Integrating Communities Under The Umbrella Of Big Data For Effective Public Health Policies

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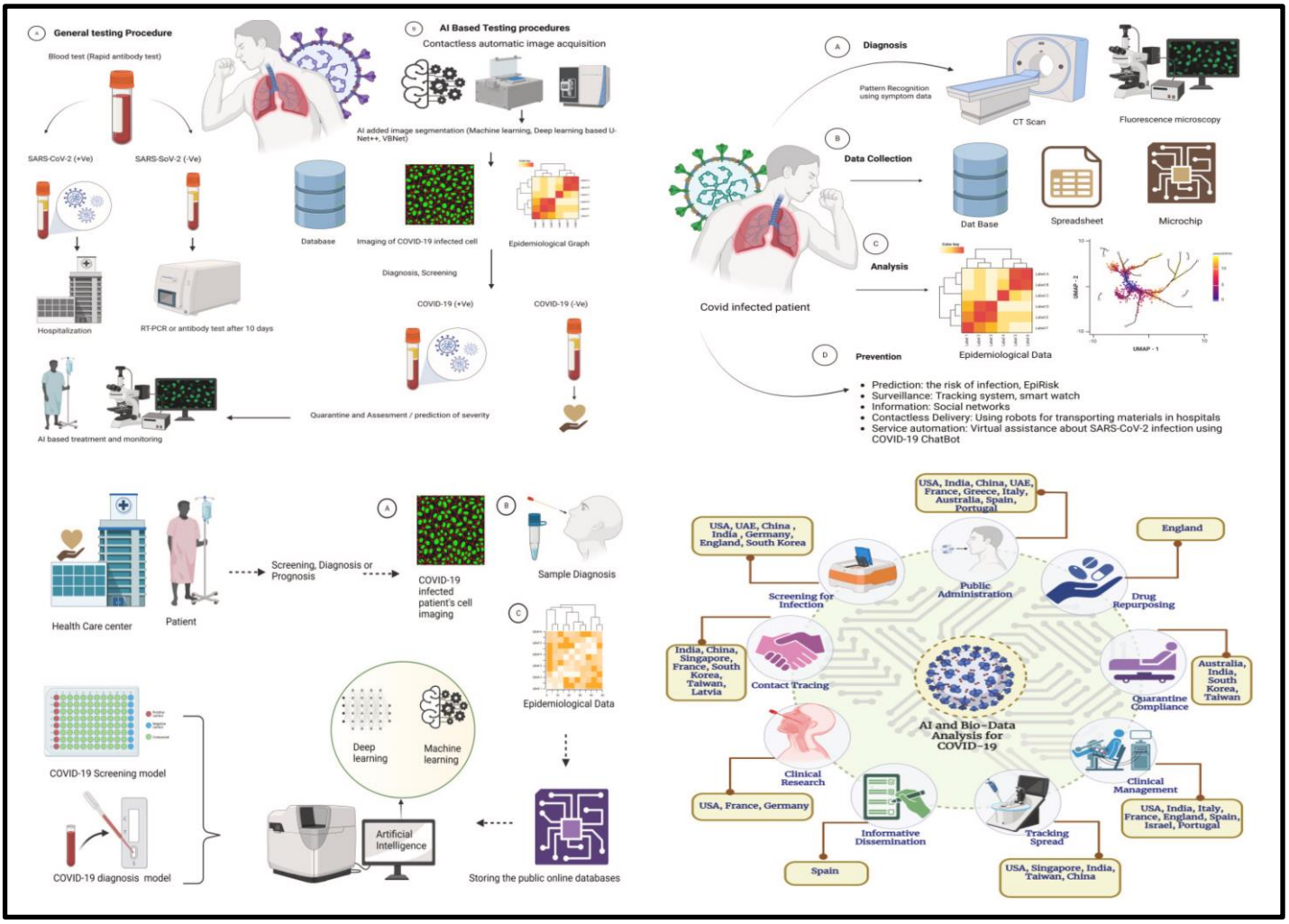

Source: Application of artificial intelligence (AI) to control COVID-19 pandemic, Current status and future prospects - ScienceDirect

Abstract

The sudden emergence and the uncontrolled spread of the COVID-19 virus in 2020 in becoming a global pandemic without any previous learning or precedent or understanding about its configuration, behavior, spread and speed of transmission led to public administrations and institutions turning towards technology for prompt management of the crisis. This paper discusses the multiple steps employed by public administrations and other associations through the application of Big Data analytics (BD) and Artificial Intelligence (AI) for various objectives, viz., the prognosis of outbreaks, detection of symptoms and diagnosis of infected individuals, contact tracing and identifying disease hotspots, measures to constrain the spread of the pandemic and plotting the future action plan. Further, BD and AI have also enriched research studies by simulating viral morphology and its evolution; delivering precise medical diagnoses and offer appropriate medication for the treatment of patients. It proved invaluable help for hospitals in anticipating the demand for medical resources for suitable allocation. In responses to this pandemic, BD and AI empowered many governments across the world to mitigate the pandemic effects and tackle the immediate public health emergencies with effective policies, real time.

Additionally, the smartphone apps have enabled easy access to medical help and contact tracing amongst millions at a time of social distancing. It aided rigorous investigation of disease outcomes, raised public awareness about the pandemic, tracked the outbreak amongst patients, especially those suffering from co-morbidities. This article also highlights the role played by the Indian Government to combat the Coronavirus, the evolution of the ‘Aarogya Setu’ application, the functioning technology utilizing GPS and Bluetooth features, benefits to the society and the challenges it encountered. Continued usage of such apps can help the governments to build a significant infrastructure for tackling both the current outbreak and future pandemics.

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Introduction

The early part of the 21st century experienced the surge in contagious infections and illnesses across the world; for example, SARS, H1N1, MERS, Ebola and Zika Virus, and then the COVID-19 pandemic which stands as a global pandemic. The spread of this new pandemic took the world by surprise as being a fresh ailment there was inadequate knowledge and comprehension regarding the disease; for example, from the cause of the pandemic and the total impact of the infection to the ailment-incubation-duration and the time during which the disease became infectious. Additionally, there are plenty of other mystery elements with regards to the COVID-19 pandemic, for instance, how long does the virus exist in the environment, can surface contact point to transmission, how does the new virus strain vary from the earlier known strains, what is the fresh virus' demeanor and its capacity to infect individuals, identify the scale of infections and whether the patients infected earlier and later healed will be immune from a re-infection. Further, the velocity of the pandemic's spread across the globe and the high mortality heightened global anxiety about the virus.

A suggested manner in which a pandemic of this scale can be controlled is by a collective strategy of doctors, scholars, scientists and technology experts to investigate a study on preventive or curative actions. Additionally, governments and private enterprises should collaborate to facilitate sufficient and timely inputs and aids and ensure proactive news dissemination, clarity of efforts and resource sharing; which would be effective to tackle the pandemic scenario effectively. Also, non-profit institutions should strive towards the rescue of weak societies that are worst hit by the pandemic.

Technology and AI play a major role in controlling the spread of the pandemic. An exhaustive collection of data using Big Data revealed a starting point to assess the spread of the global pandemic. An advancement in access to epidemiology knowledge obtained via real-time spatial databases representing the number of COVID-19 patients in a particular area, their disease intensity, availability of medical care for pandemic-hit patients, pandemic spread related to physical contact of individuals and trip patterns of people collected via collaborative public administration endeavors and efforts of scholar societies, facilitates effective possibilities to deal with the pandemic crisis. Identification of pandemic patterns utilizing examination of these database inputs can aid in comprehending evolutions in pandemic hotspots and aid disease surveillance efforts. Scaling the usage of analytical skills and devices for such big databases, scrutinizing the spread of the pandemic and figuring out the transnational condition of the pandemic is quoted as pandemic analytics.

Amidst these uncertainties, the centralization of all the databases and their examination helped decode insights into how the pandemic got transmitted. Armed with this, various countries, governments and private institutions utilized BD and AI for favorable management of the pandemic emergency. This study examines

the efforts of administrations and private companies in employing digital technologies to impede the spread of the pandemic. Exhibit 1 illustrates the map of COVID-19-confirmed cases reported to the World Health Organization and brings to light the early adopters of AI and other cognitive mechanisms.

Exhibit 1: Application of big data analytics and AI and total reported COVID-19 cases by different nations

Source: World Health Organization. WHO Coronavirus (COVID-19) Dashboard. 2021

Applications Of Big Data Analytics And Artificial Intelligence During The Pandemic For Supporting Medical Care Facilities And Formulating Public Policies

When the COVID-19 pandemic began in China, before the declaration of the World Health Organization (WHO), BlueDot, a Toronto-based contagious infection surveillance firm, had warned its customers of a collection of uncommon pneumonia incidences in Wuhan. Hence, utilizing their deep knowledge of contagious infections, and employing big data analytics and digital skills, this firm notified the likelihood of the outbreak of contagious infection. Furthermore, utilizing big data analytics, the Chinese government and private firms check the spread of the pandemic in the nation through contact tracing. Following this other nations across the globe also took swift action to check the spread of the disease using digital technology and big data analytics. Exhibit 2 explains such digital technologies employed internationally by various nations.

Exhibit 2: Application of big data analytics and AI to track the spread of the pandemic and manage the disease control activities

Country	Application area	Application/advantage	Solution	Technique/technology used	Organization and partners
Canada	Disease Surveillance	Registered a cluster of unusual pneumonia cases in Wuhan and alerted its clients of possible global spread through international air travel	BlueDot Insights—cloud platform for outbreak risk awareness	Artificial Intelligence	BlueDot
China	Clinical Research	Secondary structure prediction for COVID-19 RNA sequence to accelerate and optimize vaccine design	Linearfold Algorithm	Artificial Intelligence	Baidu Research Institute; Oregon State University; University of Rochester
	Disease Diagnosis and Clinical Research	AI model for pneumonia CT image analysis	PaddlePaddle (company's open-source deep-learning platform)	Artificial Intelligence	Baidu; LinkingMed
	Disease Diagnosis and Detection	Prediction of the probability of different pneumonia types including COVID-19	CT Image Analytics technology with deep-learning algorithm	Artificial Intelligence	Alibaba Cloud
	Disease Surveillance	Contact tracing of people and alerting for potential infection risk prediction	Close Contact Detector App	Big Data	General Office of the State Council, the National Health Commission; China Electronics Technology Group Corporations (CETC); National Health Commission, the Ministry of Transport, China Railway; Civil Aviation Administration of China
	Pandemic Prevention and Control	Visualized data for informing public of the risk-prone areas	Self-developed platforms for population flow, pandemic assessment, AI pandemic compliance monitoring	Big Data and Artificial Intelligence	Unicom
	Pandemic Prevention and Control	Modeling epidemic characteristics of COVID-19	Epidemic Prediction Solution based on machine learning	Artificial Intelligence	Alibaba DAMO Academy
	Strengthening Medical Infrastructure	Navigation map for COVID-19 designated hospitals	Baidu Map	Big Data	Baidu; National Commission of Health, China
Taiwan	Pandemic Prevention and Control	Real-time alert on high-risk zones, tracking availability of critical medical supplies, and quarantine compliance measure	Predictive analytics	Big Data Analytics	Taiwanese government
England	Disease Diagnosis and Detection	Real-time tracking of disease progression for identification of COVID-19 symptoms	Predictive model	Artificial Intelligence	ZOE Global Ltd.; UK Government Department of Health and Social Care; NHS Wales; NHS Scotland; King's College London; Massachusetts General Hospital Boston
	Disease Diagnosis and Detection	Identify abnormal chest X-rays in COVID-19 patients	Red Dot AI algorithm	Artificial Intelligence	behold.ai

	Drug Discovery	Identify highly potential compound for COVID-19 treatment	Prediction Engine	Artificial Intelligence	AI VIVO
	Drug Discovery	Predict drug combinations that would succeed against coronavirus and improve immune response	Healnet	Artificial Intelligence	Healx
	Drug Repurposing and Clinical Research	Search for pre-approved drugs with anti-viral properties	Knowledge Graph	Artificial Intelligence	Benevolent AI
	Drug Repurposing and Clinical Research	Screening pre-approved drugs to search for rapid treatments against COVID-19	Drug Discovery Platform	Artificial Intelligence	Exscientia; Diamond Light Source; Scripps Research
	Pandemic Prevention and Control	Insights through analysis of consolidated information about COVID-19, for key government decision-makers	Data platform for tracking the spread	Big Data, Cloud Data Processing and Artificial Intelligence	National Health Service, UK; Microsoft; Amazon Web Service; Google; Faculty; Palantir
United States	Clinical Research	Visualize connections across millions of unique research documents and publications to expedite research	Tellic graph.C19	Artificial Intelligence	Tellic LLC
	Clinical Research	Real-time tracking of COVID-19 specific T-cell response for Vaccine development	ImmuneCODE based on machine learning	Artificial Intelligence	Adaptive Biotechnologies; Microsoft
	Clinical Research	Prediction of protein structure to understand SARS-CoV-2 virus structure	AlphaFold	Artificial Intelligence	Google's DeepMind
	Clinical Research Pandemic Prevention and Control	Identification of effective treatments and policies for managing COVID-19	CORD-19: COVID-19 Open Research Dataset	Artificial Intelligence	Allen Institute for AI (AI2); The White House Office of Science and Technology Policy (OSTP); National Library of Medicine (NLM); Chan Zuckerburg Initiative (CZI); Microsoft Research; Kaggle (Google); Georgetown University's Center for Security and Emerging Technology (CSET)
	Disease Diagnosis and Detection	Early detection of pneumonia associated with COVID-19 infection	AI algorithm	Artificial Intelligence	UC San Diego Health; Amazon Web Service
	Disease Monitoring and Management	Remote health care delivery for COVID-19 patients	Remote-monitoring system	Artificial Intelligence	Baptist Health; Mayo Clinic; Current Health Ltd
	Pandemic Prevention and Control	Visualize and track COVID-19 reported cases	Web-based interactive dashboard	Artificial Intelligence	Center for Systems Science and Engineering (CSSE), John Hopkins University
	Pandemic Prevention and Control	COVID-19 projections and state-wise data	COVID-19 case tracking dashboard	Artificial Intelligence	Institute for Health Metrics and Evaluation, University of Washington
European Union Nations	Clinical Research	Mining and analysis of research content from publications, clinical trials, patents etc. for helping researchers accelerate their research activities	Clinical Research Navigator (CRN) tool	Artificial Intelligence	Expert System; French national institute for Health and Medical Research (Inserm)

	Clinical Research	Provides insights to researchers about cause and progression of diabetes and helps understand impact of SARS-CoV-2 infection on diabetes patients	Neo4j Graph Software	Artificial Intelligence	DZD (Deutsches Zentrum für Diabetesforschung)—German Centre for Diabetes Research; German Society of Infectious Diseases (DGI); German Center for Infection Research (DZIF)
	Disease Diagnosis and Detection	Identify COVID-19 patients with chest X-ray analysis	Lunit INSIGHT CXR	Artificial Intelligence	Lunit
	Disease Surveillance	Heat map visualizing the spread of coronavirus infections	Vodafone Analytics Platform	Big Data and Artificial Intelligence	Vodafone
	Pandemic Prevention and Control	Automated information dissemination for pandemic awareness	Hispabot-COVID19	Artificial Intelligence	Sngular; Spanish Government
	Pandemic Prevention and Control	Map mobility flows to facilitate containment of COVID-19 pandemic	City Analytics—Mobility Map	Big Data	Enel X; HERE Technologies
Singapore	Pandemic Prevention and Control	Real-time monitoring of compliance with social distancing norms	SafeDistancer	Artificial Intelligence	AI Hub Singapore
South Korea	Disease Diagnosis and Detection	Quick identification of COVID-19 suspected patients by analyzing chest X-rays	Lunit INSIGHT CXR	Cloud technology and Artificial Intelligence	Lunit
	Disease Surveillance	Automated epidemiological investigation by contact tracing	Smart Management System	Big Data	Government of South Korea
	Strengthening Medical Infrastructure	Quick development and distribution of COVID-19 test kits	Artificial intelligence-based big data system	Big data and Artificial Intelligence	Seegene Inc
Israel	Disease Diagnosis and Detection	Monitoring disease progression and recovery through analysis of patient voice samples	VocalisCheck	Artificial Intelligence	Vocalis Health; Israeli Ministry of Defense
	Disease Monitoring and Management	Prediction of surge in ICU admission and proactive management of disease severity and resources	CLEW-ICU predictive analytics platform	Artificial Intelligence	Sheba Medical Center; Ichilov Hospital; CLEW
Australia	Pandemic Prevention and Control	Developing epidemiological models to understand the impact of COVID-19 and assist decision-makers	Data Modeling	Big Data	Australian Government; Quantium Group Pty Ltd
United Arab Emirates	Disease Diagnosis and Detection	Detection of risk and exposure to COVID-19	Aya, virtual personal assistant	Artificial Intelligence	Nabta Health
	Disease Diagnosis and Detection	Rapid detection of SARS-CoV-2 infection	LamPORE assay	Cloud technology and Artificial Intelligence	Group 42; Oxford Nanopore Technologies
	Pandemic Prevention and Control	Predict the infection rate and plan response against COVID-19	Impact Assessment Tool (IAT)	Artificial Intelligence	Abu Dhabi Health Services Company (Seha); Draper and Dash
	Strengthening Medical Infrastructure	Tracking and management of health supplies during COVID-19	asset.ai	Artificial Intelligence	Dubai Health Authority; Nybl

India	Disease Diagnosis and Detection	Rapid self-use test for COVID-19 detection	CoviSelf	Artificial Intelligence	Mylab Discovery Solutions
	Disease Monitoring and Management	Rapid detection of COVID-19 by analyzing chest X-ray and instant triage	Red Dot AI algorithm	Artificial Intelligence	Apollo Radiology International, Apollo Hospitals Group; Behold.ai
	Disease Surveillance	Monitoring crowd and providing real-time alerts to authorities for ensuring compliance to social distancing and lockdown rules	Smart Technology Solution	Artificial Intelligence	Larsen & Toubro's Smart World & Communication; Municipal Authorities across 20 cities
	Pandemic Prevention and Control	Real-time alerts on digital proximity with a COVID-19 infected patient	Aarogya Setu App	Big Data Analytics	National Informatics Centre (NIC), Ministry of Electronics and Information Technology, Government of India
	Pandemic Prevention and Control	Assistance to authorities in contact tracing, diagnosis, patient triage and remote monitoring of COVID-19 patients	qXR and qScout	Artificial Intelligence	Qure.ai

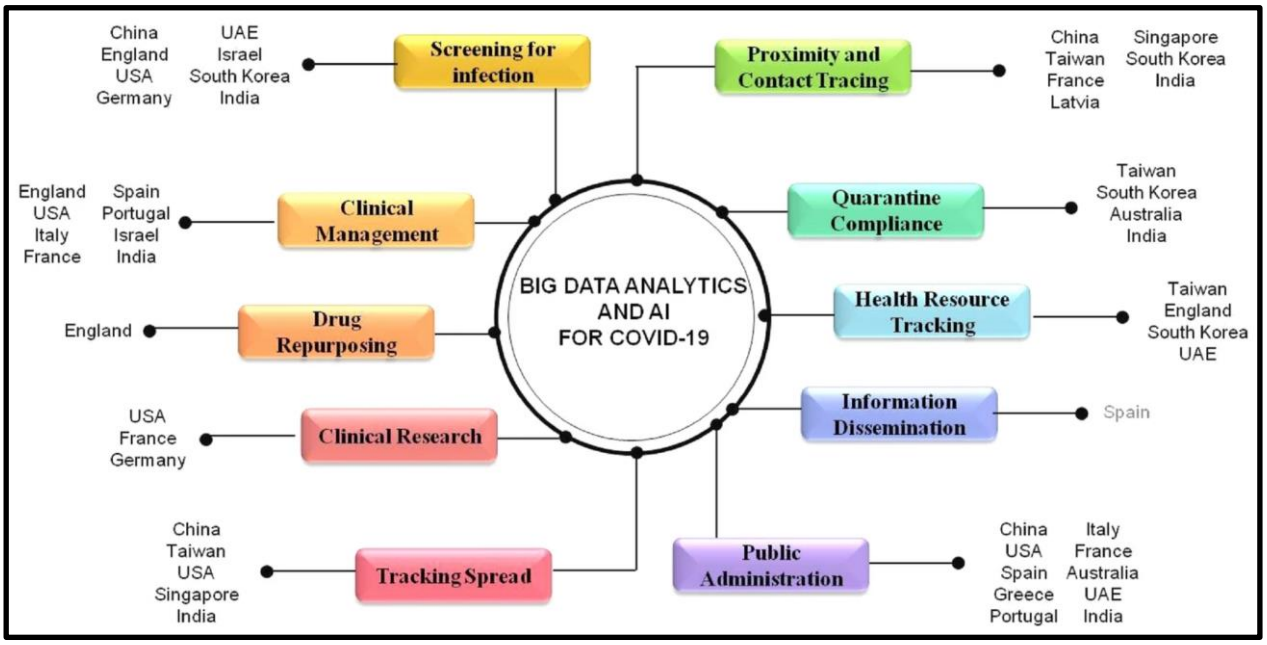
Source: Pandemic Analytics: How Countries are Leveraging Big Data Analytics and Artificial Intelligence to Fight COVID-19? SN Computer Science, Springer Nature Link

Discussions And Conclusions Based On Big Data Analytics And Artificial Intelligence Applications Initiatives

To minimize the adverse consequences of COVID-19 on human fitness and medical care; diminish economic losses and regularize the new normal scenarios, administrations and private institutions in various countries employed AI and various advanced analytical mechanisms. The first step was contact tracing for which multiple digital applications were employed extensively to understand the extent of virus transmission. Additionally, many nations used analytical mechanisms for medical diagnosis as well as for health monitoring and management of pandemic-impacted victims. Big data analytics were utilized for clinical study and speeding up medication findings and healthcare expansion.

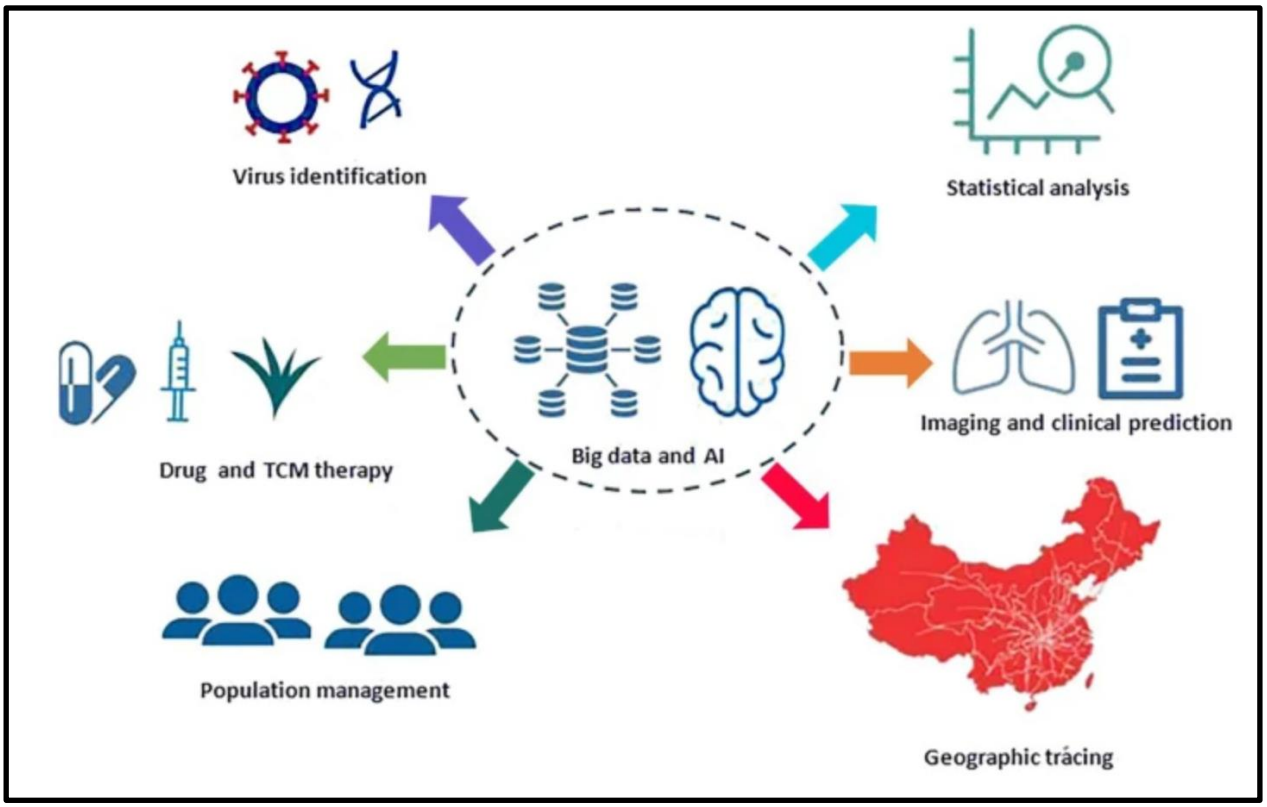
Furthermore, cognitive analytics was employed for managing medical care management and valuable judgment consent, which comprised applications like securing the gush of accurate data; recognizing regions with a demand for medical aid and assuring sufficient medical care allotment; deciding the necessity for quarantine period; and developing robust procedures to control the spread of the pandemic. Exhibit 3 illustrates big data analytics and artificial intelligence initiatives utilized by nations for pandemic tracking and related responses. Exhibit 4 discusses the detailed application of big data and artificial intelligence in various domains of solving the pandemic crisis; striving to facilitate prevention, diagnosis, treatment and administration conclusions related to public healthcare.

Exhibit 3: Big data analytics and artificial intelligence endeavors employed by multiple countries for COVID-19 pandemic tracking and related reactions



Source: Pandemic Analytics: How Countries are Leveraging Big Data Analytics and Artificial Intelligence to Fight COVID-19? SN Computer Science, Springer Nature

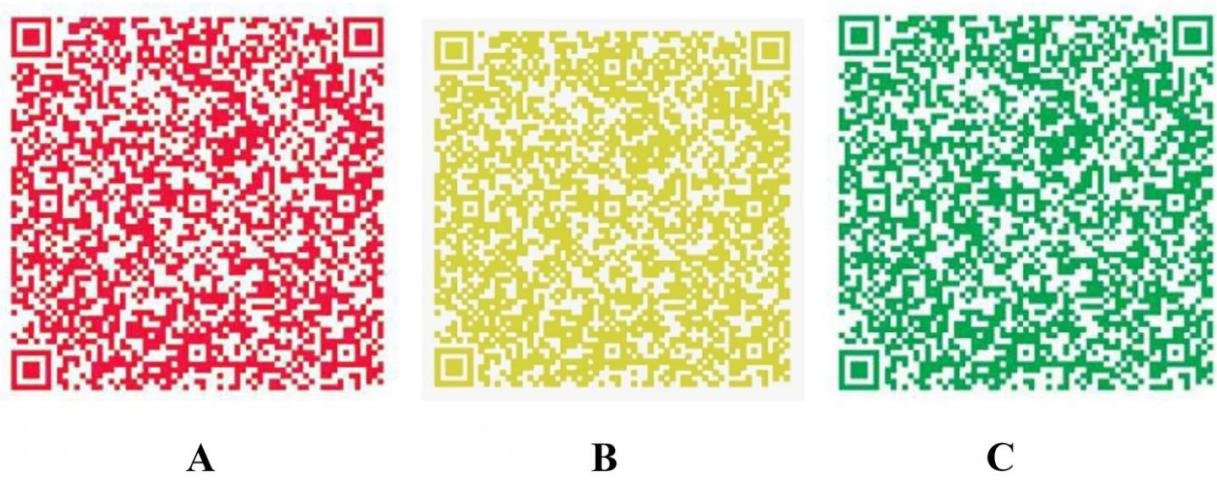
Exhibit 4: Big data analytics and artificial intelligence summed up domains in pandemic prevention and control



Source: Application of Big Data and Artificial Intelligence in COVID-19 Prevention, Diagnosis, Treatment and Management Decisions in China, Journal of Medical Systems, Springer Nature

Another beneficial finding using the big data platform was to differentiate individuals who have contracted the disease or have been in close contact with a COVID-19 patient or if the individual is totally healthy. Two-dimensional medical code images with three red, yellow and green colors were created to segregate the population into three classifications. This assisted public administrations, medical organizations and societies to take appropriate measures corresponding to control, prevention, supervision or surveillance steps. Exhibit 5 explains this concept.

Exhibit 5: Real-time disease tracking using different health color codes for identifying the population to prevent the spread of the pandemic

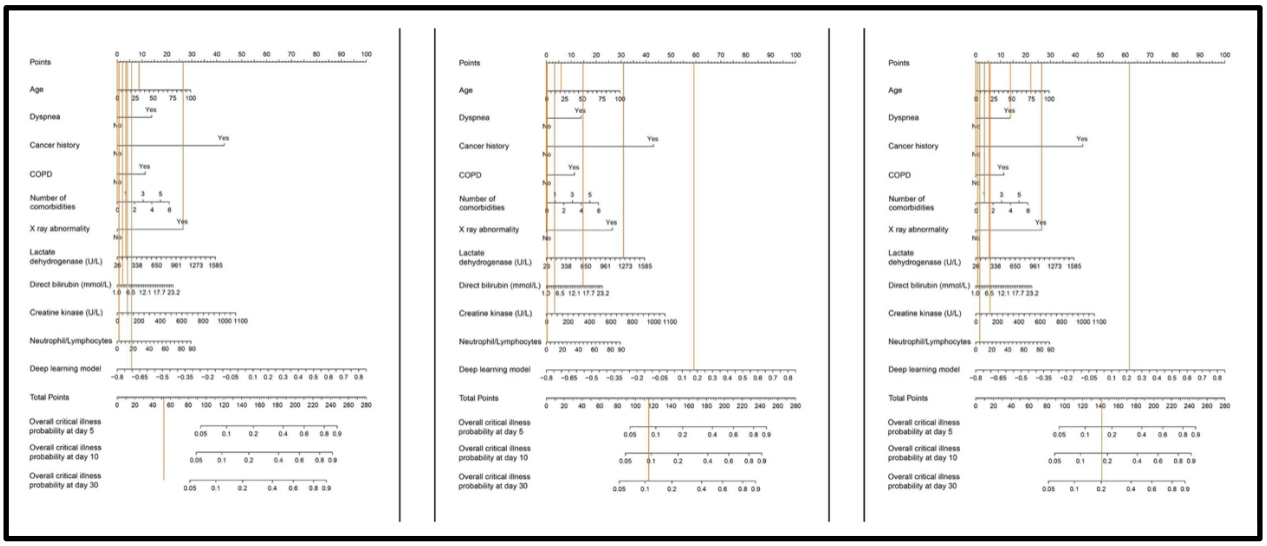


The definition of populations represented by different colour health codes. A: Red code: including confirmed cases, suspected cases, asymptomatic cases, persons who had close contact with confirmed cases, and persons under medical observation. B: Yellow code: including fellow travellers who have no close contact with confirmed cases, persons registered in fever clinics, persons with discomfort such as fever, fatigue, cough, diarrhoea and conjunctival congestion or persons who left a high-risk epidemic area in the past 14 days. C: Green code: indicating that the health status of the holder is basically normal, without discomfort, and that they are allowed to move around and resume work and production.

Source: Application of Big Data and Artificial Intelligence in COVID-19 Prevention, Diagnosis, Treatment and Management Decisions in China, Journal of Medical Systems, Springer Nature

Additionally, a discovery made by a Chinese physician, Zhong Nanshan, in collaboration with the Tencent-affiliated artificial intelligence laboratory combined profound learning technology with a conventional Cox model to conduct survival estimation on the nonlinear impact of clinical covariates was used globally to aim for foreseeing the clinical result of the pandemic impacted patients. 10 clinical characteristics with statistically notable risk ratios were identified connected to patients with serious diseases by machine learning, and a COVID-19 prognosis prototype was formulated as discussed in Exhibit 6.

Exhibit 6: The nomogram prediction results of three different severe cases by the COVID-19 model developed by Zhong's team



Source: Application of Big Data and Artificial Intelligence in COVID-19 Prevention, Diagnosis, Treatment and Management Decisions in China, Journal of Medical Systems, Springer Nature

Impediments Of Data-Driven Measures To Prevent The Spread Of COVID-19

Nonetheless, utilizing big data and predictive analytics for technical applications to control the spread of the pandemic can lead to several challenges.

Privacy issues and data security: Nations that depended on geographical location data to track the stretch of the pandemic have put forward problems about disclosing sensitive personal healthcare information and disrupting privacy. Further, the exchange and accumulation of healthcare databases from various authorities pose a hazard to the protection of healthcare databases and there have been examples where cybercriminals were phishing the institutions involved in COVID-19 vaccine study analysis and allotment.

Absence of pre-existing medical database: Due to the recency of the pandemic virus, there was little knowledge about its transmission, incubation time required, related pathophysiology and span of the disease-related infection. Additionally, there was a lack of a database on the magnitude of protection, period of immunity and the likelihood of re-infection after contracting the virus earlier. Furthermore, the genetic evolution of the virus and the growth of various mutant variants over a span, make forecasting the pandemic incidence and results, more complicated.

Interoperability and availability to real-time databases: The beneficial usage of databases in the medical field has been restricted due to the absence of cross-system interoperability, which has intensified during the spread of the COVID-19 era and has impeded real-time access to disease therapy and clinical trial databases.

Capture, recording and diffusion of medical data across various concerned organizations would mandate a manual compilation in spreadsheets for satisfactory surveillance of the pandemic emergency, hence spending additional time and resources on documenting and swapping databases which would postpone the response and cost millions of lives.

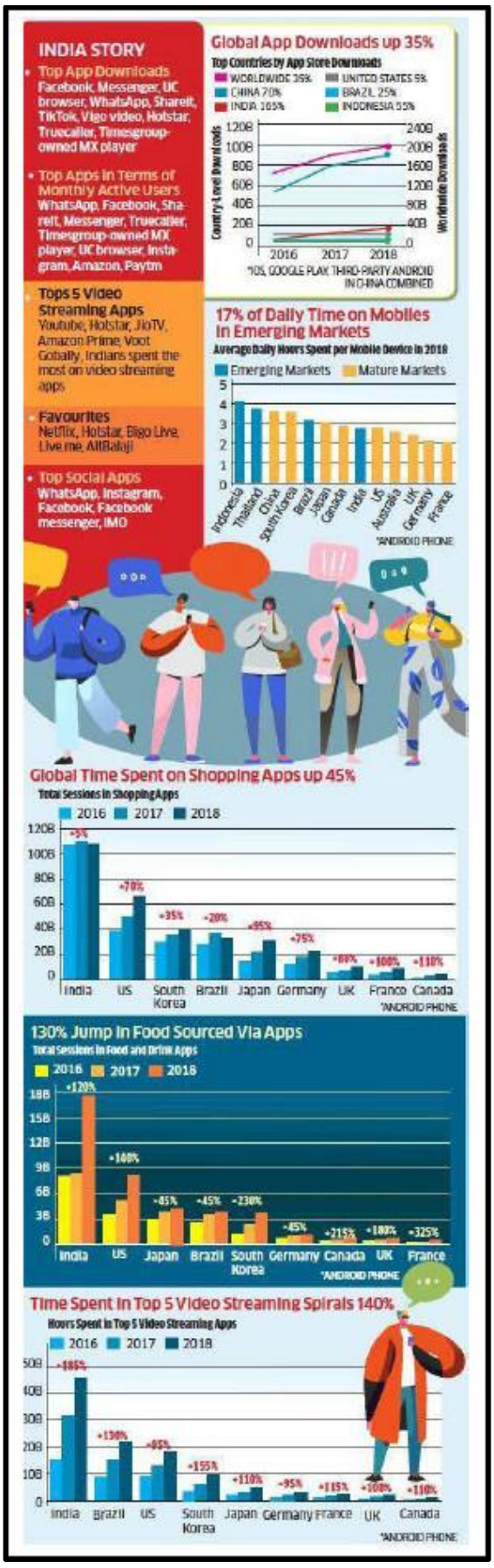
Inadequate data exchange facilities and unsatisfactory quality data collected from different sources: A majority of countries during the pandemic experienced problems with insufficient data exchange. The immediate challenges faced by public administrators and medical institutions were the consolidation of the databases that varied in their characteristics and extent, regulations connected to efficacious databases exchange, restricted economic backing and lack of global communication; resulting in the evolution of false predictive prototypes related to the pandemic.

Government Of India COVID-19 Support App Aarogya Setu

The spread of the COVID-19 pandemic has put immense strain on the medical care systems of various nations. Nations with limited numbers of doctors and healthcare professionals, for example, India were finding it hard to curb the spread of the disease and treat patients. Hence, one of the distinctive techniques needed to deal with this emergency was the software applications.

Mobile apps are computer programs or software applications developed to operate on mobile gadgets like cellular phones, tablets or smart watches and run distinct tasks for users. With the comfort of functioning on all smartphones and on both Android and IOS operating systems, the adoption success rate of mobile apps is relatively elevated as compared to additional technological innovations. Exhibit 7 depicts the leading digital apps in India and the rate of adoption of apps in India as compared to other nations. Exhibit 8 depicts different mobile applications founded by different countries to prevent the spread of the pandemic.

Exhibit 7: Top digital apps in India and the adoption of apps in India as compared to other nations



Source: Economic Times

Exhibit 8: Mobile applications founded by different countries to prevent the spread of the pandemic

Name of Mobile Application Launched	Country
Covid safe	Australia
BeAware Bahrain	Bahrain
Alipay	China
CoronApp	Colombia
eRouška (eFacemask)	Czech Republic
GH Covid-19 Tracker App	Ghana
VirusRadar	Hungary
Rakning-19	Hungary
HaMagen	Israel
MySejahtera	Malaysia
StopKorona	North Macedonia
Smittestopp	Norway
Corona Map	Saudi Arabia
WHO COVID-19 app Global	

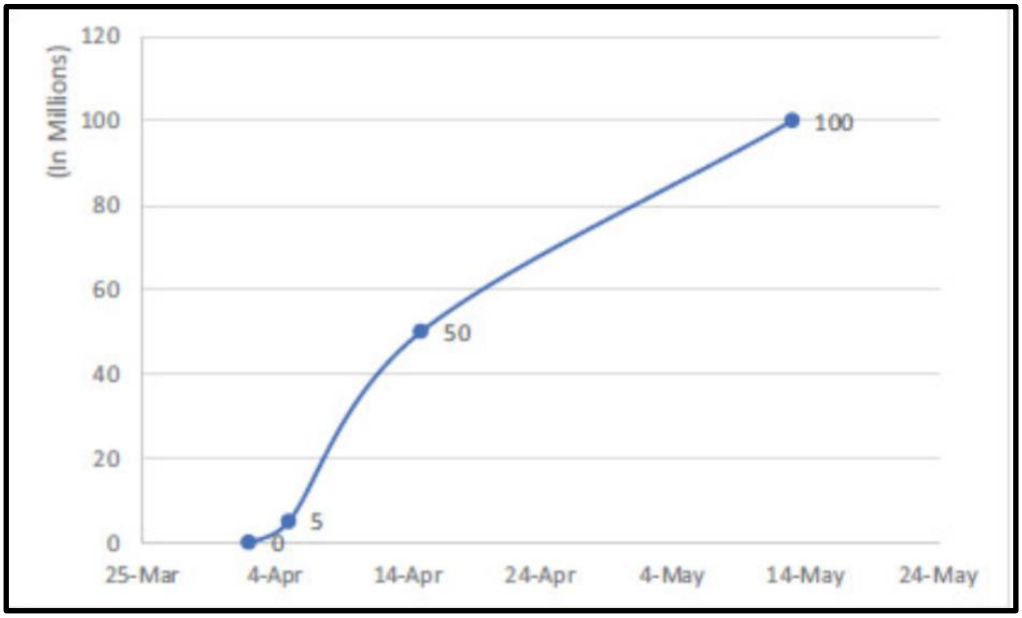
Source: Fighting Pandemic - The Mobile Application Way (a Case of the Aarogya Setu App)

The Aarogya Setu App translates as the 'bridge to health' in the ancient Indian Sanskrit language. It was created in 2020 in response to the urgent need for a database on COVID-positive patients and contact tracing, to restrain the sweep of the disease. This app was developed by the Indian Government in alliance with academia, technologists and industries. The app can be downloaded at https://www.mygov.in/aarogya-setu-app/ and is utilized by more than 190 million individuals. The app also assists the Indian public in dealing with self-detecting COVID-19 symptoms. The Aarogya Setu connects every user with their unique identification code (Aadhar Card) ensuring the validity of data and is clubbed with GPS and Bluetooth features, so it can identify the user's geographical location within a 100-metre range and provides information on active cases in the vicinity.

India, the second most populated country globally has had a significant gaps in medical care and the doctor-to-population ratio (1.34 doctors for every 1000 Indians) is extremely low. A ruffling immediate task for the Indian government was to limit the spread of the pandemic, provide rapid medical care and treatment for pandemic-impacted patients and protect lives with fixed resources. Aarogya Setu assisted in achieving this goal. India has around 451 million monthly active internet users and is home to one of the gigantic and most rapidly evolving bases of digital consumers. Additionally, the low price and availability of smartphones pushed the expansion of digitally connected customers. The nation also has the second-largest mobile subscriber base globally and the second-largest internet subscription base. Hence, the Aarogya Setu came across to be considered as a promising choice to help solve the pandemic crisis as it was economical to develop and could stretch out to a tremendous number of inhabitants in urban and rural areas at a quick rate and brief period.

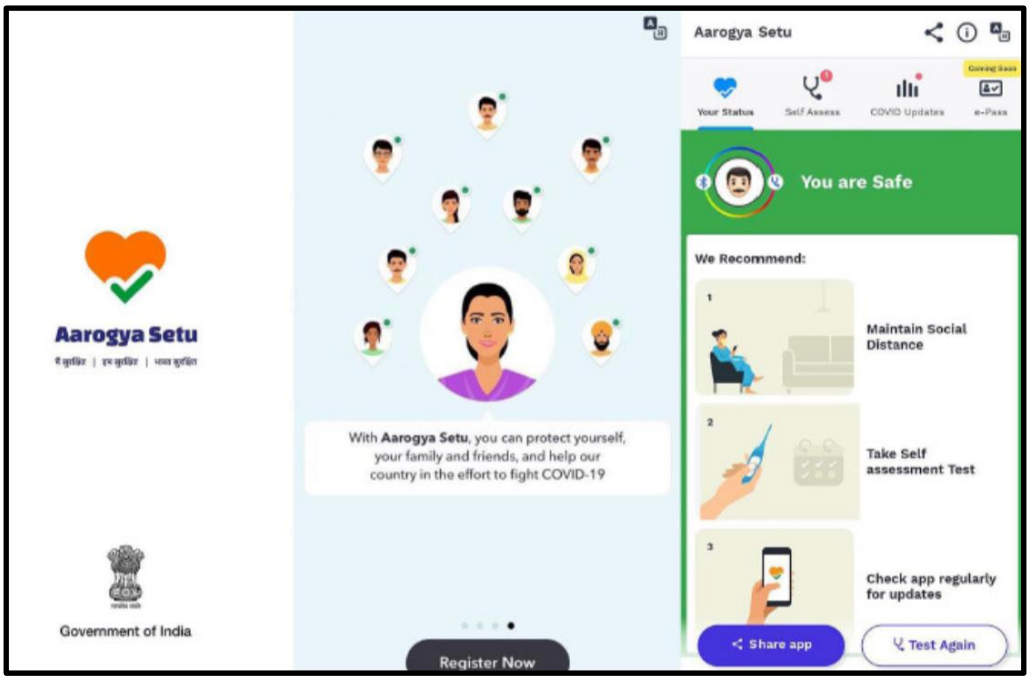
The Aarogya Setu app delivered information related to the COVID-19 pandemic, self-detection of coronavirus symptoms, control measures and had the proficiency to track infected patients thereby reducing the burden on the inadequate number of healthcare professionals, medical infrastructure. The adoption rate of the Aarogya Setu app took only 13 days to reach 50 million and 40 days to touch the 100 million people mark. Exhibit 9 depicts these details.

Exhibit 9: Rate of adoption of Aarogya Setu app in 2020 when it was launched



Source: Aarogya Setu app

Exhibit 10: Image of the Aarogya Setu app



Source: Aarogya Setu app

The government appealed to all social media platforms present in India to build awareness about the Aarogya Setu app. Furthermore, the administration made it mandatory for all public and private sector

workers to download apps on their mobile phones. The app was formulated and launched for Android, KaiOS and iOS users ensuring coverage to a broader expanse of instrument users and enriching the compatibility of the application and simpler adoption prospects. Low data connectivity and regular electricity breakdowns are some of the greatest issues in rural areas of the nation. Hence, once downloaded the application functioned with the support of Bluetooth. To cater to non-smartphone users, the administration launched the Aarogya Setu Voice Interactive Response System and helplines.

A sample study (Hense et al., 2020) using the coding technique to analyze 503 reviews on Aarogya Setu using the Google algorithm available by the users in 2020, provided user feedback on Aarogya Setu, which is depicted in Exhibit 11.

Exhibit 11: Sample survey results of users for the Aarogya Setu app

Dimensions	*n* (%)
User acceptance	418 (83.10)
Usefulness of the app	366 (72.76)
Ease of use	19 (3.78)
Data completeness and accuracy	70 (13.92)
Mobile ownership	35 (6.96)
Bluetooth use by the app	68 (13.52)
Software issues	94 (18.69)
User interface	118 (23.46)
Power consumption	33 (6.56)
App characteristics	313 (62.23)
User adoption	86 (17.10)
Government focus	115 (22.86)
Trustworthiness of the app	26 (5.17)
Recommendations on GIS and maps	80 (15.90)
Language compatibility of the app	10 (1.99)

GIS: Geographic Information Systems

Source: Kodali PB, Hense S, Kopparty S, Kalapala GR, Haloi B. How Indians responded to the Arogya Setu app? Indian J Public Health 2020; 64:S228-30

According to the Indian Government evaluation established on the initial database, it was analyzed that among the Aarogya Setu app users who were suggested to undertake testing, 24% were found COVID-19 positive, almost five times higher as compared to the across-the-board COVID-19 positivity rate in the nation.

Functioning Of Aarogya Setu

In the Aarogya Setu, for tracking the pandemic the symptoms of the patient are reported and submitted. The essence of the Aarogya Setu app pertains to epidemiologists, statisticians, software technologists and solicitors. The central identity of the app is that the infection through contact is gauged as a function of proximity and time. The evolution process comprises software provision determination; operational, performance and safety testing, deployment, end-user approval, usage and inference. The procedure prerequisite determinations comprise three parts:

Edge Sensor: Bluetooth was employed as a sensing tool. Utilizing Bluetooth, contact connections can be traced. A distinctive device ID is provided to the cell phones of individual X and individual Y, which will be kept in each other's cell phones. In the case of individual X contracting the disease, the Cloud will pull out the data of mobile X; and this data would comprise the mobile IDs, period and closeness of all individuals who have come into personal connection and interaction with individual X. Established on this and regulations formulated by virologists, warning messages are sent to all the cell phone IDs that have come into physical connection with individual X. However, the privacy of all these individuals is maintained. The alerted individuals do not figure out where the message has come from. The latitude and longitude data are extremely crucial for the closest pandemic healthcare facility to reach the infected individual. Success is estimated by how many individuals operate the system.

Intermediate Data Aggregation: The Aarogya Setu app on the cell phone stores the sensed database in encrypted form and interfaces with the Cloud. It removes data that is greater than two weeks old, as a COVID-19 patient cannot transmit the disease after two weeks. The app permits the user to upload self-assessment data with the disease symptoms. The data from the cell phone will only be utilized if the individual tests COVID-19 positive.

Cloud Analytics: The self-assessment database is uploaded by the users of the app. The contacts of all COVID-19 positive-tested individuals are selected. The epidemiological prototype analyses the contact trace data to categorize each contact as high risk, moderate risk and low risk. When the database is correctly studied it saves life. The data is sent back to the cell phone of traced device IDs on the classification. Also, data linked to infection spread in the proximity and healthcare centers is provided to users.

ITIHAS (IT-enabled Telco Information based Hotspot Analysis System) is the data-driven backend for hotspot prediction. The functioning principle of ITIHAS involves the data of COVID-19-positive patients in a given location over the last two weeks to be accumulated. Self-assessment data is documented, along with

the latitude and longitude locations. Depending on the database, regions are categorized as immediate security area (pink color), scrutiny area (amber), watchlist area (light blue), and immediate watchlist area (dark blue). The aim is to recognize, warn and categorize the likely regions of disease at the pin code sub-post office level and to determine detailed sub-areas within those regions. Immediate steps are to be taken within that neighborhood concerning the cell phone numbers that have notified the disease symptoms via the app. Across India, a 100 x 100 grid-based system is adopted. The latitude and longitude of every post office is mapped onto a box on the grid. State-wise downloadable reports are formulated, with district-wise hidden C-19 areas that were not covered under hot spots.

Additionally, this app is accurately interconnected between the user, testing and vaccination institutions. The linkage between the Aarogya Setu app and the vaccination drive was done. Knowledge of how to register and hyperlink to the Co-WIN portal (vaccination portal) has been merged with the Arogya Setu app. The Aarogya Setu application also featured the e-pass facility provided for essential service providers, which was a compulsory prerequisite for localized transport movement during the pandemic lockdown.

Challenges Encountered With The Adoption Of Aarogya Setu App And The Strategies Adopted To Overcome Them

Awareness: Endeavors to build awareness associated with the app among lesser-income societies have been the greatest obstacle encountered by the government, particularly how to tap and track the populace residing in media-dark rural areas but with phones. Additionally, there is a stigma among individuals that in case an individual is not infected with the disease then why should one download the app?

Data privacy and safety related to the app: The storage of the database on a centralized public administration server has resulted in certain worries about the safety of the stored data, data access and retention. Furthermore, the application needs the cell phone's Bluetooth to be on and visible to all users to ensure that the infection situation is realized by all individuals in the local region. Nonetheless, utmost caution was taken to ensure not to disclose the identity of the infected user, but certain users indicated suspicion associated with the privacy and security concerns related to the app.

Effectiveness of the app: Furthermore, the app relies upon the self-diagnostic mechanism of users and the users may deliver inaccurate data resulting in false prognoses. Nonetheless, to reduce these issues, all people who are tested positive during an RT-PCR lab test are automatically characterized as active by the testing lab. Numerous users contest the usefulness of the app, as it will be useful only if 50% of the population

downloads the application, which itself is tough to execute leaving aside the lack of awareness and readiness to do so. However, the app's user-friendliness is the major characteristic of its adoption.

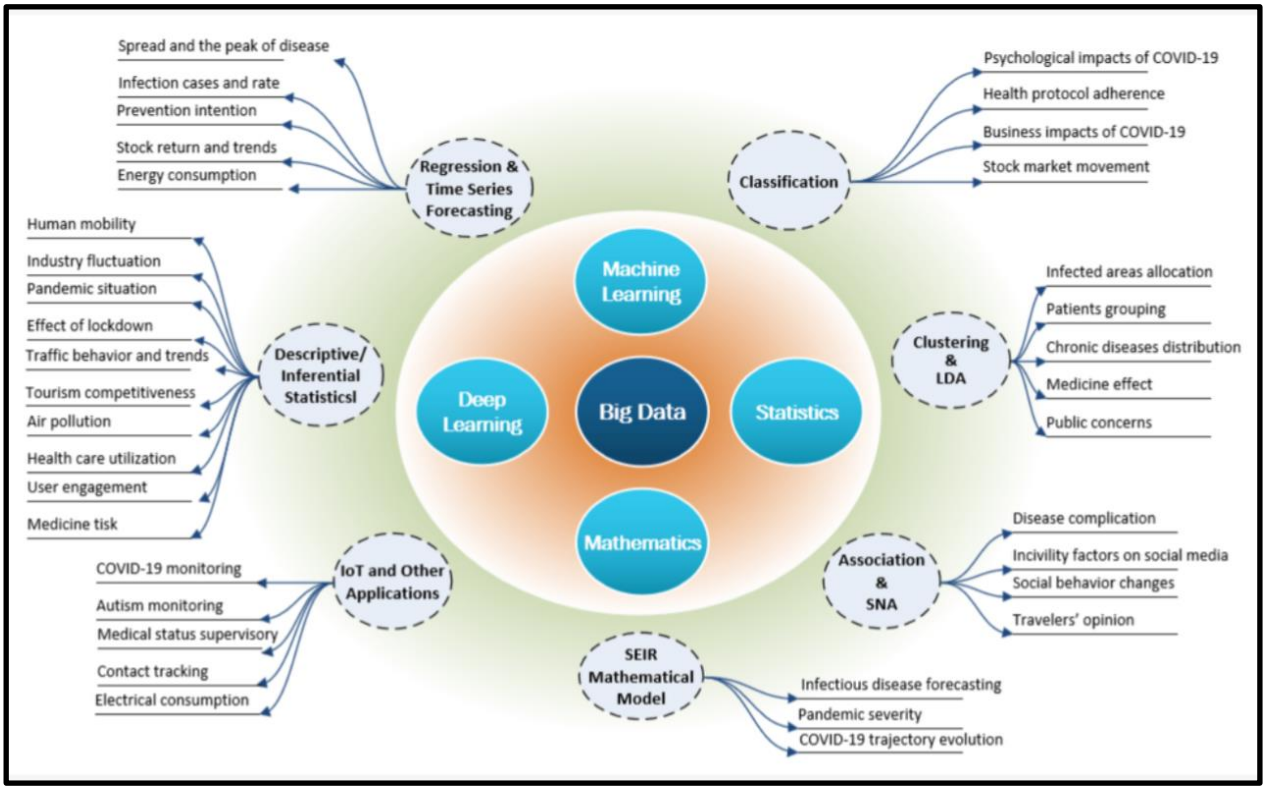
Accessibility of the app: Digital literacy, possession of cellular phones, understanding the functionality of mobiles and monetary inclusion are extremely low in certain sections of the population, particularly females residing in villages. Since the app is compulsory to employ for specific public services, it has been extremely limited activity for many rural females. Further, there are logistical challenges in recognizing the contact persons in dense localities, who travel via mass public transport are feasible and apparent.

Nonetheless, keeping in mind these obstacles there have been strategies to deal with such challenges. The app is holistically developed with multiple elements and numerous language choices securing greater user engagement and catering to various segments of the population. The application has a chatbot element to assist the user with coronavirus symptoms, updates and helpline numbers for every state. The app includes messages, announcements and videos of some famous Indian celebs who are asking readers, listeners and viewers, to utilize the different segments of the app for useful and efficacious control. The app has content related to advice from doctors which motivates the public to use the application. The application provides advice on how to boost individual immunity, recommending some home remedies as immunity boosters and how to keep engaged during quasi-quarantine. To cater to users with greater cognitive demands a learning hub feature has been put in for their engagement, where users can comprehend various methods to battle the pandemic and there is content associated with various do-it-yourself actions in the same. A positive harmony consisting of musical themes from prominent Indian artists woven into the app reduced stress levels of individuals.

Conclusion

Utilizing BD analytics and AI has definitely helped to cope with the pandemic by providing awareness of the disease, contact tracing and identifying hotspots, medical support etc. Contact tracing applications are developed to aid both the user via warning, alerting them of contacting the disease-infected patient and the community by facilitating early recognition of infection groups and formulation of practical and useful public health measures to avert further disease transmission. The warning signals sent to app users who have been in contact with disease-positive patients even enabled them to go into early isolation and restrict the sweep of the infection leading to medical expense savings. Additionally, the large-scale use of such applications is supported to be favorably cost-effective and mitigate the work applied in the labor-intensive manual tracing processes. Likewise, for countries under lockdown, such apps could be employed as a part of their exit or unlock strategies. Exhibit 12 explains these features in detail. In conclusion, Covid was cruel and brutal in its global transmission but one of the silent byproduct of that uncertain phase was the onset of the digital app which connected the dots faster for the governments working in tandem with the rise of the pandemic. Covid was reined in after millions of deaths, but the timely use of t BD and AI were leveraged means that the genie of technology cannot be put back into the bottle – for good reasons.

Exhibit 12: Knowledge mapping of analytical techniques



Source: Big Data Research in Fighting COVID-19: Contributions and Techniques, MDPI

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