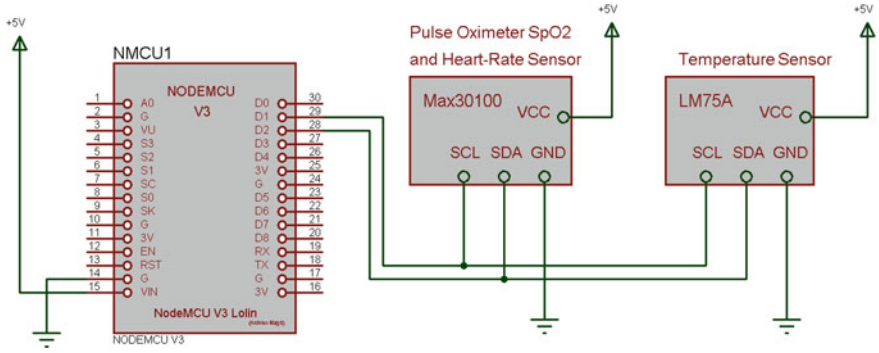

Fig. 6 Schematic diagram of the wearable sensor unit with MAX30100, LM75A, and NMCU1 modules

cloud via a URL. The source file was encoded using HTML (Hypertext Markup Language) and submitted using the server's HTTP protocol. The browser could convert the HTML file into a graphical user interface (GUI) that would enable users to log in to the server. Another HTML format was used to visualise acquired sensor information, that was submitted to the HTTP server.

The Wi-Fi NodeMCU communicates with the Firebase database, and this NodeMCU operates based on the information obtained from the Firebase database. The web application acquired all sensor data from Firebase and represented it as a matrix (T_{sensor}). Equation (2) represents the sensor matrix and contains the three linear accelerations, heart rate, body temperature, and blood oxygen saturation. The image of the patient's throat was acquired from a different process. After the image was taken by the patient and needed to be uploaded to Firebase separately.

$$T_{\text{sensor}} = \begin{bmatrix} P_{\text{act}(0,0)} & S_{\text{hr}(0,1)} & S_{\text{tmp}(0,2)} & S_{\text{spo2}(0,3)} \\ P_{\text{act}(1,0)} & S_{\text{hr}(1,1)} & S_{\text{tmp}(1,2)} & S_{spo2(1,3)} \\ P_{\text{act}(n,0)} & S_{\text{hr}(n,1)} & S_{\text{tmp}(n,2)} & S_{\text{spo2}(n,3)} \end{bmatrix} \tag{2}$$

The following pseudocode represents Google Firebase's data acquisition process and results were assigned to the sensor matrix (T_{sensor}). In here, the NodeMCU was equipped with a local Wi-Fi link to connect with Firebase.

```
program DATAPro
define FIREBASE_HOST
define FIREBASE_AUTH
define WIFI_SSID
define WIFI_PASSWORD
var Con_wifi, Con_firebase
var S_hr, S_tmp, S_spo2, P_act
Var i, j, N

begin
if (Con_wifi.connect) then
     while (Con_wifi.connect)
if (Con_firebase.connect) then
       read S_hr
       read S_tmp
       read S_spo2
       read P_act
       for (i=0 to N)
             for (j=0 to 3)
                   T_sensor = S[i,j]
end for
end for
end if
     end while
end if
end
```

Figure 7 illustrates the program flow chart of the proposed TeleCOVID diagnostic system. Once the program starts its operation through the URL provided by the healthcare provider, the system begins to search the user by Patient ID. The system was then requested data from the Google Firebase, once the request had a response *Var1*, *Var2*, *Var3*, *Var4*, and *Var5* were initialized with the sensor data. Otherwise, the program was immediately stopped by handling the error exception.

Once the program received all the sensor data, matrix T_{sensor} was generated. Using the T_{sensor} matrix, results were shown in the HTML body by writing commands into

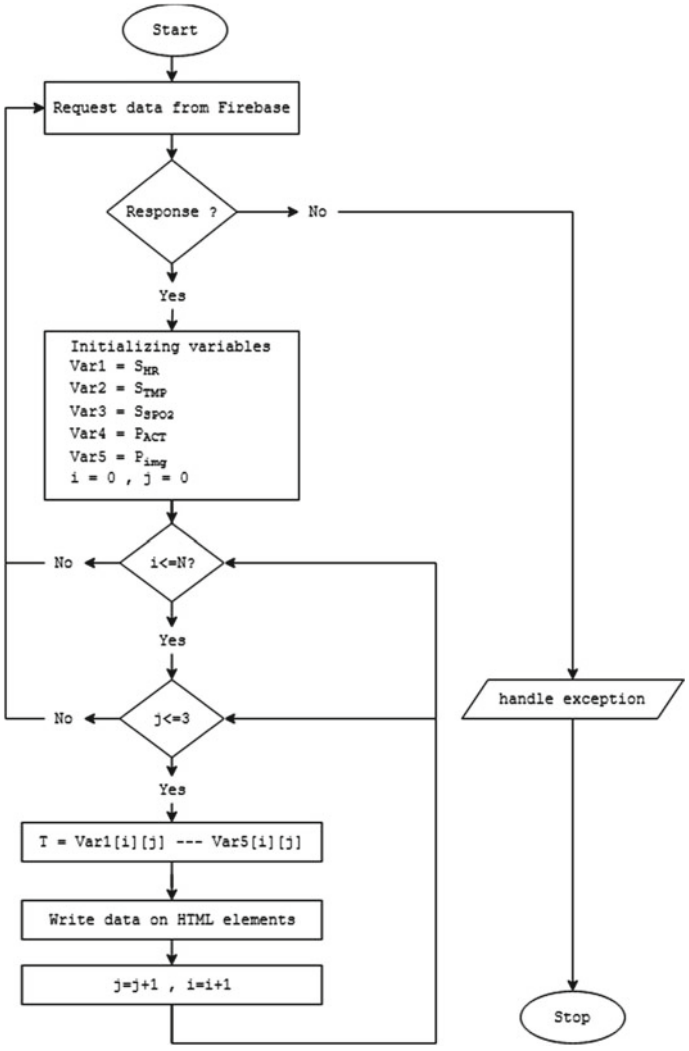

Fig. 7 Program flowchart of the TeleCOVID diagnostic system

the HTML elements using the JavaScript (JS) computer language. The sensors were stored data on Firebase every 60 s. Since sensors were collected more significant quantities of data, there are large numbers of rows in the matrix. A single row holds the sensor values for a period of 60 s.

4 Results and Analysis

This section discusses the results and observations of each objective. Section 4.1 describes the results and observations of the patient's activity detection system with ten test subjects. Sect. 4.2 discusses the results of the proposed TeleCOVID diagnostic system.

4.1 Results and Analysis of Activity Detection System

When conducting five sets of tasks, we enlisted ten volunteer subjects' assistance to carry a smartphone. Concerning the results, no noise cancellation or preprocessing was carried out. Subjects were asked to pause and wait for three seconds before beginning the next task to avoid mislabeling. In order to test the model, it was necessary to have subjects carry a developed Android smartphone application while performing specified activities.

The ANN model for better prediction required a lower Mean Square Error (MSE). As shown in Fig. 8, the best training performance of 0.20955 was observed at epoch 100.

Figure 9 (walking, downstairs, and upstairs activities) and Fig. 10 (resting, and sitting activities) shows the developed Android application for the user activity detection system.

In machine learning, a confusion matrix or also known as an error matrix is commonly used, particularly in the field of statistical classification [37]. A confusion matrix is a table often used on a collection of test data for which the actual values are known to explain the output of a classification model or classifier. The confusion matrix was used to validate the results of our developed algorithm. Equations (3) and (4) were used to calculate the test results' accuracy and precision based on the data extracted from the confusion matrix.

$$\text{Accuracy} = \frac{\sum (\text{TP} + \text{TN})}{\sum (\text{TP} + \text{FP} + \text{FN} + \text{TN})} \tag{3}$$

$$\text{Precision} = \frac{\sum (\text{TP})}{\sum (\text{TP} + \text{FP})} \tag{4}$$

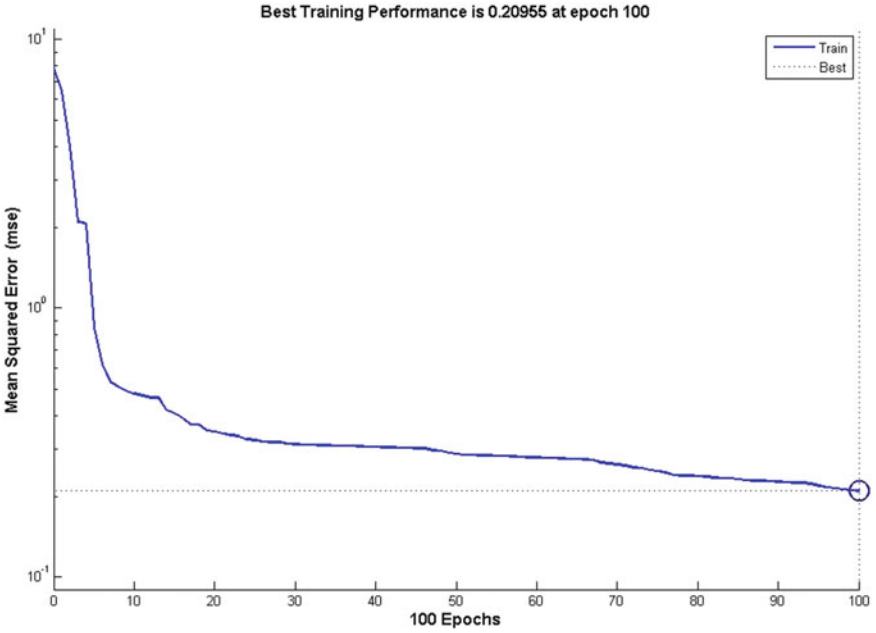

Fig. 8 Training performance of the activity recognition ANN model

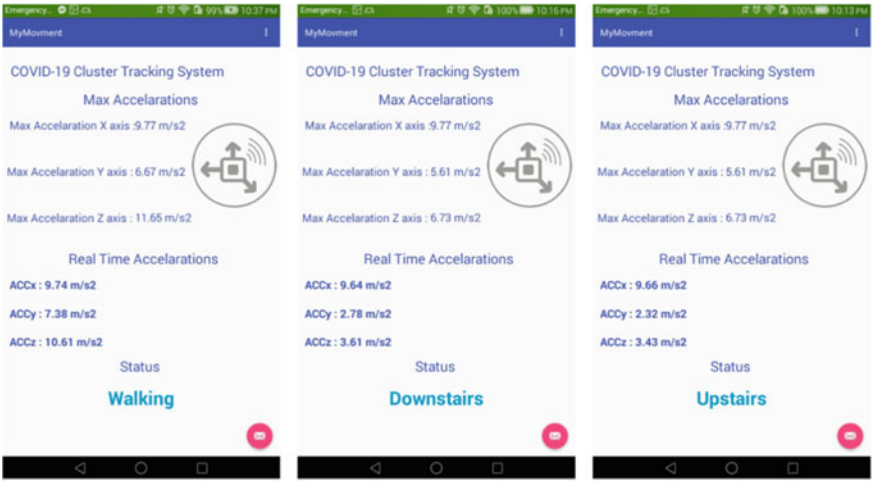

Fig. 9 Results of the activity detection system—Android application (walking, downstairs, and upstairs activities)

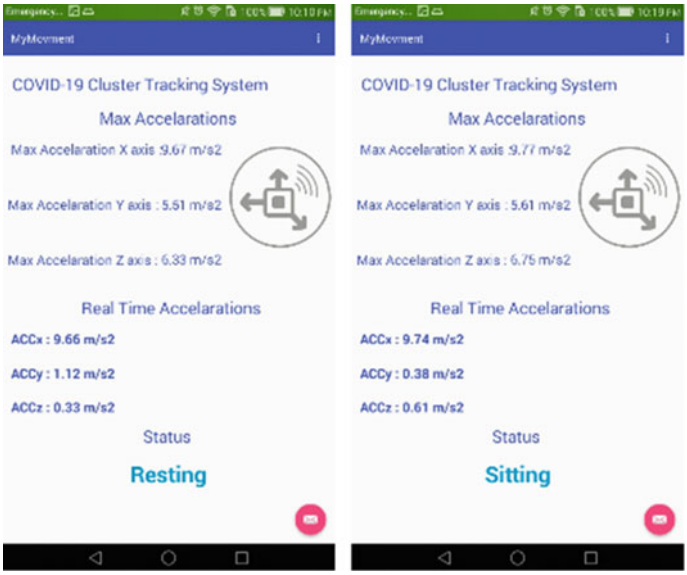

Fig. 10 Results of the activity detection system—Android application (resting, and sitting activities)

The entries in the confusion matrix were calculated from the coincidence matrix. Table 4 depicts the hypothesis used for the coincidence matrix.

For five activity classes, the experiment was performed with 500 test trials for each test subject. 100 test trials from each activity class (sitting, walking, resting, stairs up, and stairs down) were performed by all the subjects. The confusion matrix of the proposed activity detection system is shown in Fig. 11. As shown in the figure, the confusion matrix of each test (S1–S10) represents the test subjects, and Class 1–Class 5 represents sitting, walking, resting, stairs up, and stairs down activities.

Table 5 depicts the accuracy and precision of each activity class for ten test subjects. The accuracy of the activity detection system was found to be 81.82% at 0.82 precision.

Table 4 The hypothesis of the coincidence matrix

Notation	Case	Description
TN	True negative	The number of correct predictions of a negative case
TP	True positive	The number of correct predictions of a positive case
FP	False positive	The number of incorrect predictions of a positive case
FN	False negative	The number of incorrect predictions of a negative case

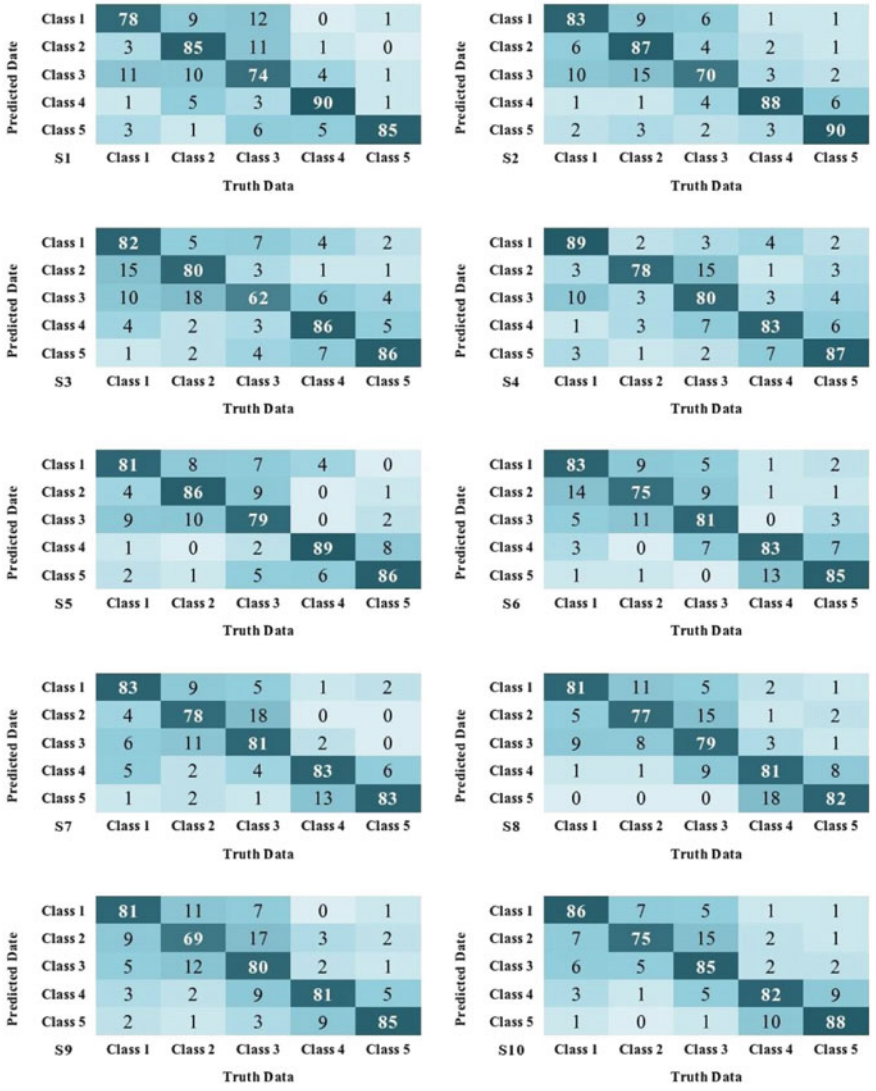

Fig. 11 Confusion matrix of the activity detection system for ten test subjects

4.2 Results of the TeleCOVID Diagnostic System

A Serial Monitor is a separate option that acts as a separate terminal and communicates by receiving and transmitting serial data. Serial hardware sends and receives information as electric pulses that represent sequential bits. The zeros (0) and ones (1) that contain the information that makes up a byte can be interpreted in various ways.

Table 5 Accuracy and precision of each activity class for ten test subjects

Test subject	Accuracy (%)	Precision				
		Class 1	Class 2	Class 3	Class 4	Class 5
Subject 1	82.4	0.78	0.85	0.74	0.90	0.85
Subject 2	83.6	0.83	0.87	0.70	0.88	0.90
Subject 3	79.2	0.82	0.80	0.62	0.86	0.86
Subject 4	83.4	0.89	0.78	0.80	0.83	0.87
Subject 5	84.2	0.81	0.86	0.79	0.89	0.86
Subject 6	81.4	0.83	0.75	0.81	0.83	0.85
Subject 7	81.6	0.83	0.78	0.81	0.83	0.83
Subject 8	80.0	0.81	0.77	0.79	0.81	0.82
Subject 9	79.2	0.81	0.69	0.80	0.81	0.85
Subject 10	82.3	0.86	0.75	0.83	0.82	0.88

To represent a bit value of 0, the Arduino scheme uses 0.0 V, and 5.0 V (or 3.3 V) uses to represent a bit value of 1.

We connected all sensors to the Arduino development board for the testing purposes and observed the results through the serial monitor. Figure 12 illustrates the heart-rate, temperature, and SpO2 sensor readings through the Arduino Serial Monitor. Figure 13 shows the stored sensor data on Google Firebase. Unique user id represents the unique patient. The entities "*hr*", "*spo2*", and "*temp*" represent the heart-rate, oxygen saturation, and body temperature of the patient.

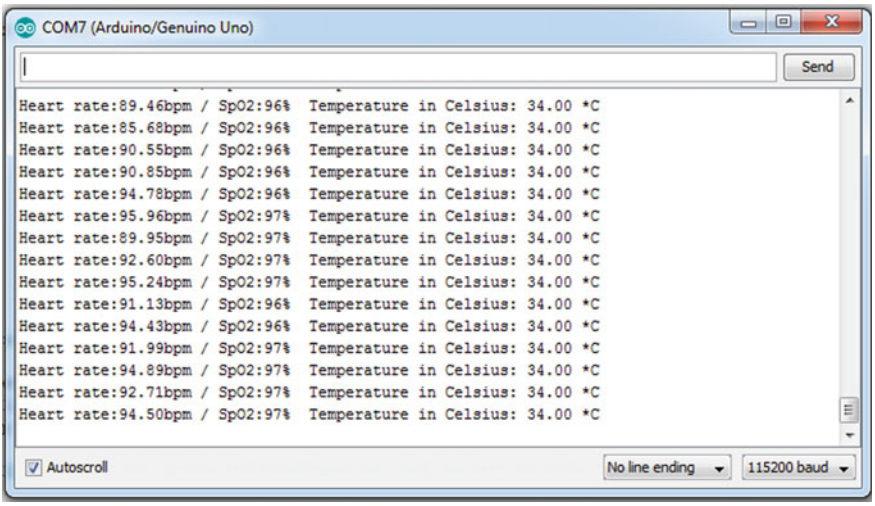

Fig. 12 Acquisition of sensor data (heart rate, SpO2, and temperature) through the Arduino serial monitor

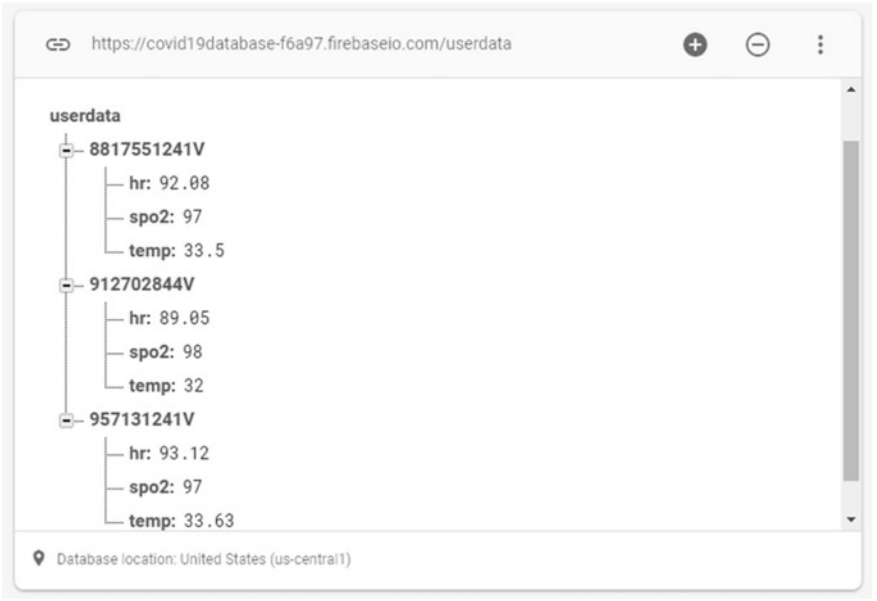

Fig. 13 Sample of stored sensor data in the Google Firebase

Figure 14 illustrates the developed web-based application of the TeleCOVID diagnostic system. Patient information was acquired through the "*patient-info*" branch on the Google Firebase. The "*patient-info"* contains the name, age, height, weight, and gender information. After data was acquired, Body Mass Index (BMI) was calculated

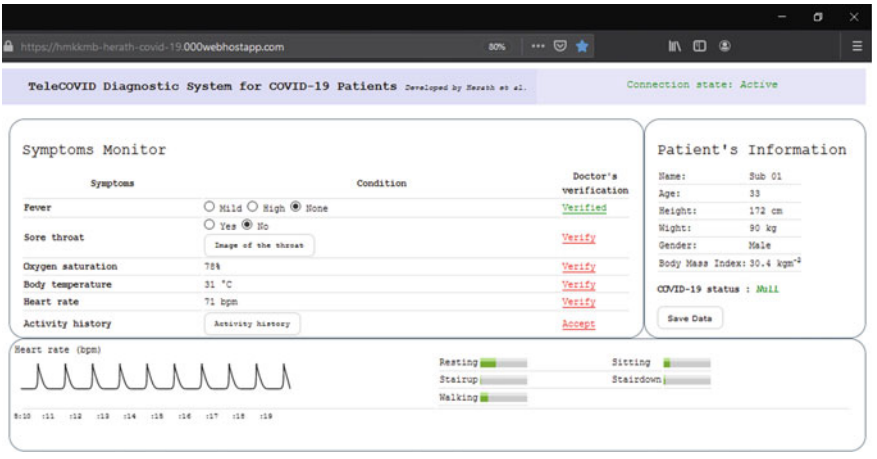

Fig. 14 TeleCOVID diagnostic system from the admin side (left-top: symptoms monitor, right-top: patient's information, bottom: heart rate and activity summary)

using JavaScript (JS) language. The BMI was calculated using Eq. (5).

$$\text{BMI} = \frac{\text{Weight}}{\text{Height}^2} \quad \text{kg m}^{-2} \tag{5}$$

Using the JavaScript computer language, the heart rate plot was developed. After the system acquires the sensor measurements, the doctor has to check the results whether patients have symptoms or not. The patient's COVID-19 status was auto-generated based on the doctor's decision.

5 Conclusion

Since the end of 2019, the world has faced the threat of the COVID-19 virus that originated in Wuhan, China. Precautionary steps must be taken globally to combat the COVID-19 pandemic before an effective vaccine is developed. The second phase of the pandemic is now confronting several countries, and smart innovations [38] (smart healthcare, smart logistics, smart infrastructure, smart education) are being proposed to keep the pandemic from spreading. The IoT technologies are now adapting to the healthcare sector, and recently the Telehealth system has been promoted to diagnose patients. This chapter proposed the development of a TeleCOVID diagnostic system for COVID-19 patients. The system was developed with an Android smartphone for acquired images (image of the patient's throat) and accelerometer data (activity detection). A wearable sensor unit was developed to measure body temperature, heart rate, and oxygen saturation of the blood. A web-based system was developed to monitor the acquired data from smartphones and sensor units remotely. The activity detection system was achieved with 81.82% accuracy at 0.82 precision. The web-based system was tested with several test trials, and the proposed TeleCOVID diagnostic system showed promising results.

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