Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Application of industry 4.0 technology in containing Covid-19 spread and its challenges

K.P. Paranitharan [a,*], G. Ebenezer [b], Venkataraman Balaji [a], M. Adham Khan [b], T. Ramesh Babu [c]

[a] Department of Corporate Planning Cell, TVS Sensing Solutions Private Limited, Madurai 625122, India
[b] Department of Mechanical Engineering, Kalasalingam Academy of Research and Education, Krishnankoil 626128, India
[c] Department of Industrial Engineering, College of Engineering Guindy, Anna University, Chennai 600025, India

ARTICLE INFO

ABSTRACT

The pandemic of Covid-19, an epidemic outbreak created many challenges and increased the demand for medical equipments, medicines, and related accessories and most of them had to be imported from abroad. The advanced information technology (Industry 4.0) was considered imperative to track and monitor the spread of the SARS-2 Virus that is Covid-19. A detailed review of literature is done to understand the challenges and the remedial action taken so far during the Covid-19 epidemic outbreak had been gone through using appropriate search engines and databases like Google-search, Science Direct, Scopus, Research Gate, and relevant blogs. The case reports were also considered in this study. We have found ten significant challenges (barriers) and identified several useful technology of industry 4.0 to control and manage the Covid-19 pandemic. This research paper is an attempt to examine and discuss the application of 4.0 technologies in containing the pandemic outbreak. Ten challenges were identified and those could be overcome by promptly applying appropriate technologies of industry 4.0 to control the spread of virus. These technologies help to educate and communicate the public and make them aware of the hazardous attack of Covid-19 virus when properly used.

© 2022 Elsevier Ltd. All rights reserved.

Selection and peer-review under responsibility of the scientific committee of the International Conference on Advanced Materials and Modern Manufacturing

1. Introduction

Covid-19 is caused by SARS-Cov-2 Virus and intensively affects the respiratory system of human being with multiple damages to the lungs. If we move, virus will move. When the veracity of the virus grows up, other important systems of a body are largely affected beyond recovery. This disease is called in medical term as Acute Respiratory Syndrome (ARS). Covid'19 was reported as a global health crisis and became as a major health hazards and challenge to health sector as well as to the medical industry. This necessitated new technologies to control and prevent the pandemic spread of Covid'19. Many scientists and Researchers are involved in the task of manufacturing devices and kits to control disease spread, to improve monitoring system, to invent vaccine etc. Acute respiratory syndrome became a tremendous chaos around the world affecting people's lives and causing a large number of deaths [1]. The very first infected case was detected in Wuhan, China in December'19 and now it has been spread to almost every country. World Health Organization(WHO) declared the outbreak of Covid-19 as Public Health Emergency of International Concern(PHEIC) on January 30, 2020 and announced it as pandemic on March 11.2020 [2]. It predominantly affected every country without sparing a single country and the countries were pushed to a precarious situation and became helpless. It could affect any person who comes in proximity to any COVID'19 positive individuals, to which even healthy persons are not spared. The efforts to cure the disease are being taken relentlessly; sometimes this too became futile due to non availability of suitable and appropriate medicines. Still the medical world is testing with various types of medical therapies and could not find a suitable medicine to cure the ARS. Prevention is better than cure; therefore, prevention measures are given top priority at present and are on anvil. Greater efforts are towed up by a number of scientific laboratories around the world to invent a vaccine for prevention of this pandemic. The global initiation by proposing in the form of policies and measures to contain the pandemic are still on the way. The mortality rate in India is greater than that of any other Asian

* Corresponding author.
E-mail address: paranikp4@gmail.com (K.P. Paranitharan).

Countries. For example, the mortality rate of Pakistan is 43 per million, Srilanka is 8 per million and India is 145 per million. Comparing to the world mortality rate, India stands less than the global mortality rate [3]. The reason behind the high rate of spread may be that the researches belong to Biotechnology, Biomedical, Biochemistry, immunology and Virology was not given much importance by Indian Government. Meanwhile, few of the European and Asian countries are in the doldrums of second or the third wave. Science and technology have a significant and major contribution to bring down the pandemic to considerable level and in due course it could be completely break down the chain. The countries strictly followed the preventive rules were less affected.

World Health Organization (WHO) took a lot of efforts to educate people of their responsibility to coordinate with governments in the prevention effort on this line of activities, lockdowns were announced and people were advised about keeping social distancing, washing hands often with soap or sanitizer and importantly to wear mask [4]. Many novel inventions of Science and technology have done enormous contribution in this pandemic such as robots were involved to serve patients in the Covid-19 clinics. Drones were and still are used for sanitizing the public places including the areas prone to Covid-19 spread. Virtual classrooms were setup to provide to teach lessons on line for students of all kinds. The latest Information Technology facilitated the business people to conduct business through 'online' meetings and conferences using popular information Apps. These latest technological applications are considered as a boon to business at this lock out times. The Covid-19 pandemic has destroyed the, world economy to unexpected and unimaginable low level and dipped to a larger extent beyond recovery and has seen a downturn of economic development all over the world. However, it was prevented from further loss and kept continue to some extent possibly through the Virtual technological developments. Thus, in this worldwide health crisis, the medical industry is looking for new technologies to monitor and control the spread of COVID'19 pandemic. Due to the recent massive growth in the Industry 4.0 technologies, it provides immense opportunity for sustainable manufacturing of health care product to fight against the COVID'19.

Industry 4.0 is commonly known as Fourth Industrial Revolution featured by innovative technologies and greater involvement of digital technologies which primarily aims to establish a digitized smart industry. These technologies, has been widely applied in numerous ways in our day to day life. This clinical manifestation has created huge demand for world healthcare equipment's and help from digital technologies to contain its spread [5]. Thus, the numerous technologies embedded with Industry4.0 can be very much helpful in diagnosis of COVID'19. Moreover, with the aid of these technologies all the polices and preventative measures taken by countries throughout the world such as Lock – down, maintaining Social distance and quarantine to control the spread of the Virus can be monitored managed and could be overcome to a greater extent. The unprecedented situation caused by the attack of COVID'19 and the recent development of the virus necessitated applications of industry 4.0.

The tremendous increase in the use of industry 4.0 technologies has a greater impact in healthcare and medical field. Industry 4.0 technologies consist of wireless technology and wearable sensors, Artificial Intelligence, Big Data,3D Image / Scanning,3D Printing, Wireless Communication4G/5G Technologies, Tele –Robot, Wearable Technology,Cloud computing, IOT [6,7].

Hence, significant role of Industry 4.0 technology in the battle against COVID'19 are multi directional and multi usable. Few of the benefits of Industry 4.0 in are as follows:

- Disease forecasting
- Social control
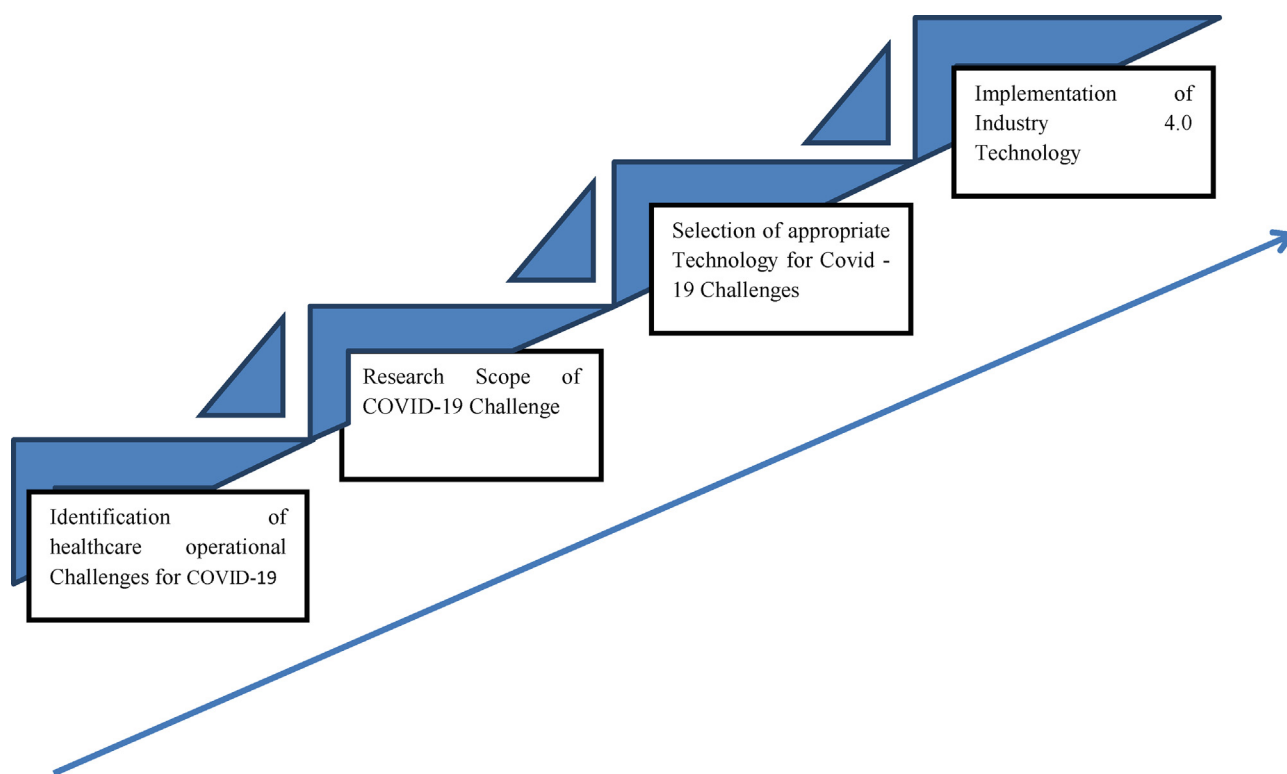- Disease Diagnosis & treatment
- Patient tracking
- Disease Control

Fig. 1. Proposed road Map for implementation of Industry 4.0 technology for COVID-19 Challenge.

This research paper includes few following important objectives.

i) To present a comprehensive survey of various Industry 4.0 technologies in healthcare those are useful to reduce and handle the impacts of the COVID'19 outbreaks.
ii) To identify the healthcare challenges on managing COVID'19crisis especially in the Indian context.
iii) To proposed the significant benefits of Industry4.0 technologies to combat against the COVID'19 pandemic.

2. Literature review

Today technology in healthcare offers a greater promise for enhancing quality of care and improved access to the user. The unexpected and the sudden outbreak of pandemic have been threatening the human race with dare consequence of leading to a larger mortality. New ways of fighting and managing the disease caused by the unknown deathly virus prompted to look for advanced technology in Industry 4.0 and has high challenges and cost in implementation to manage the pandemic [8]. Though, there are a number of articles published in journals and daily news papers regarding eruption of COVID'19, the possible ways for containing it by application of 4.0 technologies in the containment process seemed to be less. The dearth of availability of literature on application of 4.0 technologies in containing COVID'19 process prompted the researchers to pursue this study. This research study primarily focuses on the use of 4.0 technologies in managing and controlling the disease to ramping up it completely.

2.1. Epidemic outbreak and technology impact

Apart from human lives, the global economy and the business enterprises had to intensively react to the Covid-19 pandemic and are becoming increasingly reliant on technologies to support the people and workforce to mitigate the spread of virus. Bragazzi,[8] pointed out that the first epicentre and initial outbreak in Wuhan, becoming a global pandemic with high mortality rate. The ministry of industry and information technology had inclination to prevent the pandemic with the support of Industry 4.0 technologies and t with various measures. The application of industry 4.0 technology includes, monitoring, tracking and prevention of virus spread using internet of things, big data, cloud computing, artificial intelligence and 5G network for medical treatment to patients in cities and home. The sophisticated 4.0 technologies help individuals by providing with health QR codes in order to collect the data during their presence in public places [9]. India is the second most populated country in the world. The first COVID'19 case in India was reported in the state of Kerala on the 30th January 2020 and by March 16th, 114 confirmed cases were reported in the country and after the steady rise of cases could not be stopped [10]. India has adopted various public health measures to battle against the spread of the disease. The Government of India constituted a number of committees with members picked from across various departments like, ministries of home and health affairs for screening and surveillances on virus spread of patient. The Non-Governmental Service Organizations (NGOs) were also pumped into the service. The passengers from other Countries and across the Nation, the movement of people from State to State, and District to District was also restricted. 4.0 technologies largely helped to identify the travellers from outside and the keep them under 14 days quarantine. Non-contact type IR Thermometers are under use [11]. Non-contact automatic sanitizer's sprayers have been developed with IOT sensors and are used in public places for frequent hand washes was advised to avoid disinfection

from the infected areas [12]. The ZOOM app, Google meet, Skype and etc were used to monitor, and track the pandemic spread in order to contain the spread using the patients' data already stored. The above apps are more helpful in analysing the information and to share the resources for consultation in different state in India during epidemic situation. The 'Cloud Computing' helped to analyse the information already shared [7]. Inter communication was possible with API (developed by Apple & Google) based on IOS and Android phone via Blue tooth largely helped to collect the individual health data to assess the pandemic spread. Due to growing concerns about the privacy infringements of personal data by Apps of this kind, the privacy-preserving proximity tracing app has been designed. For example, the Apps like Arogya Setu and Sahyog were developed by Indian government for preventive measures and consultation about the spread of COVID19 Virus which help the healthcare researchers [13] and also help to identify the data points of diseases spread and real time diseases surveillance of individuals and to identify the early sign of disease cluster in epidemic and predict the forecast of spread to become pandemic.

2.2. Technology impact and pandemic

The infectious disease caused by severe acute respiratory syndrome called COVID'19 was spread at faster rate and it is declared as pandemic by WHO on 11 march 2019. As of 05 July 2020 in India more than 648,300 positive cases have been reported and declared as pandemic. India faced severe threat due to COVID'19 outbreak and thought that it would lead to severe consequences due to large population. Many countries experienced the surging in demand for the essential healthcare equipments, medicines and longing for new technologies to stop the spread. Ko, [14] explored the role of China using a powerful technological armoury to combat the deadly pandemic and the government facilitate mass surveillance outlast in pandemic to save the lives. The digital technology which had already been leveraged by China helped to accelerate, and optimize health care service even before the outbreak. Similarly, digital health technology has been deployed to address the most urgent needs during the pandemic to track the immediate outbreak response and later mitigate the impact [15]. Today several affected countries severely and truly followed Chinese model for the best use of technology to fight against COVID'19 pandemic to save their population. The positioning technologies are used to pin point the risky area for rehabilitation efforts. BeiDou-enabled drones, image satellite and robots are used to transport medicine and locate the site for hospital construction [16]. TFSTAR and ADA-Space are powerful processing analytics that create health visualization of people and geographical reach of virus and find the distance between them and active infection. The countries like USA, Singapore, Poland, Israel and South Korea mostly use smart phone tracking for collecting data about the location and clusters of spread. Ghosh, [17]discussed the management of diabetic and other chronic patients in India using Telemedicine during restricted mobility during COVID-19 lockdown and it helped to analyse more data in quicker time at convenient place without spread of virus. The three dimensional printing technology is highly supported to manufacture the mask, gloves and ventilators in lesser time during pandemic in India [10,18–20] have highlighted the use of network based drones useful for thermal imaging, sanitization, record-keeping processes and patient identification in the north central region of India during indoor and outdoor healthcare operations. The industry 4.0 digitalized technologies support to combat the spread using internet of things to tracing the origin of outbreak and provide relief to medical staff during home monitoring of inpatients, Big data are used to forecast the veracity of spread of COVID'19 virus among people and was very helpful in decision making to fight against corona [13,21].

The application of technology namely cloud computing, virtual reality and artificial intelligence were used to predict the spread of virus infection and eliminate face to face interaction, upgrade the working in a group, reduce the travel costs, improves efficiency, reduce the absenteeism and lower the impact of the environment [7]. The use of smart manufacturing in industry 4.0 helped manufacture medical disposables and equipment during COVID'19 pandemic which the patient benefitted on time [22]. Industry 4.0 factories have machines with wireless compatibility and sensors. The biosensors are used in clinical analysis and diagnosis of the disease in the present time of pandemic COVID'19. The Industry 4.0 technologies are more sensitive, easy to employ, cost-saving and can provide high accuracy for monitoring and early detection of COVID-19 virus symptoms. The technologies of Industry 4.0 with multiple source and digital solution are helpful to share relevant information during the emerging of COVID-19 pandemic [7].

2.3. Ramification of COVID'19 and its significance

The COVID'19 virus ramifies into various types by adapting changes to its basic form. Scientists put hard efforts to identify exactly the ever changing virus in order to develop suitable vaccination and medicines to cure the affected persons. So far, the virus has mutated 22 times. "Survival to the fittest" and "Struggle to Live" is seemed to be the character of the virus. The daily news paper 'The Hindu" dated 22.12.2020 & 24.12.2020 by Genomics UK Consortium reported that a new variant VUI-202012/01 of the SARS-Cov-2 Virus (COVID'19) with multiple spike protein mutations have been observed in the UK on the 21st September 2020 [24,25]. This is the 23rd mutation in all. Preliminary modelling results suggest that the variant is significantly more transmissible than previously circulating variants, with an estimated increase in reproductive number (R) by 0.4 or greater with an estimated increased transmissibility of up to 70%. The new strain of the virus is known to have 13 mutations in the spike protein of which N501Y mutation is responsible for spreading 70% faster than the earlier variant of virus. The cases of new strain of SARS-Cov-2 linked to South Africa. The emergence of the new variant underlines the compulsion to undertake surveillance following vaccination to track vaccine effectiveness and to look for the appearance

of vaccine-escape mutants. The compatibility and feasibility to combat the newly mutated virus by the newly developed vaccinations have to be examined using the industry 4.0 technologies. With regard to the above two newly found variants, a question has to be raised. Whether, the already developed vaccines would be enough for those two newly found viruses. Few scientists say that the already developed vaccine would act. Some of scientists say that by making minor tweaking in the development then could be used. However, there are four proven ways of containment or prevention of the virus. The first step is the immunization programme (immunizing with vaccination), the second step is to increase medical facilities in nook and corner of the country to provide best care to the virus affected patients. The third and fourth steps are the non-pharmaceutical intervention which is considered to be the main for prevention of virus, that are; creating awareness about the virus and ways of prevention without going for medical therapy, and clamping lock down in the country. Besides the above, the world economy was vandalized by the pandemic and the global efforts to revitalize the economy still faces many challenges since the pandemic is yet to be cleared off. These situations underline the importance of industry 4.0 technologies in the prevention efforts of Covid'19 virus.

3. Challenges affecting the Industry 4.0 technology during Covid-19 outbreak

The experience of COVID'19 across the world financial and business system will survive the pandemic and it will take long term to emerge from the current major economic downturn [26]. During the crisis, larger efforts were taken to use technologies in various sectors like healthcare, education, manufacturing and other service sectors. Among which, the healthcare technology management was considered to be the highly essential one to monitor, track and diagnosis COVID'19 spread during epidemic. Few of the health care operations have been listed in Table.1. The literature related to application of industry 4.0 technologies in preventing the pandemic outbreak of Covid-19 is very limited. This research paper may add one more in the literature part since, no earlier studies were found regarding the challenges faced in the Covid-19 prevention process along with the components related to challenges and the corresponding technologies to meet out the challenges. There

Table 1
List of Challenges and its components reported during Epidemic and Pandemic.

Sl. No	Challenges	Components
1	Lack of flexibility (C1)	Delay in health care delivery, Increased throughput time, slow response of disease test result
2	Lack of social control (C2)	Poor knowledge on self-hygiene among people, Poor adherence to SOPs issued by government, Misleading information by social media, guidelines of disease spread, co-ordination and intervention, Country's Population, Cultural sensitivity and tradition.
3	Lack of disease forecasting & Surveillance (C3)	Health data points, government policy, Poor transparency in documenting and sharing the pandemic data to alert public about the consequence and rate of increase about spread, Number of emergency department visit, Daily Admission and Attendance. Infectious disease, Country of disease origin, Testing for the disease, Contact tracing & Notified disease
4	Lack of government support (C4)	Incentives (to frontline workers and clinical staff and doctors), cost-sharing treaty, monetary support to public, economical status.
5	Lack of communication (C5)	Miscommunication between central, state governments and local bodies, Information exchange between organization and government bodies, Guidelines for infection spread, Creating awareness to common people about the disease.
6	Lack of Disease Diagnosis & treatment (C6)	Clinical symptoms, complexity & education on disease management, Preparedness to face pandemic situation by the world.
7	Lack of supply chain (C7)	Reduction in supply, increase in demand, discovery of drugs & delay in supply, on time delivery of products and medicine
8	Lack of infrastructure (C8)	Testing centres, Non-flexible storage, capacity constraints of beds and medical equipment, preventing fatality due to disease, (Inadequate training to Health experts/professionals on how to deal with pandemic situation and taking precautionary measures)
9	Shortage of man power (C9)	Doctors and medical worker shortage, giving treatment at appropriate time, preventing death due to disease (and other comorbidities)
10	Patient tracking (C10)	Ethical & privacy concern, safety, Avoid Spread of Disease, Population group (Age),. Inadequate data on geriatric persons and persons with disabilities and & Location.

are 10 challenges listed in this article in healthcare operation during COVID-19 pandemic especially in Indian context. Apart from various challenges reported worldwide in Covid-19 preventive operations, the lack of expertise, education level among the workforce and cultural practice of people are considered to be important.

3.1. Industry 4.0 technology & its application in healthcare

Industry 4.0 technologies have high proficiency in offering better digital health solution for day to today lives during the crisis [27,28]. Few important advantages of Industry 4.0 technology in mitigating the effect of COVID-19 pandemic have been presented here under:

- Managing the COVID −19 related activities.
- Preventing risk and providing better experience among the health workers.
- Manufacturing of personnel protective equipment frontline health workers.
- Supply chain distribution to match the demand and supply during the crisis.
- Robots are involved in treating infected patients without risk
- Virtual reality and cloud computing are used to train the doctors, nurses and other healthcare operators in managing the COVID.
- Risk assessments of public emergency on virus are evaluated to reduce mortality.
- Several innovations are developed on healthcare and related practices in application with digital technology solution.
- Social distancing is maintained between people in public places using wireless technology and drones.
- Covid-19 Patient tracking are established using mobile applications and drones scanners.

Furthermore, Vasanth & Josephine [29] in the daily newspaper "The Hindu" dated 25.12.2020 reported the statement given by the Directorate of Public Health and Preventive Medicine, Government of Tamil Nadu. It was experienced by the Health Department that the Covid-19 has given plenty of knowledge in handling any pandemic and helped the State Government to improve the health infrastructure in the areas of setting up clinics inclusive for treatment of Corona patients, and multi-tasked trained manpower. Sero surveillance was conducted in 888 Covid-19 (Corona) clusters so far in the State of Tamil Nadu and the results are being analysed with the help of industry 4.0 technologies and is going to be published soon. Further, the State has planned to set up 2000 mini clinics and the locations have been identified using the above technologies. The above technologies helped the State government to identify 5 lakh workers to train and implied in the vaccination programme. Identification of individuals who are to be given priority in vaccination programme is also done through the above technologies. The Health department had now identified 21000-odd vaccinators and 46,000 points for vaccination in the first phase of the programme. All the apparatuses used to diagnose the attack of Covid-19 are very much based on the industry 4.0 technologies. All the Covid-19 preventive activities of the State and the Central Governments are also very much based on the industry4.0 technologies.

3.2. Proposed challenges of COVID 19 & scope of industry 4.0 technology

The present research work aimed to identify the challenges faced by healthcare operation during Covid-19 crisis under

epidemic and explicitly for the pandemic. In this section, the author has identified few obstacles which have been listed in Table.1. The basic components (C) have been identified and considered as challenges in this study. The proposed list of components, have been matched with the research scope which is discussed along with technologies related to Industry 4.0 shown in Fig. 1).

4. Research scope of Industry 4.0 for COVID 19 challenges

This paper describes the scope of research on Covid-19 challenges which gave been listed in Table.2. Industry 4.0 creates advanced manufacturing facilities and information technology to fulfil the customer requirement of different areas of human beings in lesser time [7]. Industry 4.0 is a smart system supported by wireless connectivity, sensors, IOT, AI, CC, CPSs and other digital technologies by enhancing the automation for flexible production lines with own decision making [7,16,30]. Industry 4.0 are helpful and well connected to other sectors like manufacturing, healthcare service, agriculture, food and transportation. This interconnectivity helps accrue mutual benefits of the connected sectors. This paper presents the details of Industry 4.0 technology in meeting Covid-19 pandemic.

It is imperative and paramount responsibility of Central and the State governments to provide information about the recent developments and changes occurred in the Covid'19 virus to health care providers and to the society at large. In this study Lack of flexibility (C1) as an important challenge in healthcare and improving flexibility in healthcare consumes usually a lot of efforts due to increase in lead time and delay in test report and uncertain environment. Healthcare flexibility in terms of operational challenges seems to be limited during pandemic. Application of Industry 4.0 technology namely Big data and Cloud computing are integrated to deal with uncertain situation to achieve higher flexibility [16]. The Covid'19 pandemic has created a threat to socio dynamics among the vulnerable groups (Aged, young, poverty, foster care, and Incarceration and marginal identities) due to lack of social control (C2) in public health system. Social psychology plays a major role in understanding and analysing the change in socio-dynamics caused by Covid-19. Various components like people containment, co-ordination and intervention, cultural sensitivity and tradition, country population made impact on the social existence. The wireless technology, drones and mobile technology are used to maintain the social control among the people and to have sustainable solution in controlling the current pandemic [23].

The various aspects of disease identification, assessment, and modelling and data analysis are essential components of disease forecasting [44]. The forecasting technique helps in assisting in designing better strategies and productive decision making. The components namely environmental factor, incubation period, age, gender and quarantine, etc., are the essential parameters of disease forecasting (C3). The parameters namely, infectious disease, contact tracing and notified disease and testing help and support the surveillance of disease. Application of IOT, CPSs, Big data, machine learning and mathematical modelling help to forecast accurately the mortality and spread rate and the time horizon. The technologies namely, IOT, Mobile Technology, Drones and Wearable Sensor Gadgets are more helpful in monitoring and tracking the disease in fast and accurately [13,16].

Lack of government initiatives (C4) for providing incentives to health staff, cost sharing among the notified private hospitals to manage the present pandemic. Monetary supports to economical deprived people are identified through digital technology.The development of IOT and Block chain enabled integrated framework helps the government to distribute financial assistance to people and incentives to healthcare workers [45]. The techniques of Indus-

Table 2
Challenges faced in the medical field during the pandemic outbreak and the technologies to overcome the challenges.

S. No	Technology	Description of Technology	How it Helpful
1	IOT & AI	• IOT is an automated sensor based technology with the components for data collection, storage and processing of data. Moreover, by using the AI algorithms the data are analysed and patterns are studied to arrive at an inference.	• IOT integrated to physical devices to track the health status [16].Developed an IOT based system (nCapp) diagnose Covid'19 earlier [31]. Smart helmet-mounted thermal imaging system identifying infected among the crowd [11].
2	5G/4G Wireless Technology, Robots & Drones	• Telecommunication network has been used widely in our daily lives in numerous ways with vast number successful stories. Throughout the world the number of people benefited by the telecommunication and mobile technology enabled with internet is tremendously increasing. Telecommunication technology based applications are providing versatile services in various domains such as health care, education and disaster management. Now, telecommunication technology has contributing vast services to humankind in facing and dealing with COVID'19 pandemic.	• Drone based COVID-19 health and respiratory platform is used in Australia for monitoring the detection of infectious and health conditions like monitoring temperatures, heart and respiratory rates [32]. Indian Robotic Solution used to collect and share the data's using secure tunnel with hospital and government [20]. Drones are used to alarming the people if the inter-personnel distance become less and without mask [33].
3	Artificial Intelligence, Machine learning, Deep learning	• AI techniques are widely used in numerous applications in our day to day life. Artificial Intelligence (AI) is defined as booming and successful technology with wider applications such as Industry automation, cyber security, Tele –medicine, Disease diagnosis and treatment. Artificial Intelligence (AI) holds two major approaches namely Machine Learning (ML) and Deep Learning (DL). Thus AI along with Machine Learning (ML) and Deep Learning (DL) in general defined to be the process to training and learning the extract pattern from the available data.	• AI plays a vital and powerful tool to in the battle against fight of COVID- 19 pandemic in the domain of medical image data processing, data mining, and text mining data analytics in the direction to address the difficulties such as disease diagnosis, prevent spread of virus and treatment [7,34].
4	Big Data	• Big data is a digital technology to store massive amount of data, it includes technology to process those stored data and infer a decision on the processed data.	• The AI with big data is considered as powerful and versatile tool to handle the current global deadly health issue [35,36].
5	Wearable Sensor & Telemedicine	• Wearable device play a predominant role in detecting the disease infected person by considering the clinical symptoms, to enhance the remote testing and to prevent the spread of the disease.	• Wearable sensors and devices are used in health care system with an objective for periodic monitoring of the patient to keep in track of the health condition of the person and for the remote diagnosis of COVID −19 and other pandemic disease [23]. Thus, Wearable sensors devices go hands along with Tele –medicine technology to cope various health issue and concern raised by pandemic condition. Moreover, many M−Health app are developed with an objective for remote patient monitoring and diagnosis of infective patient, monitoring the quarantine people to prevent the spread of disease, monitoring the patient after discharge [37].
6	Block Chain & Cloud Computing	• Blockchain and IOT technologies are integrated for providing data security, speed and Qos in health data point.	• The integration of Block chain technology with IOT, Cloud computing helps in fast decision making to process large data when drone device of scarcity of resource is limited [38]. Digital application like ZOOM video, Microsoft Azure and google cloud are helpful in fight against COVID-19 pandemic at the time of social isolation [7].
7	Virtual Reality	• Virtual reality is a digital technology that provides a simulated experience those benefits of great comfort, creativity and productivity.	• Virtual reality technology offer a great option of video calls for communicating and collaboration. It reduces travel cost, absents and lowers the impact of environment in the time of Covid-19 disease [39].
8	3D Printing & Scanning	• 3D printing and scanning is used to convert CAD digital data to physical part and vice versa. 3D printing is used to manufacture the physical product at faster rate. 3D scanning output is used to analysis of real world object for collecting about its shape and appearance.	• 3D scanning is a non-contact technique which helps the thoracic chest scanning for Covid-19 virus [19]. The integration of 3D Scanning and virtual reality is a used full tool offer higher efficiency during pandemic [40].
9	Biosensor	• Biosensor is a device used to convert biological signals to electrical signals. This technology of biosensor is entirely new to market and it is effectively used in an environment of multi-patient hospital when it connected to wireless device.	• Biosensor IOT enabled patches are used to monitor temperature, ECG trace, respiration rate in real time environment of Covid-19 pandemic [41]. Glucose monitors biosensor which used for clinical diagnosis and disease treatment of diabetics during Covid-19 crisis [42].
10	Holography	• Holography is 3D device to view with changing perspective. it helps to reconstruct the object accurately with original object using hologram.	• The digital technology of holography helps in reducing the exposure of COVID-19 to the peoples. This technology is become rapidly acceptable in COVID-19 outbreak [43].

try associated with internet of things [16,46] provide an excellent commitment to meet the communication related issues (C5). The diagnosis of disease and treatment (C6) is one of the challenges and its components are; clinical symptoms, complexity, education on disease and pandemic preparedness is found challenging in managing Covid-19. The technology like 3D scanner, robots, telemedicine and video conferencing has capability to reduce the work load of doctors and hospital manager during the crisis [47]. The industry 4.0 technologies help to improve working efficiency of a healthcare professional and provide better solution [41,48-53]. The industry 4.0 technologies like block chain technology, IOT and drones are suggested to trace and transport the essential supplies and relocating the inventory in a supply chain (C7) to infected area during the epidemic outbreak.

The lack of infrastructure (C8), results non flexible storage, capacity constraints of bed, medical equipment, advanced medical devices. The lack of such infrastructure found to be biggest challenge in managing the pandemic. Utilisation of cloud computing and AI solution Infrastructure for the storage and analytics of such huge data for further processing needs to be developed in an efficient and cost-effective manner [54]. Image satellite and BeiDou-enabled drones are used to locate the geographical position for quick construction of hospitals. The shortage of manpower (C9) is a one of the main challenge which includes lack of health experts, questionable job security, and shortage of knowledgeable and devoted medical workers. The training and education on pandemic crisis could be imparted using cloud based system to combat effectively the epidemic and the pandemic situation.

The challenge, Patient tracking (C10) by healthcare providers to track and monitor the patient during quarantine and further spread of virus infection to other areas or the clusters [55]. Remote patient monitoring system helps facing challenges in locating the Covid-19 affected patients in remote areas. Several challenges like ethical and privacy, safety by avoiding spread of disease, higher cost of device, and different population groups have to be given importance. The patient fitted with smart technology Bluetooth, WBANs, GPRS, Drones, wearable sensors & RFID technologies successfully meet the requirement and create paradigm shift in traditional healthcare delivery [56,57].

5. Conclusion

Industry 4.0 technologies offer automated solution to traditional manufacturing company and other related practice. The digital information technology help to collect, transfer, store, analyse and information system in manufacturing practice. The identical application of digital technology is an innovative method to healthcare operation especially in the event of preventing Covid-19 pandemic. This study is an unique one in the following aspects; 10 important and the practical challenges in the prevention process of Covid'19 have been identified along with the related components to each challenge with suitable industry 4.0 technologies. This technology of Industry 4.0 helps to isolate the Covid-19 infected patients to reduce the high risk of death, speed up the discovery of drug manufacturing, timely treatment and care to patient. This smart technology of industry 4.0 has capability of operating remotely, discovering new culture, work from home, video conferencing consulting, telemedicine which are helpful to track, record the patient health points during Covid-19 outbreak. In addition, it helps to maintain patient care, social control, and safety and transport management for public to prevent the spread of virus.

CRediT authorship contribution statement

K.P. Paranitharan: Conceptualization, Methodology, Writing – original draft. **G. Ebenezer:** Data curation. **V. Balaji:** Visualization, Investigation, Validation. **M. Adham khan:** Writing – review & editing. **T. Ramesh Babu:** Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] E. Callaway, Time to use the p-word? Coronavirus enter dangerous new phase, Nature 579 (2020) 12.
[2] WHO. Novel coronavirus (2019-nCov). Retrieved April 15, 2020, from, https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200211-sitrep-22-ncov.pdf?sfvrsn¼fb6d49b1_2; 2020.
[3] M.M. Reddy, S.S. Kar, Unconditional probability of dying and age-specific mortality rate because of major non-communicable diseases in India: Time trends from 2001 to 2013, J. Postgrad. Med. 65 (1) (2019) 11.
[4] R.K.R. Kummitha, Smart technologies for fighting pandemics: The techno-and human-driven approaches in controlling the virus transmission, Govern. Info. Quarter. 37 (3) (2020) 101481.
[5] G. Gopal, C. Suter-Crazzolara, L. Toldo, W. Eberhardt, Digital transformation in healthcare–architectures of present and future information technologies, Clin. Chem. Lab. Med. (CCLM) 57 (3) (2019) 328–335.
[6] G. Aceto, V. Persico, A. Pescapé, The role of information and communication technologies in healthcare: taxonomies, perspectives, and challenges, J. Network Comput. Appl. 107 (2018) 125–154.
[7] M. Javaid, A. Haleem, R. Vaishya, S. Bahl, R. Suman, A. Vaish, Industry 4.0 technologies and their applications in fighting COVID-19 pandemic, Diabetes Metab. Syndr.: Clin. Res. Rev. 14 (2020) 419–422.
[8] N.L. Bragazzi, Digital technologies-enabled smart manufacturing and industry 4.0 in the post-COVID-19 era: lessons learnt from a pandemic, Int. J. Environ. Res. Public Health 17 (2020) 4785.
[9] Chaturvedi, (2020). "The China way: use of technology to combat COVID19", April, 2020, Available: https://www.geospatialworld.net/article.
[10] T. Lancet, India under COVID-19 lockdown, Lancet (London, England) 395 (10233) (2020) 1315.
[11] Mohammed, M.N., S.F. Desyansah, E. Yusuf, in: An Internet of Things-Based Smart Homes and Healthcare Monitoring and Management System: Review, vol. 1450, 2020, pp. 1–15, https://doi.org/10.1088/1742-6596/1450/1/012079.
[12] J. Lee, J.Y. Lee, S.M. Cho, K.C. Yoon, Y.J. Kim, K.G. Kim, Design of automatic hand sanitizer system compatible with various containers, Healthcare Informatics Res. 26 (3) (2020) 243–247.
[13] Chettri, S., Debnath, D., & Devi, P. (2020). Leveraging digital tools and technologies to alleviate COVID-19 pandemic. Available at SSRN 3626092.
[14] Ko, J., 2020. How China used technology to combat COVID-19 – and tighten its grip on citizens. Available at: https://www.amnesty.org/en/latest/news/2020/04/how-ch ina-used-technology-to-combat-covid-19-and-tighten-its-grip-on-citizens/. (Accessed 29 August 2020).
[15] D.G. Costa, J.P.J. Peixoto, COVID-19 pandemic: a review of smart cities initiatives to face new outbreaks, IET Smart Cities 2 (2) (2020) 64–73.
[16] Kumar, A., Gupta, P. K., & Srivastava, A. (2020). A review of modern technologies for tackling COVID-19 pandemic. Diabetes & Metabolic Syndrome: Clinical Research & Reviews. Volume 14, Issue 4, July–August 2020, Pages 569-573.
[17] Ghosh, A., Arora, B., Gupta, R., Anoop, S., & Misra, A. (2020). Effects of nationwide lockdown during COVID-19 epidemic on lifestyle and other medical issues of patients with type 2 diabetes in north India. Diabetes & Metabolic Syndrome: Clinical Research & Reviews. Volume 14, Issue 5, September–October 2020, Pages 917-920.
[18] K. Iyengar, S. Bahl, R. Vaishya, A. Vaish, Challenges and solutions in meeting up the urgent requirement of ventilators for COVID-19 patients, Diabetes Metab. Syndr. Clin. Res. Rev. 14 (2020) 499–501.
[19] Y.Y.C. Choong, H.W. Tan, D.C. Patel, W.T.N. Choong, C.H. Chen, H.Y. Low, C.K. Chua, The global rise of 3D printing during the COVID-19 pandemic, Nat. Rev. Mater. 5 (9) (2020) 637–639.
[20] A. Kumar, K. Sharma, H. Singh, S.G. Naugriya, S.S. Gill, R. Buyya, A drone-based networked system and methods for combating coronavirus disease (COVID-19) pandemic, Future Generation Comput. Syst. 115 (2021) 1–19.
[21] S. Magesh, V.R. Niveditha, P.S. Rajakumar, L. Natrayan, Pervasive computing in the context of COVID-19 prediction with AI-based algorithms, Int. J. Pervasive Comput. Commun. 16 (5) (2020) 477–487.

[22] J. Zeng, J. Huang, L. Pan, How to balance acute myocardial infarction and COVID- 19: the protocols from Sichuan Provincial People's Hospital, Intensive Care Med. 11 (2020 Mar) 1–3.

[23] G. Manogaran, C. Thota, D. Lopez, R. Sundarasekar, Big data security intelligence for healthcare industry 4.0. Cyber security for Industry, 4.0, Springer, Cham, 2017, pp. 103–126.

[24] Genomics UK Consortium.(2020, Dec 22). SARS-Cov-2 Virus (COVID'19) Updates. The Hindu Newspaper,pp.6.

[25] Genomics UK Consortium.(2020, Dec 24). SARS-Cov-2 Virus (COVID'19) Updates. The Hindu Newspaper,pp.11.

[26] D.R. Singer, Health policy and technology challenges in responding to the COVID-19 pandemic, Health Policy Technol. 9 (2) (2020) 123–125.

[27] Cheng GJ, Liu LT, Qiang XJ, Liu Y. Industry 4.0 development and application of intelligent manufacturing. In2016 international conference on information system and artificial intelligence (ISAI) 2016 Jun 24 (pp. 407–410). IEEE.

[28] G. Grasselli, A. Pesenti, M. Cecconi, Critical care utilization for the COVID-19 outbreak in Lombardy, Italy: early experience and forecast during an emergency response, Jama 323 (16) (2020) 1545–1546.

[29] Vasanth.P & Josephine.S. (2020, DEC 25).TamilNadus covid'19 journey 700000 and counting. The Hindu Newspaper,pp.9.

[30] Devi K, S., Paranitharan, K. P., & Agniveesh A, I. (2020). Interpretive framework by analysing the enablers for implementation of Industry 4.0: an ISM approach. Total Quality Management & Business Excellence, 1-21.

[31] Q. Li, W. Feng, Y.H. Quan, Trend and forecasting of the COVID-19 outbreak in China, J. Infect. 80 (4) (2020 Apr 1) 469–496.

[32] Draganfly selected to globally integrate breakthrough health diagnosis technology immediately onto autonomous camera's and specialized drones to combat coronavirus (covid19) and future health emergencies. [Online]. Available: https://apnews.com/Globe%20Newswire/dc01344350423d7d64c99ebbe8fb7548.

[33] Drone technology: A new ally in the fight against COVID-19. https://www.mdlinx.com/internal-medicine/article/6767 (Accessed 15 April 2020).

[34] S.F. Ardabili, M. Amir, P. Ghamisi, F. Ferdianand, A. Varkonyi-Koczy, R.U. Reuter, R. Timon, P.M. Atkinson, Covid-19 outbreak prediction with machine learning, MedRxiv, Preprint Server Health Sci. (2020), https://doi.org/10.1101/2020.04.17.20070094.

[35] Y. Lu, Industry 4.0: A survey on technologies, applications and open research issues, J. Ind. Inf. Integrat. 6 (2017) 1–10.

[36] Lasi Heiner, Fettke Peter, Kemper Hans Georg, Feld Thomas, Hoffmann Michael. Industry 4.0. Bus. Inf. Syst. Eng. 2014;6(4):239-242.

[37] Hassantabar, S., Stefano, N., Ghanakota, V., Ferrari, A., Nicola, G. N., Bruno, R., & Jha, N. K. (2020). Coviddeep: Sars-cov-2/covid-19 test based on wearable medical sensors and efficient neural networks. arXiv preprint arXiv:2007.10497.

[38] S.C. Sethuraman, V. Vijayakumar, S. Walczak, Cyber attacks on healthcare devices using unmanned aerial vehicles, J. Med. Syst. 44 (1) (2020) 29.

[39] G. Czifra, Z. Molnár, Covid-19 and Industry 4.0. Research Papers Faculty of Materials 28 (2020) 36–45.

[40] A.B. Youssef, A. Zeqiri, Hospitality industry 4.0 and climate, Change No (2020) 2020–2023.

[41] Pejcic B, De Marco R, Parkinson G. The role of biosensors in the detection of emerging infectious diseases. Analyst [Internet] 2006;131(10):1079e90. https://doi.org/10.1039/B603402K. Available from:.

[42] N.S. Elbarbary, T.J. Dos Santos, C. de Beaufort, J.C. Agwu, L.E. Calliari, A.E. Scaramuzza, COVID-19 outbreak and pediatric diabetes: perceptions of health care professionals worldwide, Pediatric diabetes 21 (7) (2020) 1083–1092.

[43] Irvine C. New holographic virtual events will reach millions amid coronavirus (COVID-19) crisis [internet]. DVEholographics. Available from: https://www.prnewswire.com/news-releases/new-holographic-virtual-events-will-reachmillions-amid-coronavirus-covid-19-crisis-301025496.html.

[44] N.V. Hardwick, Disease forecasting, in: The epidemiology of plant diseases, Springer, Dordrecht, 1998, pp. 207–230.

[45] A. Panarello, N. Tapas, G. Merlino, F. Longo, A. Puliafito, Blockchain and iot integration: a systematic survey, Sensors 18 (8) (2018) 2575.

[46] Q. Ruan, K. Yang, W. Wang, L. Jiang, J. Song, (2020) Clinical predictors of mortality due to COVID-19 based on an analysis of data of 150 patients from Wuhan, China, Intensive Care Med. 3 (2020 Mar) 1–3.

[47] Haleem A, Javaid M, Vaishya R,. (2019). Industry 4.0 and its applications in orthopaedics.J Clin Orthop Trauma 2019;10(3):615-616.

[48] T.B. Moeslund, E. Granum, A survey of computer vision-based human motion capture, Comput. Vis. Image Understand 81 (3) (2001) 231–268.

[49] M. Wand, B. Adams, M. Ovsjanikov, A. Berner, M. Bokeloh, P. Jenke, et al., Efficient reconstruction of nonrigid shape and motion from real-time 3D scanner data, ACM Trans. Graph. 28 (2) (2009).

[50] C. Sampol, Covid-19: developing high tech protective masks [Internet] Available from: MedicalExpo e-mag. (2020). http://emag.medicalexpo.com/covid-19-development-of-high-tech-protective-masks/.

[51] Kim P, Chen J, Cho YK. SLAM-driven robotic mapping and registration of 3D point clouds. Autom ConStruct 2018;89(May):38e48

[52] Patch for detection and monitoring of COVID-19 symptoms fast tracked [internet]. Med-Tech Innovation/News; 2020. Available from: https://www.med-technews.com/news/patch-for-detection-and- monitoring-of-covid-19-testing-fast-/.

[53] J.L. Ren, A.H. Zhang, X.J. Wang, Traditional Chinese medicine for COVID-19 treatment, Pharmacol. Res. 4 (2020 Mar) 104743.

[54] S. Tuli, S. Tuli, R. Tuli, S.S. Gill, Predicting the Growth and Trend of COVID-19 Pandemic using Machine Learning and Cloud Computing, Internet of Things 100222 (2020).

[55] Uddin, M. I., Shah, S. A. A., & Al-Khasawneh, M.A. (2020). A novel deep convolutional neural network model to monitor people following guidelines to avoid COVID-19. Journal of Sensors,2020.

[56] J.P. Piccini Sr, L.A. Allen, P.J. Kudenchuk, R.L. Page, M.R. Patel, M.P. Turakhia, Wearable cardioverter-defibrillator therapy for the prevention of sudden cardiac death: a science advisory from the American Heart Association, Circulation 133 (17) (2016) 1715–1727.

[57] IEEE, (2020). How COVID-19 is Affecting Industry 4.0 and the Future of Innovation. Avilable :https://transmitter.ieee.org/how-covid-19-is-affecting-industry-4-0-and-the-future-of-innovation/