Digital Response Framework for COVID-19 Pandemic Monitoring and Control in India

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RESEARCH

Digital Response Framework for COVID-19 Pandemic Monitoring and Control in India

Iqbal Hasan^{1*}, SAM Rizvi¹
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Abstract

Background: The COVID-19 pandemic is atypical in scale, perseverance, and geographical progression throughout the world in recent history. It is declared a public calamity in India wherein the Prime Minister's Office is directly associated with every aspect of surveillance, control, and relief measures. This paper aims to present the digital response framework for management, surveillance, and control of the COVID-19 crisis across the country. The paper also presents technological adoption by various states and union territories and analysis of COVID cases in India.

Methods: The Ministry of Home Affairs and its various organizations such as the National Disaster Management Authority, and Ministry of Health and Family Welfare are managing various authoritative and administrative activities, and Ministry of Electronics & Information Technology through National Informatics Centre (NIC) are providing technological solution to manage the COVID-19 pandemic in India. The NIC is playing a crucial role to develop and manage digital solutions for surveillance and control of COVID-19 in India.

Results: On analysis of COVID 19 data of reported confirmed, recovered, and deceased cases across India in various states, it is observed that Maharashtra was most affected followed by Karnataka, Kerala, Delhi and other states.

Conclusion: The technological solutions developed, implemented, managed by NIC making up the digital response framework for monitoring, surveillance, and control of COVID-19 are standard for India and proved to be effective in combating the COVID-19 pandemic and are widely used in central, state, and local governing bodies.

Keywords: Digital Surveillance; Public Health; COVID-19; Corona Virus; Digital Technologies

1 Introduction

The current COVID-19 pandemic has detrimentally impacted the entire world. The first known instance of the COVID-19 disease was reported in Hubei territory in China in November 2019 [1]. Subsequently, a cluster of COVID-19 instances were reported on 31st December 2019 in Wuhan, China, and it was notified to the World Health Organization (WHO) China [1, 2]. Later, on 30th January 2020, India reported its first COVID-19 case [3] which was only a tip of the iceberg. Quickly, the COVID 19 disease spread almost every region in the world, threatening health systems and governments worldwide. Governments all around the world are adopting various measures to limit the spread of the coronavirus and confine the disease within the specific region to prevent further escalation of the number of cases. Different Measures such as social distancing, partial or complete lockdown and the banning of the large gathering area have been followed and continuing to follow in many countries. The overall goal of these initiatives is to isolate the infected individuals to prevent the spread of this highly contagious disease. The biggest challenge is to track and isolate the infected individuals. However, in this digital era, various digital technologies are helping a lot to fight the pandemic by providing means for tracking, isolations, surveillance, control and preventions. Containment of COVID 19 is the first priority by all the governments around the world to tackle the spread of this highly contagious disease. In India the public health and sanitation comes under state and local governments whose responsibility is to formulate legislation for public health. However, in this unprecedented time of COVID 19 pandemic, the union government whose legal responsibility is to manage quarantine and interstate migration, plays important role to fight and contain the corona virus. In the wake of the rising number of cases and death tools the Indian government has taken several precautionary, informative, technological, medical and financial steps to fight against the deadly virus. On March 24, 2020, a complete 21-day lockdown was announced by the prime minister for the entire nation prohibiting the movement of peoples from their houses and issued a comprehensive guideline to contain the COVID 19 pandemic in the country. The government soon initiated dissemination of authentic information about the virus, its spread, control and preventive measures, various guidelines, helpline numbers, registered COVID 19 cases, and death tool, through the Ministry of Health's official website. Moreover, the government has designed various diagnostic and treatment centers, isolation wards,

vaccine development facilities, and financial help and other relief packages for poor and low-income families. The government is widely taking the advantage of digital technologies and deploying new, smart and innovative technological solutions to facilitate various services in response to this global crisis. Government institutions are adopting digital tools to support widespread dissemination of information, track real time disease transmission, create virtual meetings, and provide medical and treatment facilities to patients. Besides COVID 19 related essential function and services, government bodies are also adopting digital tools and technologies to keep the pace of learning, teaching, legal, transport, economic, social, and many other services for public welfare, and are working in coordinative, collaborative, and collective manner to limit the spread and manage the risk of COVID 19, and resume the economic and social activates to its normalcy. However, considering all these things, a digital surveillance and management framework is essential to combat a pandemic, effectively utilize the resources, and priorities various healthcare and management activities. This paper presents a digital response framework for surveillance and control of COVID 19 in India highlighting ways India has adopted and integrated digital technologies for pandemic planning, management, monitoring, surveillance, prevention, and control. The paper presents the adopted and deployed technologies by various government bodies, central ministries, public health departments, state government departments, and district and local bodies for contact tracing, quarantine management, testing, and health care facilities. As a part of the framework, the paper covers the organizational hierarchy combating the pandemic crisis in India in addition to the best technological initiatives by various state and central agencies. We hope it would be worthwhile for governments around the world to fight the highly contagious disease.

2 Related Works

Rapid dissemination of the highly contagious corona virus disease has necessitated the Government and other stakeholders to take various initiatives to contain its spread. Researchers around the world together with academia and industry are working on various tools and techniques to limit its spread or confine into a specific area. The authors in [4] discussed about the role of IoT, Blockchain, 5G in managing its impact, as it placed government around the world in a precarious position and highlights the impact on the global economy to the direct health implications associated with the outbreak of COVID-19. Moreover, authors in [4] explored the use of technologies such as the Internet of Things (IoT), Unmanned Aerial Vehicles (UAVs), blockchain, Artificial Intelligence (AI),

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and 5G, among others, to help mitigate the impact of the COVID-19 outbreak. Pham et al. [5] emphasized the importance of AI and Big Data responding to the COVID-19 outbreak and preventing the severe effects of the pandemic. They [5] presents applications of AI and Big data in fighting against COVID-19 and highlight challenges and issues associated with state-of-the-art solutions, and finally come up with recommendations for the communications to effectively control the COVID-19 situation. Mondal et al. [6] described different aspects of novel coronavirus disease (COVID-19), presented a visualization of the spread of the infection, and discussed the potential applications of data analytics on this viral infection. They [6] have highlighted several factors including COVID-19 origin, its transmission capacity, its symptoms. Researchers have also discussed about Smart health systems such as E-Quarantine [7] for health services workers who deal with Covid-19 patients as it measures patient's temperature, respiratory rate, pulse rate, blood pressure, and time which helps in monitoring corona virus patients of worst cases and saving mild cases at homes [7]. Zhang et al. [8] described a large-scale agent-based model for epidemic prediction in the context of the metropolitan area of Beijing, where a microscopic public transport system is simulated and integrated with the agent-based model. This public transportation component is microscopic as they [8] modelled all lines and stops for both the metro and the bus system in Beijing. Through this component, agents can realistically 'travel' to their destinations and the component will provide accurate travel routes and durations. Mobile applications technology has been leveraged in a number of ways to control the spread of COVID-19, including to support knowledge translation [9]. Mobile applications are accessible, acceptable, easily adopted, and have the ability to support social distancing efforts. Moreover, for infectious disease pandemic planning and response, Web app such as ISIS [10] is designed to support networked epidemiology – the study of epidemic processes over social contact networks. This system can handle airborne infectious diseases such as influenza, pertussis, and smallpox.

Machine learning and cloud computing are also being used to identify the patterns and predict the trends of COVID 19 spread. Tuli et al. [11] discussed an improved mathematical model to analyze and predict the growth of the epidemic. They have applied an ML-based improved model to predict the potential threat of COVID-19 in countries worldwide. It can be deployed on a cloud computing platform for a more accurate and real-time prediction of the growth behavior of the epidemic. Yuan et al. [12] establish a general framework for predicting the so-called critical "Turning Period" in an infectious disease epidemic such

as the COVID-19 outbreak in China. The underlying mathematical model in the framework is the individual Susceptible-Exposed- Infective-Removed (iSEIR) model, which is a set of differential equations. The paper [13] discusses the response of public health to the COVID-19 outbreak in china and for this taken action accordingly which demonstrated the importance of transparency, surveillance, and testing laboratories during an outbreak. Ye et al. [14] developed a technical framework to respond to the COVID-19 epidemic from a health informatics perspective. They [14] collected health-related information to understand the actions taken by the health informatics community in China during the COVID-19 outbreak and developed a health information technology framework for epidemic response based on health information technology-related measures and methods. Wearable smart devices like IoT-Q band [15], and Smart Thermometers [16], drones such as Thermal Imaging Drone [17], Disinfectant Drone [18], and Surveillance Drone [19], automatic and telerobots [20] are developed to limit and confine the spread of disease. Similarly, researchers in [21] developed a graphical smart health system for physicians who can remotely visualize the patient's data. Likewise, smart medical systems for hospitals to monitor patients' health status proposed by many researchers [22, 23]. Most of the earlier works on healthcare wearable are based on fitness tracking [24, 25]. Governments all around the world are taking necessary steps to curb the spreading of the highly contagious COVID-19 disease using various means of digital, smart, and intelligent technologies [26–28]. In the same line Government of India is also taking various initiatives to monitor and control the threat incurred due to the COVID-19 pandemic through effective surveillance.

3 Digital Response Framework

The COVID 19 pandemic is posing a great challenge to the public healthcare systems, transportations, medical and clinical systems, and emergency response managements of the governments' worldwide. The approaches used by the governments to combat the pandemic and respond to the outbreak largely depend on the availability of resources, medical and healthcare facilities, and collective and collaborative efforts of government bodies. Government bodies including central, state, district, and local bodies in their close coordination are playing their key roles to mitigate the impact of pandemic in different sectors by developing, implementing, and deploying new digital systems, tools, and techniques. In India, Prime Minister's office (PMO) is the nodal authority to provide secretarial assistance

to prime ministers to manage and coordinate government and his office. While National Informatics Centre (NIC) is the core organization that provides digital technology solutions, Information and Communication Technology (ICT), and eGovernance support to the governments at various level. Figure 1 presents the layered architecture of the various organizational hierarchy involved in surveillance, control, and management of the pandemic in India. The detailed description of each organization bodies involved to tackle COVID 19 challenges is presented in the following sub sections.

3.1 Government Bodies Combating against COVID 19

The government of India is taking all necessary measures to fight against the COVID 19 pandemic and working together in partnership with World Health Organization (WHO) to effectively contain the COVID 19 in India.

World Health Organization: World Health Organization is a United Nations agency responsible for universal healthcare with an objective to ensure universal health coverage, monitor public health emergencies, coordinates responses during health emergencies, provide better health and well-being, and serve the vulnerable. WHO directs and coordinates international health within the UN system to the member countries, and addresses health issues related to communicable and non-communicable diseases. It sets guidelines and health standards internationally and assists Governments in strengthening the health services and works towards eradicating epidemic, endemic, or pandemic (1). WHO and the Government of India consistently have worked together to eradicate Polio and made India Polio free. With the same might, dedication, and sincerity, WHO is supporting India through valuable guidance and contributions to fight against COVID 19 and contain its spread. WHO with its dedicated team tirelessly working across the country with state governments to strengthen the health systems and proactively involved in COVID 19 response measures including epidemiological data collection, capacity building, contact tracing, hospital preparedness, laboratory diagnosis, community engagements, and control and prevention of infections. WHO India team have trained doctors, nurses, and paramedics to manage COVID 19 at Sardar Patel COVID Care Centre (SPCCC), which is one of the world's largest COVID 19 care center operated by Indo-Tibetan Border Police (ITBP) personnel. Further, WHO is consistently working and guiding state governments and various institutions such as National Institute of Disaster Management (NIDM), Ministry of Home Affairs, Indian Council of Medical Research (ICMR), National Centre for

Disease Informatics and Research (NCDIR), and Indian Society of Clinical Research (ISCR) to formulate strategies and fight against COVID 19.

Prime Minister's Office (PMO): Prime Minister's Office comprises immediate staffs with which the Prime Minister of India directly communicates and various supporting staff at different levels that report and coordinate the Prime Minister. PMO is led by Principal Secretary to provide secretarial assistance and help the Prime Minister to coordinate with various ministries that include cabinet ministers, ministers with independent charges, and the state ministers. PMO office is leading India's fight against the deadly COVID 19 disease and coordinating with various ministries and top organizations including the Ministry of Home Affairs, Ministry of Health and Family Welfare (MoHFW), National Disaster Management Authority (NDMA), Ministry of Electronics and Information Technology (MEITY), and other concerned ministries. The Prime Minister (PM) of India with the help of PMO is continuously interacting with various stakeholders and monitoring India's fight against COVID 19. The PM is regularly reaching out to various State Governors, Chief Ministers, Health Ministers, and other stakeholders such as COVID warriors (e.g. doctors, nurses, health workers, and sanitation staff), Pharma Sectors, and AYUSH Practitioners through telephonically, video conferencing, or virtual meetings to get feedback and suggestions, and encourage their efforts to fight against the menace of highly contagious COVID 19. PMO through various meetings review the preparedness and response on this pandemic crisis and takes important decisions in partnership with state governments to implement rapid testing, isolation, and quarantine facilities at all parts of the country. Moreover, to create awareness and disseminate information's including advisories PMO office guides Ministry of Information and Broadcasting to collaborate and work in cooperation with Ministry of Health, Ministry of Human Resource Development (MHRD), and NDMA. The PMO office is also taking care of other activities such as providing e-learning facilities to help teachers and students to have access of quality education at the time of lockdown as closing of schools and colleges have caused huge loss to student's precious learning times. Moreover, PMO monitors of all the preparedness and responses, law and order issues, and various relief measures during the COVID 19 crisis.

Digital technologies have become a backbone to conduct all the activities including interaction, virtual meetings, video conferencing, and dissemination of information. PMO has initiated many steps to leverage the benefits of digital resources, mainstream me-

dia, and social media to combat the COVID 19 crisis. One of the great initiatives by PMO is a citizen engagement platform MyGoV to crowdsource governance ideas through the active participation of citizens. Launched on July 26, 2014, MyGoV is hosted and managed by NIC and works as an important interface for interaction of government with the citizens. MyGoV has become one of the leading sources of information about COVID 19 providing daily updates about the number of active cases, deaths, testing status, state-wise COVID status, response and management guidelines, and other COVID 19 related information.

Ministry of Health and Family Welfare (MoHFW): Ministry of Health and Family Welfare is responsible for formulating health policies and dealing with healthcare including public health awareness, immunization, preventive medicine, and various aspects of health and family welfare. MoHFW and its supporting institutions regularly release clinical and non clinical guidelines for control and preventive measures to combat against COVID 19 and limit its spread. MoHFW has an objective to provide universal access to healthcare services in an equitable and affordable way across all sections of the society. MoHFW presents regular daily briefings of the COVID 19 information, GIS mapping of disease hotspots, and access to real-time data about COVID cases and deaths across various states and regions.

National Disaster Management Authority (NDMA): The National Disaster Management Authority is a government organization headed by the Prime Minister of India with a vision to build disaster resilient India through proactive, sustainable and technology driven strategy. NDMA is responsible for planning, policy making, and formulating guidelines for disaster management to safeguard effective response to disasters (1). NDMA approves national plans prepared by departments or ministries of Govt. of India and coordinates the enforcement and implementation of disaster management policies and plans. Moreover, NDMA also considers various measures including prevention, mitigation, and preparedness of disasters, and capacity building to deal with adverse situations during disasters or natural calamities. NDMA approves national plans prepared by departments or ministries of Govt. of India and coordinates the enforcement and implementation of disaster management policies and plans. Moreover, NDMA also considers various measures including prevention, mitigation, and preparedness of disasters, and capacity building to deal with adverse situations during disasters or natural calamities. Because of its scale and complexity, COVID 19 has become a disaster of unusual proportions in India

(1). On February 4, 2020, NDMA issued an advisory to States and Union Territories to disseminate guidelines on travelling, maintaining hygiene and avoiding the crowding places, and enhancing quarantine and isolation facilities across the country. To track the geographical distribution of COVID 19 risk and the migrant labours movement, NDMA established a GIS-enabled dashboard that combine and visualize information from different data sources with a common location reference. The GIS dashboard displays the existing cumulative number of confirmed, recovered, and deaths because of COVID 19 in India and across various states. It also displays GIS maps, pie charts, line graphs, and bar charts of the cumulative number of confirmed cases in various states and across India that helps for planning and management of COVID 19 distribution at state and national level.

Ministry of Electronics and Information Technology (MEITY): Ministry of Electronics and Information Technology is a Govt. of India agency responsible for promoting e-Governance, inclusive and sustainable growth of electronics and IT-ITES industries, development of human resources through e-learning, enhancing digital services and providing secure cyberspace. It promotes and executes different policies associated with IT and IT-enabled services, and helps various departments to facilitate e-infrastructures. It is a premier agency to build electronics and IT products to counter the COVID 19 pandemic. National Informatics Center (NIC) is one of its organizations responsible for setting up of ICT infrastructure and digital solutions to support government at different levels. MEITY also facilitates to produce products such as low-cost polymer swab for COVID testing kits, antiviral and anti-bacterial masks, plasmonic portable sensor for covid 19 virus antigens, and digital thermometers to help government fight against COVID 19.

Directorate General of Health Services (DGHS): Directorate General of Health Services is an organization associated with MoHFW that provides technical suggestions on all medical and public health affairs to MoHFW. It coordinates with health directorates of states and union territories to implement national health and family welfare programs and supervises the hospitals under central governments and addresses the public health concerns.

State Governments: State governments in India have proactively responded to contain spread of the COVID 19 pandemic through various means such as declaration of emergency, restriction of movement of peoples, closure of institutions and public places, and prevention of mass gatherings. It is the constitutional mandate of state governments, local governments, and municipalities to coordinate during public

health emergencies and collectively fight to contain the outbreak of COVID 19. As the “public health and sanitation” comes under state list of Indian constitution, it is the responsibility of individual states to take effective measures to contain the spread of the disease. States are using their own machinery and resources to fight against the deadly COVID 19 pandemic and some states are more successful than the other states due to their disparity in the actions and measures taken to contain the disease. Rajasthan’s Bhilwara model to identify, isolate, test, and treatment is a widely acclaimed model to contain the spread of the disease and have been widely accepted in many district of other Rajasthan and other states. The Kerala government’s prompt response and quick deployment of resources, active surveillance at various levels, risk communication, and community engagement helped to contain the disease.

State Disaster Management Authority (SDMA): According to the disaster management act 2005^[1], all the states and UTs have been provided the right to constitute state disaster management authority (SDMA) with its own advisory committee to formulate state policy, guidelines, and plans in coordination with NDMA for preparedness and mitigation measures to combat any disaster. In addition, the state government is responsible to constitute a state executive committee to coordinate and monitor the implementation of policies, examine vulnerable disaster-prone regions, and evaluate preparedness and response measures in any threatening disasters or such situations. During the current covid 19 pandemics, Indian state governments have responded actively by invoking the disaster management act 2005 along with the declaration of emergencies, restriction of movements, closure of institutions and public places, and many other measures to restrain the spread of the virus. SDMA in various states took important decisions in implementing lockdown measures and ensuring the supply of essential commodities. Moreover, SDMA facilitated various means to collect funds and contribute to state disaster relief funds (SDRF). The funds thus collected have been used to combat the pandemic and help the needy persons.

District Disaster Management Authority (DDMA): The DDMA is a district level body that works under the chairmanship of District Magistrates/Collectors/Deputy Commissioners besides an elected representative of local authority as co-chairman. The district authority is liable for planning, management, coordination, and implementation of disaster response and relief measures at district level.

District Health Officers (DHO): At the district level, the District Health Officer (DHO) manages the public health affairs and is assisted by one or two assistant DHOs. The public health authorities in the local area work through a network of healthcare centers consisting of Primary Health Centers, sub-centers, and dispensaries. All these centers are managed and supervised by DHOs, additional DHOs and assistant DHOs.

District Surveillance Officers (DSO): All the disease-related surveillance activities at the peripheral level are managed and coordinated by district surveillance officers. Each district has its district surveillance units (DSUs) that receive surveillance-related data about diseases and transmit them to state/central surveillance units. DSUs coordinate rapid response and training activities, collate and analyze collected data, monitor the trends, and sends regular feedback to the reporting units. Each DSU is headed by a DSO, who assess the disease surveillance status and report them to the District collector, CMO, and Zila Parishad Chairman. Moreover, DSO ensures timely response and action taken, reports are sent to state authorities, training and capacity building, and regular feedback from the district and peripheral units.

3.2 Government of India's Health Department

Initiatives with NIC as Technology Partner

The Government of India (GoI)’s first step to curb the spread of COVID-19 was the screening of air passengers coming from infected countries and tracing of positive cases along with their travel history. However, the situation started worsening by the end of February 2020. There felt a need for a dedicated system to track and trace positive cases and isolate them to prevent the spread of infection in the large masses. GoI started taking the benefit of technology for detection, prevention, and control of the disease. Many mobile and portals were introduced for better covid-19 surveillance and management. NIC, a technological partner of GoI, having its presence at the national, state, and district-level helped to develop technological solutions.

At the time of this covid-19 crisis, NIC played a pivotal role to combat the pandemic by providing crucial e-Services to the Government and citizens throughout the country. Many tools and digital solutions developed by NIC are functioning as the milestone to deliver the government services to citizens at the time of the covid-19 crisis. NIC has created a digitally-enabled ecosystem to assist government and government-run institutions to discharge essential services throughout the covid-19 triggered lockdown. It provides plenty of services including video conferencing, e-office, web hosting, networking, messaging, and found-the-clock IT supports to central, state,

^[1]http://ndma.gov.in/sites/default/files/PDF/DM_act2005.pdf

and district administrations. The video conference services provided by NIC during this challenging time has helped to connect government officials without any physical contact or exposure to address important matters. Moreover, NIC has developed systems for monitoring and management of the covid-19 crisis by disseminating information, quarantine guidelines, and advisories. Moreover, online portals developed by NIC such as COVID Warrior Portal^[2] plays a crucial role to support the availability of covid-warriors such as healthcare workers, doctors, nurses, and volunteers in critical situations. Many technology-enabled solutions have been developed by NIC at various state levels to track, test, monitor, and treat COVID patients. The **Corona Sample Collection Monitoring System** developed by NIC Delhi, **COVID-19 Test Sample Management System** by NIC Anantnag, **Nurses Registration and Tracking System** by NIC Telangana, **Telemedicine Software** by NIC Tripura, **Covid-19 Tracking & Monitoring System** by NIC Uttarakhand, **Covid-19 Quarantine Monitoring & Tracking System** by NIC West Bengal, **Covid-19 Jagratha**^[3] by NIC Kerala **COVID-19 Transmission Chain Prevention System** by NIC Meghalaya, and similar systems by NIC Punjab, Telangana and other state NICs are important initiatives by NIC's at various states. Moreover, district-level NIC units are also playing a pivotal role in developing customized solutions for rural and urban areas.

Besides various systems, NIC has also developed many android-based mobile apps for monitoring, surveillance, contact tracing, maintaining patient records, monitoring ASHA workers' visit to quarantined subjects, for applying medical-aids, ambulance, and pass for volunteers and vehicles' movement. For example, **Aarogya Setu** app, **Covid Care Kerala** app, **COVID Suraksha** app by NIC Hojai, Assam, and many similar apps have been developed for monitoring, tracking, and surveillance purposes.

Apart from monitoring and tracking systems, NIC states units have developed various helpline portals for lodging complaints and resolving issues associated with covid lockdown and healthcare services. For example, NIC UP integrated the 24X7 UP CM Helpline with Jansunwai Samadhan Portal, and NIC Srinagar has developed integrated **COVID Call Centre** for essential services and grievance redressal. Besides these many systems and applications for registration of migrant workers and stranded peoples, web applications for online education and employment, issuing e-Passes, and financially supporting government and affected citizens. In near future, NIC will be leading to deliver

smart solutions based on artificial intelligence, neural network, and machine learning techniques.

Digital technologies have been widely adopted and integrated throughout the world for covid-19 management and response. From surveillance, contact tracing, testing, quarantine to essential services, medical supplies, screening, and clinical management, digital technologies have played a crucial role [29]. The government of India has taken many technological initiatives to combat the pandemic. Important technological initiatives are discussed in the following subsections.

3.3 COVID19 India Portal:

Covid19 India portal is a web portal developed by Centre for Health Informatics, Ministry of Health and Family Welfare (MoHFW), Government of India for maintaining records and situational updates of COVID 19 cases and deaths throughout the country. Besides number of deaths, it maintains the records of number of confirmed, active, and discharged/cured/migrated cases. The portal contains a dashboard depicting district-wise analysis of the confirmed, active, recovered, and deaths. The dashboard gives a comprehensive view of health preparedness, testing, and case monitoring for effective decision making at this global crisis. The dashboard also facilitates the reporting of surveillance, quarantine, ambulance availability, and other logistic supports. The portal also presents the positive case management and hotspot analysis. Moreover, the portal is integrated with the Aarogya setu app to forecast and reports the emerging hotspots and Bluetooth and self assessment reports. Figure 2 presents the work-flow and various field entry updates of the Covid India Portal. The figure presents that the data updated to Covid India portal be free from redundancies and multiple entries and ensures correct entries per confirmed covid 19 cases.

3.4 Aarogya Setu App:

The Aarogya Setu app^[4] is a real-time patient tracking application developed by the NIC, under the Ministry of Electronics & Information Technology, Government of India. The app runs on both Android and iOS platforms and available in 11 different languages. It is an important tool for managing the ongoing pandemic through contact tracking of individuals who may have come or likely to come in contact with an infected person. The app informs its users through notification whenever they come across COVID-19 positive patients within the specified range of distance (e.g., 500 meters to 10 kilometers). It uses Bluetooth and GPS technology to track users' movement and discover nearby infected individuals with a smartphone

^[2]<https://covidwarriors.gov.in/>

^[3]<https://covid19jagratha.kerala.nic.in/>

^[4]<https://www.mygov.in/aarogya-setu-app/>

having the app installed. The app also facilitates self-assessment tests through a questionnaire to indicate the risk level and current health status of users. Based on the risk level the app recommends self-quarantine at home or to approach public health authorities. The app is people-centric and depends on input from the user's self-reporting of their health status, thus the effectiveness and accuracy of health assessment are compromised. However, due to its multitude of benefits, such as self-assessment, social distancing tips, and self-quarantine guidelines, the app has received country-wide acceptance.

3.5 ICMR Portal:

To manage sample collection for Rapid Antigen Test (RAT) at authorized sample collection centers with the help of authorized persons the government has developed a dedicated ICMR portal^[5] for COVID 19 sample collection and management. Only the authorized government officials can use the portal through mobile phones for transferring RAT and RT-PCR data to the ICMR portal for probable positive or negative cases. The registered users can view lab sample collection centers/labs in their respective states or districts. More specifically, the portal is meant to monitoring of actual data by the GOI and ICMR about the details of people who underwent RAT and RT-PCR tests. The portal is integrated with RATI^[6] and RT-PCR^[7] app for data collections. Figure 3 presents the data-flow between Aarogyasetu app and ICMR portal.

3.6 Integrated Disease Surveillance Program:

The Integrated Disease Surveillance Programme^[8] (IDSP) is a flagship program of the Government of India under the National Health Mission for all states and union territories to strengthen the surveillance of epidemic-prone diseases at the early phase of transmission. It involves the integration and decentralization of surveillance activities such as monitoring disease trends, detecting any prevailing outbreaks, and responding to the identified outbreak at the earliest phase of transmission. Under the IDSP, weekly disease case counts as suspected, presumptive, and the confirmed cases are collected from the district, states, and central surveillance units to identify the disease trends and seasonality. Once the rising trends or outbreaks are identified in any specific region, the trained rapid response teams (RRTs) are assigned to diagnose and control the outbreak. It is an IT-enabled project

with various data centers and equipment managed by NIC for transmission of data from the district levels to the central surveillance units. IDSP takes various control and preventive measures such as interactive electronic discussion, training, e-learning, reviewing, and monitoring various activities.

3.7 COVID-19 Vaccine Intelligence Network (CoWIN):

To make covid vaccine available to all the citizens the central government has initiated **COVID-19 Vaccine Intelligence Network (CoWIN)** system, which is a digitalized platform to roll out and scale up nationwide distribution of COVID vaccine. CoWIN is a cloud-based IT solution and an extension of the ongoing **electronic Vaccine Intelligence Network (eVIN)** for planning, implementation, monitoring, and evaluation of COVID-19 vaccination across the country. The CoWIN system will help to track the beneficiaries of vaccination and monitor the utilization, wastage, and coverage of the vaccination at the National, State, District, and Sub-District level. The system has a CoWIN web site^[9] for creation of users (admins, supervisor, and vaccinator) at state and district levels, maintenance of vaccinator databases, session sites, and beneficiaries. The system also has a dedicated CoWIN mobile app^[10] for registration of individual beneficiaries and their authentication and recording of vaccination. The vaccination will be initiated in a phased manner on a priority basis starting from the health care workers, frontline workers, and population at higher risk. Figure 4 presents the integration of eVIN to CoWIN network. The eVIN contains an easy to use mobile app for recoding vaccine data and health worker updates, whereas the CoWIN beneficiary management platform tracks beneficiaries and manages vaccination session. All this information is fed into the cloud-based centralized server from which important information all visualized in near real-time the information is through a dashboard of CoWIN web interface. The CoWIN web interface visualizes the alert on low stock, expiry, and optimal recommendation of vaccines. It also visualizes the beneficiary vaccination status and other monitoring and coverage information.

3.8 RT-PCR App:

The union health ministry has launched a dedicated real-time polymerase chain reaction (RT-PCR) mobile-based application for medical staff to fill the sample collection data at the sample collection centers. It is an important initiative to report sample collection for various type of specimen to authorities at ICMR, state governments, etc. in near real-time and minimize

^[5]<https://covid19cc.nic.in>

^[6]<https://apps.apple.com/us/app/rati/id1508539268>

^[7]<https://apps.apple.com/us/app/rt-pcr/id1509701314>

^[8]<https://idsp.nic.in/>

^[9]<https://www.cowin.gov.in/>

^[10]<http://www.app.cowin.gov.in/>

the sample collection error. Using only one entry point the information can be shared everywhere with the respective government authorities with minimum error in the real-time reporting of data. The application is connected to the main database used by the health ministry and keeps updating automatically. To keep track of the place of sample collection for RT-PCT test the app uses location parameters (latitude, and longitude).

3.9 COVID Facility App:

Covid facility app uses the individual health status and hotspots information from Aarogya Setu for optimized treatment, patient referral, and monitoring immediate utilization of infrastructure and essential supplies to scale up health system preparedness and enable data-driven decision making.

Figure 5 represents the entire data flow and management during covid 19 pandemics through various portals and apps from the patients to the central reporting agency ICMR that monitors and coordinates different government offices and health agencies. It can be observed from the figure that the samples and data from the patients are fed and update at the collection point by medical staff through the RT-PCR app. Thereafter, these data throughout the country are collected at the single sources in the ICMR database for testing to prevent any redundancy and multiple entries. This single source of data is now used for surveillance of the disease incidences and reporting of positive cases through the centralized dashboard to various state and district surveillance officers.

Table 1 presents the state-wise technological solutions, apps, and essential supports provided by various state and district level NIC centers to combat the COVID-19 crisis. The technological solutions and supports are provided in almost all sectors of government organizations that include health, labour, education, food, transport, finance, justice, secretariats, and various ministries. NIC's video conferencing services have been used widely across ministries, secretariats, cabinets, and other government organizations to conduct meetings for planning, management, preparedness, and monitoring of essential services during this global crisis. NIC's various technological services helped to connect government officials, covid warriors, and other staff without coming into direct physical contact and ensuring the least possible physical contact and exposure to the infection. The table lists solutions/services developed and implemented in various states and union territories and their detailed descriptions. It can be observed from the table that states and union territories have adopted different online and offline technological solutions such as dedicated portals,

tools, dashboards, and mobile applications to combat the pandemic crisis.

Dedicated apps are being developed by various state and district NIC units for sample collection centers for conducting RT-PCR, antigen, and antibody tests and updating the number of covid positive cases. The developed COVID portals have the facility to login for district collectors, medical staff, health officers (i.e. CMO, DMHO), and district surveillance officers (DSOs). The dedicated COVID India portal facilitates the verification and updating of real-time positive cases data and entry and updates of COVID care centers. Many other technological solutions that include systems for patients, home isolation, logistic infrastructure, quarantine management, corona test monitoring, containment zones, contact tracking, and death tracking have been developed by various states.

4 Analysis of COVID 19 in India

India is a country with a large geographic area (3,287,240 square kilometres) and population (1.3 billion). It has high regional, climatic, cultural, and population diversity. Due to these diversities, the infection rate, its progression over time, and the preventive measures taken by various states, territories, and the public are different. Moreover, the limited availability of resources has resulted in the high spread of new infection in some parts of the country. To analyse the confirmed, recovered and deceased COVID 19 cases, we consider the data from COVID 19 India website^[11]. Figure 6 presents the daily number of COVID 19 cases across India. It presents the daily confirmed, recovered, and deceased cases from the first confirmed case on January 30, 2021 to February 15, 2021. We can observe from the figure that initially the number of daily confirmed and recovered cases increases rapidly till the mid of September 2020. Thereafter, we observe that the number of daily confirmed and recovered cases continually decreases. Both the daily confirmed and daily recovered cases show similar trends. Moreover, from the figure 6, we notice that the number of recovered cases lags behind the number of daily confirmed cases till the mid of September 17, 2020. Thereafter, the number of daily recovered cases leads to the number of daily confirmed cases and continues to be leading. Thus, we see a high recovery from the infection after mid-September 2020. We observe a fall in the number of confirmed cases and increase in recovery, which may be due to an increase in medical facilities, healthcare resources, and preventive measures by states and union territories. Figure 6 also presents the daily deceased cases due to COVID 19. The daily number of deceased is very small compared to the number

^[11]<https://www.covid19india.org/>

of confirmed case as can be seen from the line graph. More than 500 daily number of deceased were reported in the mid of July to the end October 2020. By the mid of February 2021, we observe a great decrease in the number of daily confirmed and deceased cases. This is because of the central government and various state's proactive measures to control the spread and provide essential healthcare and medical facilities.

Figure 7 presents bar graph of state-wise total number of confirmed, recovered and deaths till Feb 15, 2021. From figure 7, we observe that most covid 19 confirmed cases and deaths have been reported by Maharashtra. The other most affected states include Karnataka, Kerala, Andhra Pradesh, Tamil Nadu, Delhi, Uttar Pradesh, and West Bengal. To analyze state-wise daily confirmed, recovered, and deceased cases of the most affected states, we populated the line graphs of the top five states. Figure 9, 10, 11, 12, and 13 present the daily confirmed, recovered, and deceased cases of most affected states. These figures show the disease dynamics in Maharashtra, Andhra Pradesh, Karnataka, Kerala, and Delhi. In most of the states infection started from the patients having travel history to any COVID-19 infected countries. Maharashtra is the most severely affected state with more than 2 million total number of confirmed cases till the mid of February 2020. From figure 9, we can observe that there is an increasing trend of the daily confirmed number of infected cases from mid of March to mid of September 2021. Thereafter, the daily confirmed number of infected cases shows a decreasing trend and the daily recovery leads to the confirmed cases. Higher recovery and decrease in the number of confirmed cases may be due to the state's proactive measures to counter the spread of the infection. Among all the states, Maharashtra has reported most deaths with more than 51 thousand deceased cases till the mid of February 2021. However, we can observe from figure 9 that the number of deceased is very low compared to the number of daily confirmed cases. Many factors including different control and preventive measures by states, awareness and precautionary measures, and a person's immunity could be responsible for low deaths. Kerala observed strict lockdown and was substantially able to control the spread of infection and reported nearly four thousand deaths in the mid of February 2021. We can observe from Figure 12 the trends of the disease dynamics of Kerala in terms of daily confirmed, recovered, and deceased cases. Similarly, we draw meaningful insights about the disease dynamics from the increasing and decreasing trends of confirmed, recovered, and deceased cases for Karnataka, Andhra Pradesh, and Delhi. The infection rate in the year 2021 has decreased because of various precautionary measures by state

health departments and the vaccination drive throughout the country. There is still a danger of the second wave of COVID-19 in many states including Maharashtra because of irregularities in adopting the COVID-19 precautionary guidelines and unlocking of public places. Moreover, many people across the country are hesitating to get vaccinated because of some doubts, preconception, and fear of some adverse effects of the vaccine. Further, the vaccination drive in India is still not available for general public. The vaccination roll-out only meant for specific category of beneficiaries will leave chances of the spread of virus and may increase the infection.

5 Conclusion

Governments throughout the world are considering different measures and initiatives to tackle the COVID-19 pandemic crisis and attempting to restrict the loss of human lives and economies. The government of India is leveraging digital solutions with the help of the technological expertise of NIC in giving cutting-edge solutions to combat the COVID-19 pandemic. This paper presents a digital response framework for surveillance and control of COVID-19 in India and various other technological initiatives to fight against this global crisis. It discusses the roles, essential supports, and technical solutions under various governing bodies at different levels of governance. Moreover, the paper also presents the analysis of COVID-19 cases in various parts of India. With the help of NIC as a technology partner, the Government of India has developed and implemented many apps, digital interfaces, and dashboards to combat this pandemic and limit its spread.

List of Abbreviations

NIC: National Informatics Center
 WHO: World Health Organization
 IoT: Internet of Thing
 AI: Artificial Intelligence
 UAV: Unmanned Aerial Vehicle
 RAT: Rapid Antigen Test
 eVIN: Electronic Vaccination Intelligence Network
 CoWIN: COVID-19 Vaccination Intelligence Network
 RRT: Rapid Response Team
 IDSP: Intelligence Disease Surveillance Program

Declaration

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

Data sharing not applicable as all the dataset used are available in public domain.

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The authors declare that they have no competing interests.

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Authors' contributions

The first author drafted the manuscript and conducted data analysis with the technical inputs and expertise from other authors.

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References

- Zu, Z.Y., Jiang, M.D., Xu, P.P., Chen, W., Ni, Q.Q., Lu, G.M., Zhang, L.J.: Coronavirus disease 2019 (covid-19): a perspective from china. *Radiology*, 200490 (2020)
- Leung, K., Wu, J.T., Liu, D., Leung, G.M.: First-wave covid-19 transmissibility and severity in china outside hubei after control measures, and second-wave scenario planning: a modelling impact assessment. *The Lancet* **395**, 1382–1393 (2020)
- Andrews, M., Areekal, B., Rajesh, K., Krishnan, J., Suryakala, R., Krishnan, B., Muraly, C., Santhosh, P.: First confirmed case of covid-19 infection in india: A case report. *The Indian Journal of Medical Research* **151**(5), 490 (2020)
- Chamola, V., Hassija, V., Gupta, V., Guizani, M.: A comprehensive review of the covid-19 pandemic and the role of iot, drones, ai, blockchain, and 5g in managing its impact. *IEEE Access* **8**, 90225–90265 (2020)
- Pham, Q.-V., Nguyen, D.C., Hwang, W.-J., Pathirana, P.N., et al.: Artificial intelligence (ai) and big data for coronavirus (covid-19) pandemic: A survey on the state-of-the-arts (2020)
- Mondal, M.R.H., Bharati, S., Podder, P., Podder, P.: Data analytics for novel coronavirus disease. *Informatics in Medicine Unlocked* **20**, 100374 (2020)
- El-Din, D.M., Hassanein, A.E., Hassanien, E.E., Hussein, W.M.: E-quarantine: A smart health system for monitoring coronavirus patients for remotely quarantine. *arXiv preprint arXiv:2005.04187* (2020)
- Zhang, M., Meng, R., Verbaeck, A.: Including public transportation into a large-scale agent-based model for epidemic prediction and control. In: *Proceedings of the Conference on Summer Computer Simulation*, pp. 1–8 (2015)
- Noronha, N., D'Elia, A., Coletta, G., Wagner, N., Archer, N., Navarro, T., Lokker, C.: Mobile applications for covid-19: A scoping review (2020)
- Beckman, R., Bisset, K.R., Chen, J., Lewis, B., Marathe, M., Stretz, P.: Isis: A networked-epidemiology based pervasive web app for infectious disease pandemic planning and response. In: *Proceedings of the 20th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*, pp. 1847–1856 (2014)
- Tuli, S., Tuli, S., Tuli, R., Gill, S.S.: Predicting the growth and trend of covid-19 pandemic using machine learning and cloud computing. *Internet of Things*, 100222 (2020)
- Yuan, G.X., Di, L., Gu, Y., Qian, G., Qian, X.: The framework for the prediction of the critical turning period for outbreak of covid-19 spread in china based on the iseir model. Available at SSRN 3568776 (2020)
- Zanin, M., Xiao, C., Liang, T., Ling, S., Zhao, F., Huang, Z., Lin, F., Lin, X., Jiang, Z., Wong, S.-S.: The public health response to the covid-19 outbreak in mainland china: a narrative review. *Journal of thoracic disease* **12**(8), 4434 (2020)
- Ye, Q., Zhou, J., Wu, H.: Using information technology to manage the covid-19 pandemic: Development of a technical framework based on practical experience in china. *JMIR Medical Informatics* **8**(6), 19515 (2020)
- Singh, V., Chandna, H., Kumar, A., Kumar, S., Upadhyay, N., Utkarsh, K.: Iot-q-band: a low cost internet of things based wearable band to detect and track absconding covid-19 quarantine subjects. *EAI Endorsed Transactions on Internet of Things* **6**(21) (2020)
- Chamberlain, S.D., Singh, I., Ariza, C.A., Daitch, A.L., Philips, P.B., Dalziel, B.D.: Real-time detection of covid-19 epicenters within the united states using a network of smart thermometers. *medRxiv* (2020)
- Mohammed, M., Hazairin, N.A., Al-Zubaidi, S., AK, S., Mustapha, S., Yusuf, E.: Toward a novel design for coronavirus detection and diagnosis system using iot based drone technology. *International Journal of Psychosocial Rehabilitation* **24**(7), 2287–2295 (2020)
- Shaw, K.K., Vimalkumar, R.: Design and development of a drone for spraying pesticides, fertilizers and disinfectants. *International Journal of Engineering Research & Technology (IJERT)*, 1181–1185 (2020)
- Ding, G., Wu, Q., Zhang, L., Lin, Y., Tsiftsis, T.A., Yao, Y.-D.: An amateur drone surveillance system based on the cognitive internet of things. *IEEE Communications Magazine* **56**(1), 29–35 (2018)
- Tavakoli, M., Carriere, J., Torabi, A.: Robotics, smart wearable technologies, and autonomous intelligent systems for healthcare during the covid-19 pandemic: An analysis of the state of the art and future vision. *Advanced Intelligent Systems*, 2000071 (2020)
- Galletta, A., Carnevale, L., Bramanti, A., Fazio, M.: An innovative methodology for big data visualization for telemedicine. *IEEE Transactions on Industrial Informatics* **15**(1), 490–497 (2018)
- Sundaravadivel, P., Kougianos, E., Mohanty, S.P., Ganapathiraju, M.K.: Everything you wanted to know about smart health care: Evaluating the different technologies and components of the internet of things for better health. *IEEE Consumer Electronics Magazine* **7**(1), 18–28 (2017)
- Dziak, D., Jachimczyk, B., Kulesza, W.J.: Iot-based information system for healthcare application: design methodology approach. *Applied sciences* **7**(6), 596 (2017)
- Asimakopoulou, S., Asimakopoulou, G., Spillers, F.: Motivation and user engagement in fitness tracking: Heuristics for mobile healthcare wearables. In: *Informatics*, vol. 4, p. 5 (2017). Multidisciplinary Digital Publishing Institute
- Metcalf, D., Millard, S.T., Gomez, M., Schwartz, M.: Wearables and the internet of things for health: Wearable, interconnected devices promise more efficient and comprehensive health care. *IEEE pulse* **7**(5), 35–39 (2016)
- Zheng, N., Du, S., Wang, J., Zhang, H., Cui, W., Kang, Z., Yang, T., Lou, B., Chi, Y., Long, H., et al.: Predicting covid-19 in china using hybrid ai model. *IEEE transactions on cybernetics* **50**(7), 2891–2904 (2020)
- Wang, L., Yan, B., Boasson, V.: A national fight against covid-19: lessons and experiences from china. *Australian and New Zealand journal of public health* **44**(6), 502–507 (2020)
- Vaishya, R., Javaid, M., Khan, I.H., Haleem, A.: Artificial intelligence (ai) applications for covid-19 pandemic. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews* **14**(4), 337–339 (2020)
- Whitelaw, S., Mamas, M.A., Topol, E., Van Spall, H.G.: Applications of digital technology in covid-19 pandemic planning and response. *The Lancet Digital Health* (2020)
- Of Health, M., Welfare, F.: Covid 19 vaccination operation guideline. Technical report, Government of India (2020)

**Figures
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Figure 2: Work-flow and field entry updates of Covid
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Figure 3: Data flow between Aarogyasetu app and
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Figure 5: Flow of data during the COVID-19 management

Figure 6: Daily number of COVID 19 confirmed, recovered, and deceased cases in India

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Figure 11: Daily number of COVID 19 confirmed, recovered, and deceased cases in Karnataka

Figure 12: Daily number of COVID 19 confirmed, recovered, and deceased cases in Kerala

Figure 13: Daily number of COVID 19 confirmed, recovered, and deceased cases in Delhi

Table 1: States Activities report during the COVID19 Lockdown.

State/UT Name	Covid-19 Initiatives	Description
West Bengal	Covid-19 Quarantine Monitoring and Tracking System	Monitor and track the persons admitting and discharging from Quarantine Centres, Isolation (Pre Covid) Hospital and Covid Hospital in real time basis
	Khadyasathi	Upgradation of Supply chain Management System to incorporate PMGKAY(Pradhan Mantri Garib Kalyan Anna Yojana), and delivery of food items free of cost
	eNathikaran	Submission of draft e-deed online and its approval, ePayment and Submission of e-deed
	Covid19cc.nic.in	Aarogya Setu – Dashboard : Multiple Communications and discussion with all DIOs, WB (23 Districts) – over WebVC, VoIPs, Mobile
	Online Classroom	For School Education, WB
TamilNadu	ePass system	For issue of passes to citizens during COVID19 lockdown for any emergencies, developed and implemented using Service Plus framework in almost all the Districts of Tamil Nadu
	Online examination for classes 6 to 10	An online exam for students of classes 6th to 10th in Tiruvannamalai District was organized using NIC Software. More than 30,000 students registered and around 20,000 students took the test from their homes. Two rounds of Tests have been planned and this is mainly to motivate the students during these tough times.
	Covid-19 Volunteer registration	An application for registration of volunteers for Covid-19 relief work to help the District Administration was developed and implemented in a few districts of Tamil Nadu
	Online Disbursement of payment of 2 Days Salary to MGNREGS workers	Online disbursement of payment of 2 Days salary to MGNREGS workers has been developed and implemented successfully.
Uttar Pradesh	Advance Pension Distribution	Disbursement of two months advances pension to beneficiaries of Old Age, Nirashrit Mahila, Divyang Jan and Leprosy categories. Rs. 871.48 Crore has been disbursed to 86.72 Lakhs beneficiaries during this period.
	COVID-19 e-PASS System	8.49 Lakhs pass requests have been received and 2.85 Lakh passes were issued for 14.39 Lakh people.
	UPHAAR	Deployment of Home guards in all the districts on emergency duty to handle Covid-19
	Land Registry	Online Land Registry begins from 20th April. During this Lockdown Week 750 Land Registries done and Total Revenue Rs. 5.97 CR have been collected
Kerala	Revenue Services for Citizen through Mobile App	Implemented Revenue Services for Citizen through Mobile App
	Covid19 Jagratha Portal	Designed and Developed Covid19 Jagratha Portal for passes and surveillance
	Covid Care Kerala Mobile App	Developed a Covid Care Kerala Mobile App
	Transit Vehicle Management System	Implemented Transit Vehicle Management System
	NiCeScan Mobile App	Developed and Implemented NiCeScan Mobile App
	KSsheerasree Mobile App	Designed and Developed KSsheerasree Mobile App
	Athidhi Portal	Implemented Athidhi portal for migrant labour management System
	ePass for Domestic and International Returnees	Implemented ePass for Domestic and International Returnees
	Virtual Court Support	Provided Virtual Court Support
Uttarakhand	eOffice Support across the State	Implemented eOffice Support across the State
	Portal for GIS based monitoring System	GIS based monitoring of Covid in State, Eight Components – Hotspots, Hospitals, Test centres, Quarantined persons, Relief camps
	Portal for Online registration of Volunteer Force	Portal for Online registration of Volunteer Force in fight against Covid - 1000 + plus registrations.
	Portal to Manage IPD Patients movement	Portal to Manage IPD Patients movement from 3 Covid Hospitals to 7 Private Hospitals in Nainital District.
	Portal for Chief Minister Relief Fund	Portal for Chief Minister Relief Fund launched with many payment options.
	Portal for online tracking of Persons Quarantined	Online tracking of Persons Quarantined in Homes/ Institutions in Puducherry, through mobile phones. A joint initiative of NIC, Puducherry and Uttarakhand
Telangana	E-Learning Portal to simulate class room experience	Simulate class room experience for Govt School students - Teachers uploaded Videos & hand written text for study by students. 1500 contents uploaded, 32,000 download in portal.
	E-Pass	for Movement of persons
	Council from NRTS system	Sharing the Registered Nurses of various categories in various states Indian Nursing Council from NRTS system.
	CCTS	Online and Mobile based Corona contact Tracking system
Rajasthan	VJAI	VJAI - VC based Justice to All in Time
	COVID-19 Quarantine Tracker mobile App	COVID-19 Quarantine Tracker mobile App developed and implemented successfully at Udaipur
	COVID Suspect Monitoring System	Monitoring of screening person implemented at Jodhpur.
	Asset Management System	For District Administration, Hospitals, CMHO office, for the administration of various assets like mask, sanitizers, beds etc. and implemented at Jodhpur , Jalore and some other districts.
	ePass system	ePass system developed and implemented at Ganganagar, Churu and some other districts.
	DSC based electronic bill submission system	DSC based electronic bill submission system implemented in IFMS for all treasuries and DDOs.
	eMulakat	eMulakat launched in all central jails for virtul meeting of prisoners with their family members.
	Covid-19 support	Support for http://covid19.nhp.gov.in portal. Training provided

	RT-PCR app	Support extended for RT-PCR app and Arogya Setu App.
	ASHA-Soft System	A new software modules developed in ASHA-Soft System for DBT of incentive of Rs.1000 per month to ASHA Sahyoginis for Covid-19 activities.
	GIMS	GIMS implemented for Public Health Engineering Department
	Civil Registration system	Civil Registration system modified for registering death due to COVID 19.
	PDS system	In the PDS system, provisions made for additional wheat allotment to FPS.
Punjab	State health department and NIC HQ	Coordination with state health department and NIC HQ for the creation of Sample Collection Centre
	State Govt. and NIC-HQ for providing access to Aarogya Setu	Coordination with State Govt. and NIC-HQ for providing access to Aarogya Setu dashboard to Senior State Govt. Officers
	State Govt. and NIC-DAPRG team	Coordination with with State Govt. and NIC-DAPRG team for downloading the Covid-19 related Grievances from CPGRAMS to PBPGRAMS
	Weblink and dashboard for Covid-19	Provisioning of weblink and dashboard for Covid-19 on all citizen centric web-sites/applications
	Daily updation of District Web-sites	Daily updation of District Websites for COVI-19 related information
Odisha	web portal	Design, Development and hosting of web portal "Horticulture produce marketing (https://odihortmarketing.nic.in)" for rendering services to farmers and traders & wholesalers of horticultural produce like fruits, vegetables and flowers during lockdown.
	Online MCQ based post training Test on Covid-19	Online MCQ based post training Test on Covid-19 management for MBBS/Paramedical students/Interns in 5 batches for 1600+ participant
	COVID - 19 ePass	Issuance of COVID - 19 ePass using Service Plus
	Demonstration of Aarogya Setu App	Demonstration of Aarogya Setu App to Chief Secretary and Principal Secretary, Health and FW Department.
	Support for Covid19CC application and RT-PCR App	Support for Covid19CC application and RT-PCR App to DIOs and NHM
	Foreigner Registration and stay	Foreigner Registration (District Wise), No. of Foreigners staying in Hotels, Educational Institutions (C-Form for Hotel / Lodge / Dharmasala and S-Form for Educational Institutions)- Daily report from 34 Police Districts
Mizoram	ePermit (Android Mobile App)	Application for road movement permit for essential commodities during lockdown of Covid-19 for Food, Civil Supplies & Consumer Affairs was developed.
	District administration on Aarogya Setu app	Providing support to district administration on Aarogya Setu app and regular district wise reports to State Nodal Office from Aarogya Setu Dashboard
	District administrations on portal	Providing support to district administrations on portal https://Covid19cc.nic.in
	Updating orders on Covid-19 related matters	Updating informations / orders on Covid-19 related matters given by district administration at respective District Websites.
Meghalaya	Covid -19 Transmission Chain Prevention System	Self Registration and reporting for those who arrived in Meghalaya, Registration Form for citizens of Meghalaya stranded in the NE, outside NE, and outside India
	Chief Minister's Relief Fund Online Portal	Grant-in-aid for citizens of Meghalaya stranded in the other states
	Meghalaya Public Grievances Redressal System	Application for Vehicle Transit Pass
	VANI COVID-19 Chatbot	VANI COVID-19 Chatbot with local languages in Khasi and Garo
	RATI application	Implementation of RATI application
	RT-PCR application	Implementation of RT-PCR application in collecting centre
Manipur	Aarogya Setu Mobile Apps	Promoting Aarogya Setu Mobile Apps in the State.
	Mobile App for monitoring "Home Quarantined People"	Development of Mobile App for monitoring "Home Quarantined People" under COVID-19
Maharashtra	Chief Minister Relief Fund	Chief Minister Relief Fund, Maharashtra website is enabled to receive donations online for COVID Fund
	Google Forms and Sheets to collect covid19 information	Preparation and publicising of various Google Forms and Sheets to collect covid19 related information in the Districts
	Control Room for COVID-19	Extended support for setting up of Control Room for COVID-19
	Data collection Mobile Apps	Implementation support for collection of data through https://covid19cc.nic.in , https://covid19.nhp.gov.in and Mobile Apps (RATI and RT-PCR)
	Aarogyasetu Dashboard	User credentials provided for Aarogyasetu Dashboard to State and District Administration
	QuickSMS	Mahasamadhan-use of QuickSMS for sending Bulk SMS in Districts
Madhya Pradesh	ePass	Support for issuing of ePass
	Single click DBT	Single click DBT for Mid-Day Meal Cooks, Insurance to farmers, Social Security Pensioners, Registered building workers.
	Shramk Seva Portal and e-Payment Platform	Shramk Seva Portal and e-Payment Platform for Registration of migrant labours and payment
	Panchayat Darpan Online Covid-19	Panchayat Darpan Online Covid-19 Related Information Collection for Registration Monitoring, Tracking of Migrant workers, and manage Relief
	GeoCovid19	GeoCovid19 to find epicenter of covid19 affected cases of Indore
	Slot Booking Mgmt SYSTEM	Slot Booking Mgmt SYSTEM for APMCs to prevent crowding at mandis
Lakshadweep	Covid Pass for stranded people	Online registration, Covid Pass for stranded people in Lakshadweep using service Plus
	Administrators relief fund	Online portal developed in Service Plus for accepting Administrators relief fund
	Electricity BPSC surcharge	Electricity BPSC surcharge removed and reconnection charge removed
	Ship ticket refund system	Ship ticket refund system modified
	Tourist booking system	Tourist booking system refund system modified
Karnataka	PDS distribution	PDS distribution to 1.14 crores families
	DBT	DBT to 25 Lakh Labour and Social Security Pension beneficiaries, 271.8 Cr was disbursed
	CM relief fund	CM relief fund with payment gateway integration in SevaSindhu (service plus platform), 3811 transactions, Rs 3.13 Crores received

	E-Passes	21 Thousand E-Passes issued by 6 districts.
	e-way bill project for monitoring	New reports under e-way bill project for monitoring of logistic movement
	Online payment of court fees and e-filing of cases	Enabled online payment of court fees and e-filing of cases, obtaining certified copies of judgements
Jharkhand	Jharkhand Sahayata App	To provide financial Aid to stranded migrants of Jharkhand in other States
	Jharkhand Bazar Mobile App	Launch of Jharkhand Bazar Mobile App for issuance of m-pass to citizens and shopkeepers.
	E-Pass module	For issuance of intra district, inter district and interstate Passes during Lockdown
	Registration module	Registration for the people who are stranded due to Lockdown, either in Jharkhand (outside state people) or out of Jharkhand (Jharkhand state people)
	Mobile app for Special Ration	Mobile app for Special Ration for ERCMS pending beneficiaries
	e-OPD at RIMS	Initiation of e-OPD at RIMS, Ranchi using NIC WebVC
Jammu and Kashmir, Ladhak	e-Pass online system	Implementation of e-Pass online system with three types of passes namely Intra-District, Inter-District and Inter-State on Service Plus Framework of NIC. System implemented in 18 out of 20 districts of J& K UT and 02 districts of Ladakh UT with 25000+ applications received so far.
	Online portal for stranded citizens	Developed and launched online portal for stranded citizens of J&K (students, migrant laborers, daily wagers and others) for their data collection, location monitoring, transportation, movement tracking, quarantine facilities monitoring etc.
	Web based workflow based application	NIC Jammu helped launch a web based workflow based application for call recording, its mapping with relevant officer and finally posting remarks against each call.
	Website of School Education Department	Created and launched website of School Education Department with an interface for organizing activities for students during the Covid-19 Lockdown period.
	Portal for voluntary disclosure of travel history	NIC Anantnag helped launch a portal for voluntary disclosure of travel history and registration as volunteers for fighting Covid-19. Also launched Covid-19 Test Sample Management System to monitor test samples sent to various Labs in JK. Similar activities were also carried by the DIO of Ramban and Shopian.
Himachal Pradesh	Mobile Apps of Rati and RT-PCR for ICMR	Development of two mobile Apps of Rati and RT-PCR for ICMR on Android and iOS (Apple platforms) for ICMR for country wide usage
	Monitoring portal for Rati and RT-PCR Mobile Apps	Development of Authorization and Monitoring portal for Rati and RT-PCR Mobile Apps, along with role based access and MIS reports as per requirements
	ePass software	ePass software using Service Plus platform
	Health check-up utility	Development of local utility for health check-up of drivers of essential services utility vehicles through hospitals/ Border entry management
	Arogya Setu Mobile App/ Dashboard	Technical help at State/ District level in Arogya Setu Mobile App/ Dashboard
Haryana	Registration of Migrants	Registration of Migrants from Haryana and Vice versa
	Movement Pass during Lockdown	Movement Pass During Lockdown/ Curfew for General Public and Printing of Pass for Industrial/Commercial Establishment during Lockdown
	Haraadesh Portal	Haraadesh Portal for covid control
	Online consent for Haryana Corona Relief Fund	Online consent for Haryana Corona Relief Fund from Employees, Pensioners, Employees of Board Corporations and Ex MLAs
	Relief camp management system	Relief camp management system
	National Portal for COVID 19	National Portal for COVID 19 Affected Unorganised Migrant Workers
	Covid Appreciation & Management System	Covid Appreciation and Management System, Haryana
	Covid19 Drug Procurement and distribution	Covid19 Drug Procurement and distribution
	CS- MIS Information Collection Portal	CS- MIS Information Collection Portal
	Mobile Health Team Information System	Mobile Health Team Information System
	ArogyaSetu Dashboard	ArogyaSetu Dashboard access and Reports Support
	Connect Plus Haryana – Mobile App	Connect Plus Haryana – Mobile App
	Relief Camp Management System	Mobile App for Relief Camp Management System:
	National Portal for COVID 19 Affected Unorganised Migrant Workers	Mobile App for National Portal for COVID 19 Affected Unorganised Migrant Workers
Gujarat	PDS	PDS – Food grains and ration distribution free of cost in multiple rounds for different category card holders i.e. Antyodaya, BPL and APL
	PFMS gateway for Cash Benefits	Cash Benefits to ration card holders (66 lakhs) registered under NFSA through PFMS gateway. Approx. 48 lakhs beneficiaries have been given Rs.1000/- and remaining will get soon after data gets corrected
	Hospital MIS System	Hospital MIS System for information related to hospital and its infrastructure including human resource with GEO co-ordinates.
	Lockdown Exemption e-Pass system	Lockdown Exemption e-Pass system as a part of Digital Gujarat framework developed implemented and extended for Intra district, Inter district and Interstate transfer or movement.
	ePermit system	ePermit system was developed for Industries permission to start the establishment.
Goa	State Food Help Line	Setup of State Food Help Line at State & District Level
	State control Centre for Migrant Labour	Setup of State control Centre for Migrant Labour Registration
	Technical Support/Training for Covid19 Collection	Technical Support/Training for Covid19 Collection Centre details, Surveillance Details
	Covid19 Self Reporting PAX application	Covid19 Self Reporting PAX application for arrival and departure introduced after training at Airport & Seaport

	On-site technical support	On-site technical support for the immigration clearance of Relief flights chartered from Goa airport (45 flight with 7500 passengers)
Delhi	LG/CM Relief Donation portal	Launched LG/CM Relief Donation portal.
	Covid-Care Delhi	Developed Covid-Care Delhi App which details various services/initiatives of Delhi Government under Covid-19. The app will provide details of nearby health facilities as per the severity of symptoms of a citizen
	SaarthiCOV	SaarthiCOV launched for transport department, GNCT Delhi to overcome financial distress caused by lockdown. The scheme provides one time financial assistance of Rs. 5000 to the drivers of Para Transit Vehicles registered in NCT Delhi
	Corona Foot Warriors	Developed and implemented the Corona Foot Warriors https://cfwcst.delhi.gov.in portal with the objective for monitoring the field areas in Delhi. 14000 Corona Foot Warriors have been deployed in Delhi
	Corona Sample Collection Monitoring Module	Developed and implemented the "Corona Sample Collection Monitoring Module" https://cfwcst.delhi.gov.in portal with the objective for monitoring the Corona samples taken during the day and reports received
	Workers on e-District portal	Developed a facility to provide the financial benefit of Rs. 5000/- in the month of April 2020 to the construction workers on e-District portal
	Pensioners in e-District portal	Created a provision to pay an additional amount of Rs. 2500/- in the month of April 2020 to the Old Age Pensioners in e-District portal
	AssessKaroNa App	To help volunteers to digitally record the answers of families while doing Home survey
	Quarantine people	Web Application for monitoring the movements of home quarantine people and alerting and restricting them to their residence
	e-PDS essential services	Under e-PDS essential services, implementation of 50% Additional Allocation of food grains done
	Chain for Regular Allocation ePDS/NFS application	Completion of Supply Chain for Regular Allocation of June 2020 Modifications done in ePDS/NFS application for provision of Additional allocation (PMGKY) of 4 Kg Wheat and 1 Kg Rice per house hold.
	PMGKY Allocation	Provision made for additional allocation of fresh commodity, Pulse under PMGKY.
	dddccovid19.in	Dedicated Web Site (dddccovid19.in)
Dadra Nagar Haveli, Daman & Diu	E-Pass System	E-Pass System for public
	Volunteer Registration System	Volunteer Registration System
	PDSTracker	PDSTracker
	Health Data Tracker	Health Data Tracker (Covid19 data)
	Industries Duty Pass management	Industries Duty Pass management
	COVID19 Dashboard	COVID19 Dashboard for control room
	Covid 19 Webpage	Covid 19 Webpage (District)
Chhattisgarh	Online donations for the CM relief fund	Website http://cmrf.cg.gov.in for collecting online donations for the Chief Minister's relief fund for homeless and weaker sections affected due to the Corona outbreak. The online donations feature is powered by Serviceplus.
	Registration of migrants workers	Application launched for registration of migrants workers stuck in different states and wish to comeback their home state.
	Social Welfare department	Android app is developed for the Social Welfare department, to collect the information of the free food distribution being done to the poor and homeless persons.
	e-Petition filing web application	Security Audit got cleared for e-Petition filing web application of Chhattisgarh State Electricity Commission. Hosting on Cloud is in progress.
	State and district officials on Arogya Setu Dashboard	Necessary demo and training given to State and district officials on Arogya Setu Dashboard including DIOs
	RATI App	Necessary Demo and training was imparted to State & district officials on RATI App.
Bihar	Online e-Pass	Online e-Pass for COVID-19 Disaster using ServicePlus (https://serviceonline.bihar.gov.in) implemented for movement of vehicle / person during lockdown / curfew in 34 districts of Bihar. The software has also been shared with few other states.
	Bihar Aapda Sahyog Portal	The portal has been developed to allow entry of details of family those do not have any Ration Card at this stage. A onetime Rs. 1000 financial assistance is being provided through the portal.
	MukhyamantriVishesh-SahayataYojana	Mobile App based registration has been introduced for Migrant Workers stranded outside Bihar due to Lockdown. A sum of Rs. 1000 has been transferred to about 16.25 Lakhs workers out of 25.20 Lakhs registrations.
Assam	COVAAS (Corona Virus Alert Assam) mobile App	COVAAS (Corona Virus Alert Assam) mobile App, developed by NIC Assam, brings a host of services and information related to the pandemic on to a single platform for the convenience of the administration and citizens alike
	Covid-19 Advisory Portal	Covid-19 Advisory Portal http://covid19.assam.gov.in is a more comprehensive web portal counterpart of COVAAS. It provides additional information on all Covid-related schemes, district case details, Central/State/WHO advisories, training/capacity-building videos and materials, etc.
	COVID Suraksha	COVID Suraksha is a suite comprising an Android mobile application and a web-based application portal, developed by NIC Assam, for ensuring that Home Quarantine cases are being properly monitored by the assigned surveillance teams of health workers. It provides regular real-time online feedback on the performance of the Surveillance Teams, to the District Administration. The App is equipped with QR code/scanner and GPS tracking.

	Curfew ePass	Curfew ePass developed by NIC Assam on ServicePlus platform has facilitated regulated movement of authorized vehicles and persons at different levels during the lockdown. The initial ePass Application was for vehicles plying for essential services, this was followed by passes for inter-district movement of citizens both by private vehicles and state transport corporation buses, and finally the software was updated to include passes for vehicles of vendors selling fruits and vegetables. Applicants apply online for the passes uploading required documents, district administrations concerned approve online and the e-passes are delivered to the cell phones of the applicants. Nearly 1,60,000 e-passes have been through the system, out of which 70,000 ePasses have been generated.
	Inter-State E-Pass	This was launched for people from other states to reach Assam. Already 80,000 applications received in the system.
Arunachal Pradesh	Covid-19 Services under e-District through ServicePlus	Application for vehicle passes on essential services during the lockdown period.
	Application to extend Covid-19 financial aid	Application to extend Covid-19 financial aid for the people of Arunachal stranded in other states
	e-Permit	Three services for generating e-Permit for exempted economic activities like temporary road permit, agriculture & allied services and construction under lockdown.
	Online Ticketing System	Facilitated online booking of tickets for intra state movement of people through online ticketing system in collaboration with NIC Uttarakhand.
	Aarogya Setu	User creation and awareness related activities taken to assist district officials through DIOs on usage of Aarogya Setu portal.
Andhra Pradesh	Rapid Antibody Test & RT-PCR	User Data Collection and Awareness activities taken up to assist district officials through DIOs on usage of Rapid Antibody Test & RT-PCR portal.
	PDS	Taken up distribution of PDS twice in the month of April-2020 with PMGKY.
	LGD	Local Government Directory (LGD) was shared with the State Command Control centre for various Districts in the states.
	High Court	Online E-Filing of High Court Cases during the Lockdown period.
	NTR UHS	Developed application to collect the details of the students from Medical, Dental, AYUSH, Nursing, Physiotherapy and Para. Medical colleges under DrNTR University of Health Sciences, to work as Covid-Warriors.
Andaman and Nicobar Islands	Covid19CC, Aarogya Setu App.	Support provided to Covid19CC, Aarogya Setu App.
	Technical support to ICMR	Provided web room support to many departments from NIC State Unit.
	Teaching materials Uploading	Helped education department to upload the teaching materials

Figures

Figure 1

Layered architecture of COVID 19 digital response framework in India

Figure 2

Work-flow and field entry updates of Covid India Portal

Figure 3

Data flow between AarogyaSetu app and ICMR portal

Figure 4

Integration of electronic vaccine intelligence network to CoWIN. Source: MoHFW CoWIN manual chapter 16 [30]

Figure 5

Flow of data during the COVID-19 management

Figure 6

Daily number of COVID 19 confirmed, recovered, and deceased cases in India

Figure 7

Statewise total number of confirmed, recovered, and deaths

Figure 8

Weekly RTPCR tests conducted by various States

Figure 9

Daily number of COVID 19 confirmed, recovered, and deceased cases in Maharashtra

Figure 10

Daily number of COVID 19 confirmed, recovered, and deceased cases in Andhra Pradesh

Figure 11

Daily number of COVID 19 confirmed, recovered, and deceased cases in Karnataka

Figure 12

Daily number of COVID 19 confirmed, recovered, and deceased cases in Kerala

Figure 13

Daily number of COVID 19 confirmed, recovered, and deceased cases in Delhi