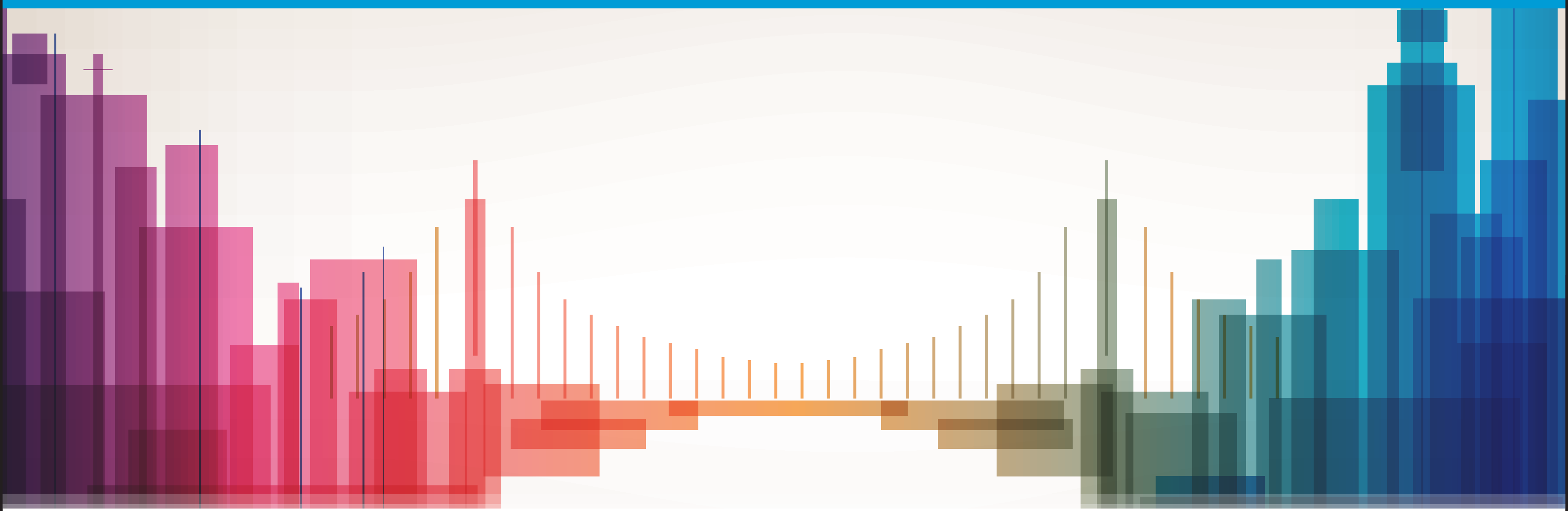
United 4 Smart Sustainable Cities

Smart public health emergency management and ICT implementations

A U4SSC deliverable on city platforms



Convention on Biological Diversity
United Nations ECLAC
Food and Agriculture Organization of the United Nations
ITU
UNDP Empowered lives. Resilient nations.
United Nations Economic Commission for Africa
UNECE
UNESCO United Nations Educational, Scientific and Cultural Organization
UN environment programme
UNEP Finance Initiative
United Nations Framework Convention on Climate Change
UN-HABITAT FOR A BETTER URBAN FUTURE
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Foreword

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Disclaimer

The opinions expressed in this publication are those of the authors and do not necessarily represent the views of their respective organizations or U4SSC members. In line with the U4SSC principles, this report does not promote the adoption and use of smart city technology. It advocates for policies encouraging responsible use of ICTs that contribute to the economic, environmental and social sustainability as well as the advancement of the 2030 Agenda for Sustainable Development.

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Executive summary

The world is currently facing an unprecedented situation owing to the Covid-19 coronavirus pandemic, which has impacted all avenues of life. Cities with growing populations have been adversely affected with significant loss of life. Despite being on the smart city transition trajectory with a variety of ICT solutions being used to fight the virus, several cities have been unable to effectively deal with the pandemic.

Smart sustainable cities (SSC), predicated on ICT-based innovation, are capable of fostering data-driven smart applications to manage limited resources and implement them to thwart the advent of future pandemics of the same magnitude. In the context of Sustainable Development Goal 3 (Global Heath) and the Sendai Framework for Disaster Risk Reduction, public health-related disasters form a core concern. Additionally, the concept of "resilience" is also elucidated in Sustainable Development Goal 1 (Poverty Eradication) and Goal 11 (Make cities inclusive, safe, resilient and sustainable).

In this scenario, linking the smart city endeavours to manage future pandemics/epidemics to the attainment of the SDGs serves a dual purpose. With the utilization of appropriate emergency communication and public health frameworks, it will become easier to develop models to predict the spread of diseases, ascertain the source of illnesses, coordinate lockdowns, detect and report symptoms, identify viral strains and provide remote assistance (as required with limited human interaction) through an IoT-based infrastructure.

Based on this premise, this document explores the context of public health and the importance of active surveillance mechanisms in the urban ecosystem to enable emerging communications for public health disasters and the incorporation of IoT, AI and data-driven frameworks to provide timely responses to epidemics and pandemics, while implementing generic public health operational processes derived from the methodologies adopted for past crises. Moreover, this document concludes with a smart public health framework, which utilizes these tools, defines a pandemic lifecycle and specifies when mass surveillance tools are applied (for dealing with the outbreak).

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List of abbreviations

AI	Artificial Intelligence
BIDS	U.S.-Mexico Border Infectious Diseases Surveillance
CDC	U.S. Centres for Disease Control and Prevention
CFR	Case fatality ratio
China CDC	Chinese Centre for Disease Control and Prevention
COVID-19	Novel coronavirus pandemic
EIN	Emerging Infections Network
EOC	Emergency Operations Centre
GOI	Government of India
H1N1	influenza A virus subtype H1N1
ICMR	Indian Council of Medical Research
ICTs	Information and communication technologies
IoT	Internet of Things
KCDC	Korean Centres for Disease Control and Prevention
MeitY	Ministry of Electronics and IT, Government of India
MERS	Middle East Respiratory Syndrome
NESID	Infectious Disease Surveillance Centre
SDGs	Sustainable Development Goals
SMG	Seoul Metropolitan Government
SSCs	Smart sustainable cities
TESSy	European Surveillance System

1 Introduction

Resilience is a broadly used term that expresses a process and not a feature with meanings that vary according to the applied domain. According to the Oxford Learner's Dictionary, it expresses *the ability of people or things to feel better quickly after something unpleasant, such as shock, injury, etc.* or *the ability of a substance to return to its original shape after it has been bent, stretched or pressed*[1].

In the same vein, according to United Nations Office for Disaster Risk Reduction[a], resilience represents *the ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt, transform and recover from the effects of a hazard in a timely and efficient manner, including the preservation and restoration of its essential basic structures and functions through risk management.* Organizational and psychological resilience express the ability of an organization to become resilient, while *city resilience represents the ability of a city to keep on operating in ways that can ensure that its community (and especially its most vulnerable members) can survive and prosper regardless of the crisis (economic, health, environmental etc.) that it experiences*[2,3,4].

Despite cities being at the core of Sustainable Development Goal (SDG) 11 for a sustainable and resilient future, the emphasis is on *resilience*, as is the case in SDG 1 (ending poverty), where it is expected to be achieved by building resilience for *the poor and the most vulnerable members of the community against extreme events* (economic, social, environmental and disasters)[5]. Closely linked to this goal is SDG 3, which is concerned with the promotion of good health and well-being for all ages, including providing health coverage and tackling health emergencies.

The current pandemic has exposed the global risks and threats posed by unpreparedness, thus lending urgency for the need to build a robust system for *early warning, risk reduction and health management*. It is believed that "worst" epidemics (single outbreaks) are most likely to occur in populations where individuals randomly mix (proportionate mixing) in cities[6]. In this context, populations living in megacities appear to be the most vulnerable, as was also confirmed during the Covid-19 crisis, where the virus spread exponentially[4,7,8,9,10].

While epidemics have occurred frequently through centuries of recorded history, in the last two decades they appear to be occurring annually with some being more deadly than others. They impact communities[11], cause national laws to be rewritten, initiate a restructuring of public health infrastructure, and encourage the application of modified methods of combating disease in the areas of surveillance and military-style lockdowns. Infectious diseases continue to be a threat to humans, regardless of age, gender, lifestyle, ethnic background and socio-economic status[12].

Despite improvements in urban conditions, including water quality and sanitary conditions as well as battling infectious microorganisms coupled with progress in developing new vaccines and antibiotics, the incidence of infectious diseases continues to be on the rise. The economic impacts and the risk to health of large-spread epidemics and pandemics are significant. Such impacts

[a] https://www.preventionweb.net/disaster-risk/concepts/resilience/.

include both immediate and long-term ones in addition to the enormous societal and economic costs.

The risk to community well-being underpins the importance of understanding this historic and complex relationship between epidemics, public health and city resilience. Such studies are rooted in the 19th century, when urbanization rates increased along with a corresponding deterioration in environmental conditions of the working class and areas that became hotbeds of diseases. High population concentrations, coupled with poor infrastructure, including the lack of clean water and sewage systems, encouraged the rise and transmission of diseases from the individual-level to entire cities and beyond. Tackling these conditions were instrumental in transforming the public's role in the control of the outbreaks, focusing on the citizenry's health and emphasizing the importance of the physical urban infrastructure. Furthermore, the failures of isolation and quarantine in combating certain diseases were countered by advances in scientific understanding of the causes as well as transmission and prevention of many contemporary outbreaks. Such progress constituted a major step in the evolution of modern public health before the early 20th century. This is best evinced in the following definition from that period: public health is "*the science and art of preventing disease, prolonging life and improving quality of life through organized efforts and informed choices of society, organizations, public and private, communities and individuals*[13]". This definition has consequently expanded the focus of public health to include the physical, social and psychological well-being of an entire community without diminishing the central component of its purpose – and that controlling and preventing disease can only be initiated by epidemiologists and in laboratories[14].

The complex array of factors that can lead to new viruses emerging and causing an epidemic makes an *emergency* very much part of the make-up of public health. It is defined as an *occurrence or imminent threat of an illness or health condition caused by bioterrorism, epidemic or pandemic disease, or a novel and highly fatal infectious agent or biological toxin that poses a substantial risk of a significant number of human facilities or incidents or permanent or long-term disability*[15]. It is also defined as *a state of affairs in which the health of a substantial portion of a community's members is either compromised or in imminent danger because of the inability of existing mechanisms for safeguarding the public's health to cope with an emergent health threat*[16]. These definitions show that an emergency can arise from natural factors (e.g., drought, earthquake etc.), human activity (war, poor sanitation, overcrowded areas, bioterrorism etc.) and illness (bacteria and viruses).

The declaration of a public health emergency permits a government to modify public liberties, suspend constitutional rights, reallocate resources, and implement *surveillance*. This is often considered a necessary public health function. In general, this term has a broad scope. Its French roots – *sur* (over) and *veiller* (to watch) – signifies the *close and continuous observation of one or more persons for the purpose of direction, supervision and control*. *When applied as part of public health measures, however, surveillance* is the *ongoing systematic collection, analysis, interpretation and dissemination of health data for the planning, implementation and evaluation of public health action*[17,18]. It does not constitute a new approach to tackling the spread of infections. In fact, public health surveillance dates back to the first recorded epidemic by Hippocrates who coined the term between 460-370 B.C.[19,20] It is only from the mid-19th century that surveillance in its current format came into being when the collection of data became key to shaping different forms of intervention. Recently, public health surveillance has become remote[21], with the introduction of various forms of distanced surveillance, including satellites and drones, and cutting-edge technologies like cameras, sensors, actuators and the Internet of Things (IoT), combined with emerging applications (e.g., dashboards, analytics and AI-based face recognition – even under masks).[22]

Surveillance systems[23] detect public health outbreaks through the routine collection of pre-defined data specific to diseases using case definitions (*Indicator-based surveillance*)[12]. Predetermined outbreak thresholds are often set for generating alerts and responses. Moreover, another detection method uses ad hoc information about acute public health events (*event-based surveillance*). A variety of official and unofficial information sources are collected to detect clusters of cases with similar clinical signs and symptoms that may not match the presentation of readily identifiable diseases. Official sources come from national and international authorities, while unofficial sources include media reports and reports from the community.

Some indicative surveillance systems are used by the U.S. Centres for Disease Control and Prevention (CDC) and others, such as a particular segment for Covid-19 known as the Emerging Infections Network (EIN), which functions as a sentinel system to monitor new or resurgent infectious diseases; the U.S.-Mexico Border Infectious Diseases Surveillance (BIDS) that was set up across the U.S.-Mexican border; EMERGEncy ID NET, a network of academically affiliated emergency medicine centres at hospitals in large U.S. cities; the ECDC also monitors for Europe through the European Surveillance System (TESSy), which includes a framework for Covid-19; the UK Public Health Surveillance System that integrated its public health and ICT strategies and launched a Covid-19 dashboard; the Australian Communicable Diseases Intelligence; the Infectious Disease Surveillance Centre (NESID); and the Chinese Centre for Disease Control and Prevention (China CDC)[12,24,25,26,27,28,29]. These are just a few examples of the endeavours undertaken. Finally, laboratory-based surveillance is utilized for emerging antimicrobial resistance.

This document intends to provide an overview of the potential of the *smart city* concept in dealing with future health related disasters, while identifying gaps in the mechanisms adopted to manage pandemics/epidemics in the past. Moreover, this document considers a smart city to be resilient, which means that the smart city infrastructure will also be resilient (i.e., redundant and sufficient) and capable of being sustainable against hazards in order to accomplish its mission.

Securing smart city resilience is difficult and is beyond the scope of this document. However, it is important that this aspect is addressed and respected because, while dealing with health-related disasters, a smart city concept should also consider the concept of "cascading disaster events or emergencies". These events are triggered by other physical hazards, which, if not considered in the preparedness and mitigation phases, can cause massive disruption of smart city infrastructure and therefore to the entire health system and services.

2 Pre-smart city responses to a pandemic: H1N1 Influenza (Swine flu)

As pandemics are events characterized by a definite time-frame, often determined by availability of a vaccine and a treatment, it is not unreasonable to wonder whether plans devised during an outbreak are shelved indefinitely or remain viable. The influenza A virus subtype H1N1 (H1N1) influenza is a case in point for which evidence can be located. Its source was a virus; there was no similar data to support specialists, and labs realized the threat early; and people had surveillance systems and technology to support them. Though briefly examined[30], it shares several attributes with the Covid-19 outbreak. It started in 1997 when the first human infected by the H5N1 avian influenza was detected. This was followed by several others within a few months and reached 400 in 2009. Public health officials could not validate that it was a pandemic since the influenza was not transmitted effectively from person to person but from exposure to a live poultry market. The preparedness period was launched in 1997 in the U.S. for this global public health disaster, which spread internationally in 2006. It included a CDC plan and the collection of clinical, laboratory and epidemic data. This crisis was followed by the H1N1 epidemic in 2009, which demanded changes and alignments to the existing planning. H1N1's mortality was lower compared to H5N1, while its symptoms are flu-like that could lead to complications of contracting pneumonia. It affected mainly the elderly demographic (over 65 years old) and its spread was mainly caused by droplets expelled from the mouths and noses of infected individuals.

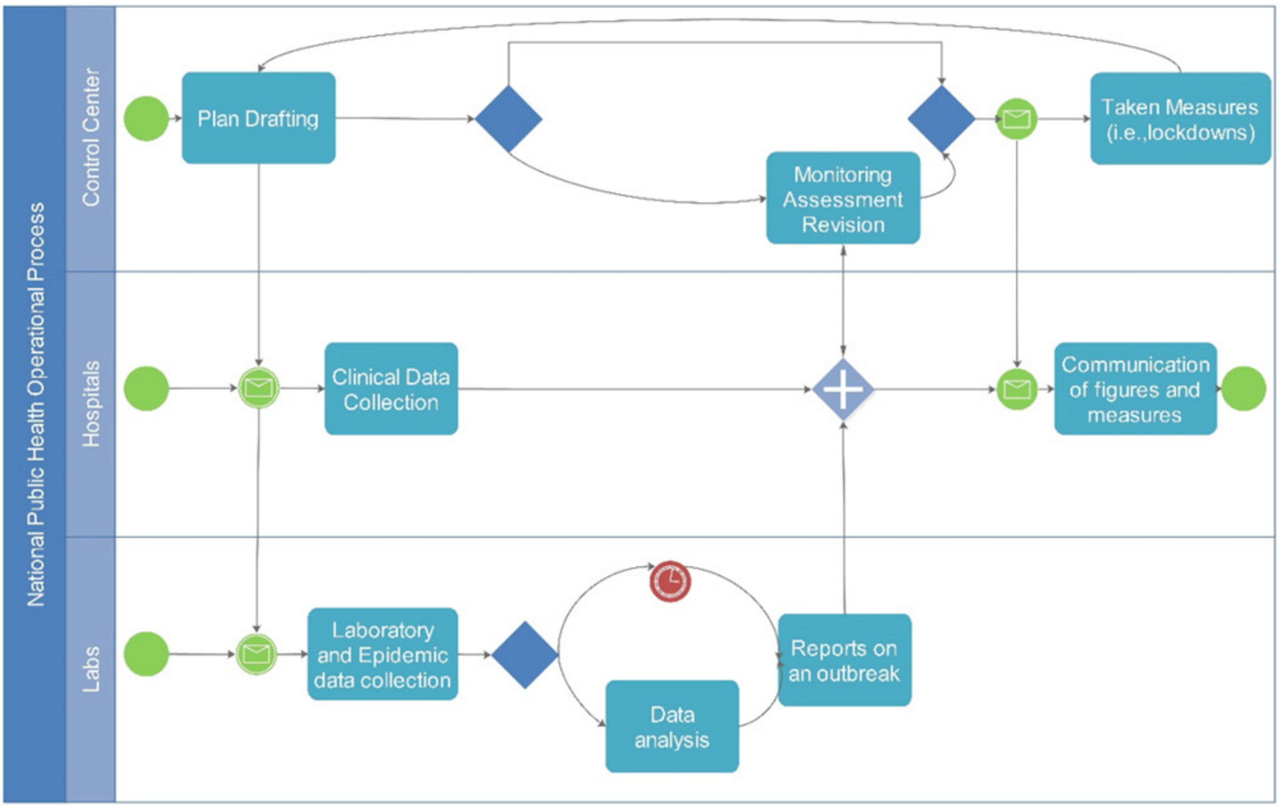
The first cases were detected with influenza-based tests in public health laboratories in the U.S. and this was considered the first success of the pandemic response. Although the first results could not recognize the virus subtype and confused it with swine-based viruses, their success was attributed to the classification of the virus in the influenza category, which assisted in generating public health alarms within 24 hours globally. The U.S. CDC undertook a complex and comprehensive set of laboratory, epidemiologic and communications measures to determine the extent and severity of each incident. The *Emergency Operations Centre (EOC)* was activated as the central public health incident management centre. *Regional surveillance* teams were launched and managed to quickly collect an increasing amount of data to deduce the extent of the spread and the severity of the illness. The regionally collected information was valuable to launch a field investigation and to raise situational awareness in relation to the pandemic. Moreover, the teams tried to determine the virus transmission process to generate accurate recommendations and to implement appropriate measures, such as restrictions and lockdowns.

The surveillance system that was launched relied on collecting data on the location, timing and severity as well as viral characteristics of influenza each season. Important information regarding the attack rates, the risk factors and the effect of medical and non-pharmaceutical interventions (school closures, isolation of infected persons etc.) were collected from the 50 U.S. states and six U.S. territories, analysed and monitored with graphs (e.g., hospitalized curve). Moreover, numerous cases were investigated, tracked and analysed for the calculation of the reproductive number and the incubation period (serial interval) for H1N1 infection. In a sensitivity analysis, making use of previous estimates of the mean serial interval, the reproductive number was estimated to be between 1.5 and 3.1 (recorded values in Hong Kong were 1.4–1.5 at the start of the local epidemic to around 1.1–1.2 later in the summer of 2009[31], which indicated that the virus was at the low end of transmissibility compared with the 1918 pandemic. More data than ever before was collected and processed during the crisis. It was then possible to describe the scope, magnitude and severity of the pandemic. Regarding the post-pandemic assessment, *case fatality ratio (CFR)* was calculated, excluding vulnerable population groups (elderly, people with chronic diseases and children, etc.). Moreover, an impact assessment framework was developed based on five measures of transmission and three measures of severity, including community, school, and workplace attack rates; secondary household attack rates; the basic reproductive number; the case-hospitalization ratio; and a death-to-hospitalization ratio in addition to the CFR.

Among the primary suggestions that the CDC provided concerned personal protective equipment, such as surgical masks. WHO declared H1N1 as a pandemic in June 2010 almost a year later and the overall response process highlighted the most important lessons learned:

1. The importance of strong public health partnerships.
2. The availability of a wide range of resources.
3. The existence of preparedness planning.
4. The importance of electronic and automated data sources.

Figure 1: Generic public health operational process

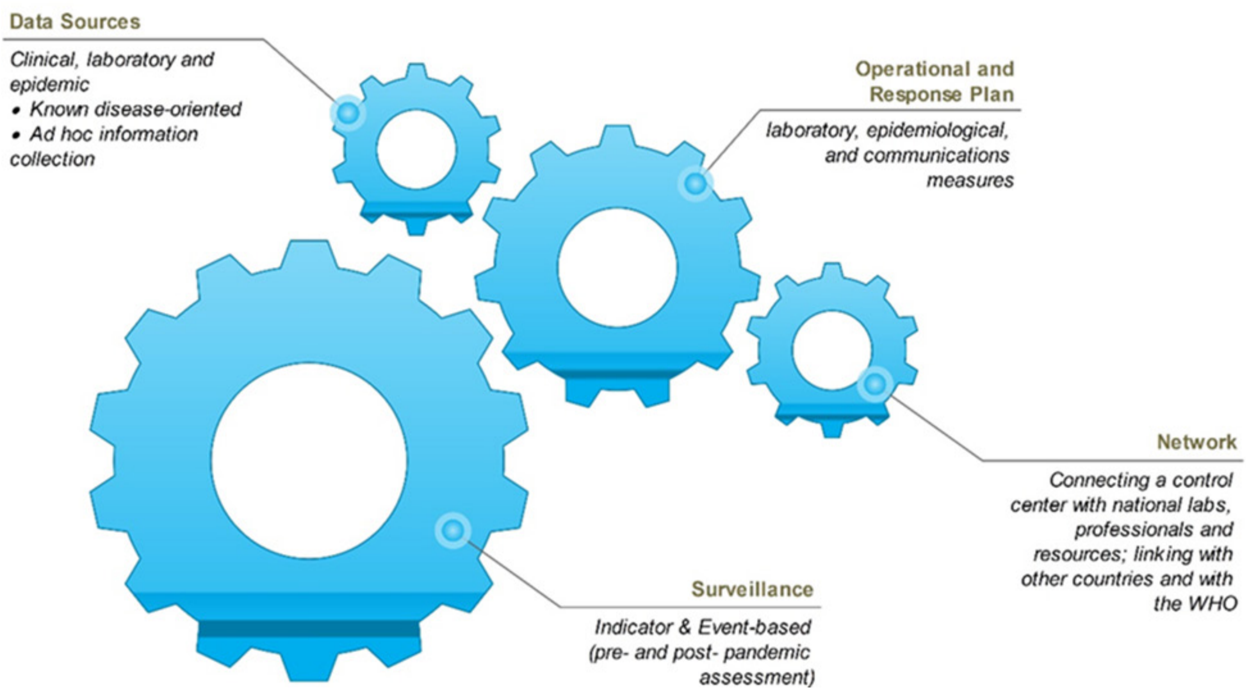


The analysis of this case, together with the theoretical findings of public health, determine the process that was followed (Figure 1), which is analysed in parallel processes running under a plan with data collection, process, analysis and communication between the centre, hospitals and laboratories. A simulation of this process execution is presented in Appendix I, which exemplifies and specifies further step 2 in the above process.

Moreover, the structure of a public health system can be depicted (Figure 2) as follows:

1. A *network* of national components (control centre, labs, professionals and resources (i.e., hospitals, warehouses etc.)) that connect with each other and other national systems along with the WHO.
2. An *operational and response plan* that determines how this network works.
3. A *surveillance system* that collects indicator and event-based data.
4. *Data sources* (clinical, laboratory and epidemic).

Figure 2: General structure of a public health system[b]



[b] The gears' scale is not of importance.

3 Smart Sustainable Cities and public health

The international definition for *smart sustainable cities*, embraced by 17 United Nations agencies, entities and programmes, under the umbrella of the United for Smart Sustainable Cities, is as follows: *"A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operations, services and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects*[32]*"*.

According to this definition, smart sustainable cities (SSCs) are in the process of leveraging cutting-edge technologies to become greener, autonomous and more homogeneous[33,34]. In this respect, cities form strategies and follow frameworks to adopt the best and most advanced technologies, especially in the field of data management, big data analytics and artificial intelligence (AI) to make cities autonomous or, in other words, enable them to make informed political and management decisions. Such AI-based services could detect emerging trends in the absence of any human intervention. However, it is still arguable whether AI's superiority in terms of speed, accuracy, reliability, latency, volume and convergence is still behind human decision-making capabilities, especially on contentious issues[35,36].

The campaign about SSCs has been associated with the importance of city resilience. In this regard, a broad discussion about *smart and resilient cities* has been uncovered, especially after the UN SDGs were established[37]. Additionally, as indicated in Table 1 and its findings showed, there is a strong interrelation between city and public health systems. However, the interrelation between SSCs and public health is still to be highlighted. An online search of the terms "smart city" and "public health" provided 522 records in March 2020 (based on Google Scholar and none in ScienceDirect and Scopus), all of which dealt with environmental disasters. In an attempt to focus on this article's scope, another online search with "smart city" and "health emergency" furnished 178 articles (on Google Scholar and none in ScienceDirect and Scopus) of which only the work of Kickbush and Sakellarides[38] approached the role of SSC during a pandemic from an optimistic perspective – a set of principles were outlined in *Flu City* that enable cities to battle the threat of a pandemic (p. 86). These include:

1. The public health system
2. Public-private partnerships
3. Trust in leadership
4. Citizen participation

The difference is that SSCs could enhance communication during pandemic threats, which does not meet the past IBM's predictions for early warnings and self-generated alerts[39].

Covid-19 has revealed that the "city of the 21st century" is unprepared to deal with a crisis, especially a pandemic. There are, however, few exceptions like South Korea which have been deemed successful by both Korean and foreign officials. This success story is attributed largely to Korea's advanced ICT infrastructure and the application of measures developed following the outbreak of the 2015 Middle East respiratory syndrome outbreak. These measures, together with the infrastructure, constitute an effective "infectious disease surveillance system".

The measures taken now by governments to enforce social distancing have emphasized the role of open space, curbside walkways, etc. – all of which are critical to improving the quality of life.

Another important discussion is how cities will recover following a pandemic. Historically pandemics are quite rare. There is evidence (from Toronto 2002) that these pandemics do not simply disappear but in fact make a comeback, and thus there is a fear of lifting the lockdowns. This brings up the question regarding the mechanisms that should be put in place to make an SSC a resilient city.

4 A Review of Existing Public Health Frameworks

Table 1: Alternative frameworks for epidemic management

Framework	Context	Source
WHO guidance framework: Public health response to biological and chemical weapons	1. Preparedness – Threat analysis – Pre-emption of attack – Preparing to respond – Preparing public information and communication packages – Validation of response capabilities 2. Response – Response before any overt release – Distinguish biological/chemical incidents – Response to biological incidents: risk assessment; risk management; activity monitoring; and risk communication	WHO (2004)[40]

Framework	Context	Source
Sendai Framework (Sendai Framework for Disaster Risk Reduction 2015-2030)	Priority 1: Understanding disaster risk. Priority 2: Strengthening disaster risk governance to manage disaster risk. Priority 3: Investing in disaster risk reduction for resilience. Priority 4: Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction.	United Nations (2015b)[41]
World Bank Public Health Toolkit	1. Case recognition to trigger interventions 2. Public health impact assessment 3. Justification for public health interventions and corresponding planning 4. Effectiveness of monitoring interventions 5. Identification of high-risk population groups 6. Risk factor determination	Garcia-Abreu et al. (2002)[42]
Process for safety performance indicator (SPI) definition	1. SPI team 2. Key issues of concern 3. Outcome indicators 4. Activity indicators 5. Data collection/process 6. Taking action 7. SPI programme evaluation	OECD (2008)[43]
i-Prevention model for training, team building and surveillance	1. i-Prevention web application 2. Community training (Civil defence guard) 3. Neighbourhood Watch surveillance process	Linkov et al. (2007)[44]
Intelligent Tutoring Systems (ITS) for community training and awareness	1. Preparedness programme design 2. Teaching with ITS 3. Community-based public health preparedness	Tseytlin (2007)[45]

Framework	Context	Source
ICT-based framework for bioterrorism prevention	1. Primary prevention i. Education ii. Understand differences in cultures, religions, beliefs and human behaviour. iii. Think of peace, freedom and equality of all human beings, not just "my group of people". iv. Eliminate the root causes of terrorism. 2. Secondary prevention i. Establish surveillance and monitoring systems on terrorism attack. ii. Improve protective systems for citizens. iii. Epidemic curve (with data gathered on cases over time) 3. Tertiary prevention i. Early detection of the sources. ii. Prevent the extension of impairments. iii. Rescue survivors. iv. Console the rest of the population.	Shubnikov et al., (2007)[46], Pavlin (2004)[47]
U.S. National framework for crisis standards of care	Framework in boxes for care preparation, substitution, adaptation, conservation, reuse, and reallocation	IOM (2010)[48]; Hick et al. (2009)[49]
U.S. Centres for Disease Control and Prevention (CDC) global infectious disease strategy	1. International outbreak assistance 2. Global approach to disease surveillance 3. Applied research on diseases of global importance 4. Application of proven public health tools 5. Global initiatives for disease control 6. Public health training and capacity building	Morse (2004)[50]; Katz (2005)[50]

Framework	Context	Source
Epidemic Outbreak System (EOS): model for micro-array identification of organisms in an outbreak investigation	1. Biologic agent identification. 2. Diagnostic correlation with specific syndromic indicators. 3. Longitudinal tracking of affected population. 4. Relationship, association and predictive modelling. 5. Clinical accuracy. 6. Cross-platform comparison with chain-reaction technologies. 7. Predictive modelling for surveillance.	Hanson et al. (2004)[51]
Operational Risk Management (ORM) model	1. Identifying threats/targets/hazards 2. Assess threats risk(s) 3. Make threat (risk) control decisions 4. Implement threat (risk) controls 5. Supervise/monitor the effect(s) of control implementation	Bellenkes (2004)[52]
Mathematical epidemiology model for worst-case epidemic outbreaks	SIR (susceptible-infective-removed) compartmental epidemic model: the population under consideration is divided into classes or compartments defined by epidemiological status	Chowell and Castillo-Chaves (2003)[53] Furushima et al., (2017)[54]
Mathematical Reaction-Convention Model	Uses continuous flow displacement immunosensor (CFI) and nonlinear methods for detecting parameter changes	Schwartz et al. (2003)[55]
Model for city resilience based on Arup/Rockfeller (2014) and Bujones/USAID (2013) frameworks	1. Definition of resilience dimensions 2. Definition of resilience indicators 3. Definition of resilience goals 4. Justification of indicators and goals 5. Measurement and monitoring of Indicators 6. Strategic alignment to goals	Patel and Nosal (2016)[56]; Bujones et al. (2013)[56]; Arup (2014)[57]

The analysis of the above frameworks shown in Table 1 indicates that managing a pandemic encompasses a generic three-step process:

1. *Preparatory step – before the crisis:* This step consists of actions that deal with the organization of a public health system that performs continuous threat analysis, accompanied by training activities and information collection, processing and release. It also involves the implementation of measures that secure the community against typical threat factors. Indices and mathematical

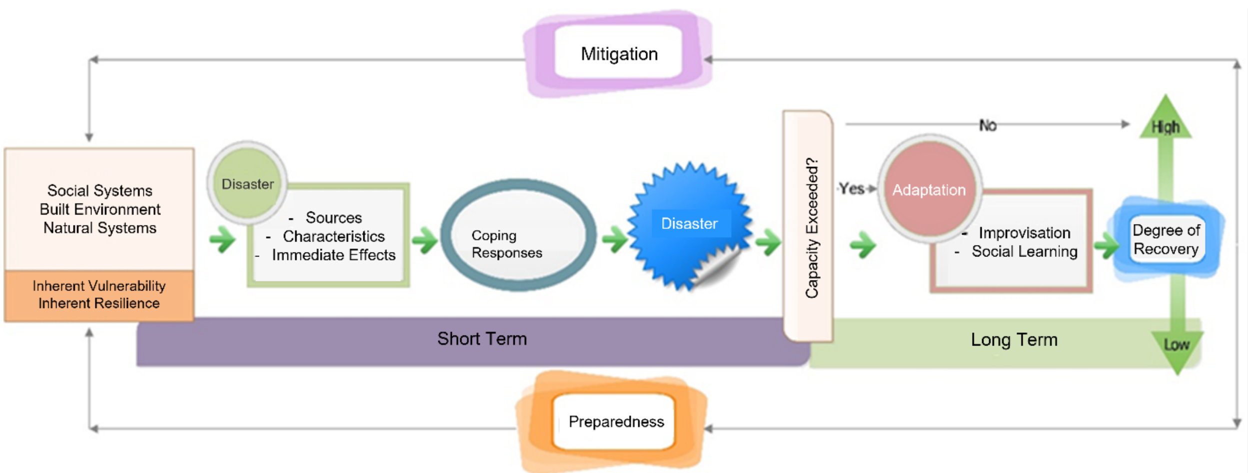
models are fed with data from several official sources, sensors and biosensors in an attempt to recognize threats as early as possible, while risk estimation processes are performed to minimize the exposure of communities to known threat factors.

2. *Operational step – after registration of the event:* This consists of initiatives that are launched after the appearance of a crisis. An effective surveillance system – consisting of laboratories connected with national and international centres – is used to ensure early detection of an epidemic and to continually monitor the progress of the crisis, potentially with the use of epidemic curves, which are produced and fed with clinical data[58]. The identification of the most vulnerable social groups, the application of the accurate clinical response and the application of measures to minimize and control the outbreak of the pandemic are also essential aspects considered within this step.
3. *Concluding step – elimination of the consequences:* Human deaths and pain are typical results of a pandemic, but social and economic damages are also a by-product and have to be overcome. This step consists of initiatives that try to strengthen social coherence and economically support the communities.

The absence of a commonly agreed upon framework for managing public health emergencies can be justified by the fact that it is only recently that corresponding standardization processes have been initiated by international standardization bodies[59,60].

Additionally, the response to a pandemic has similarities with a crisis management/emergency framework as the one presented in Figure 1. Such an emergency management framework considers the pre-event and the post-event phases of a crisis. Before the event, preparedness planning engages the social, natural and physical systems and initiates the response processes. In the case of an outbreak, there is a mitigation step to comprehend the impact and release short-term treatment and relief activities. There are measures for longer-term community relief to be considered, better known as *adaptive resilience.* These are measures that the community (i) adopts to improve its local characteristics, and (ii) learns and adapts to the changes that were caused by the disaster.

Figure 3. Disaster resilience of place model[61]



The aforementioned findings show that public health is highly interrelated with resilience and, in terms of location, with city resilience. Some of the models examined in Table 1 measure city resilience with several indicators, which are aggregated in the *social, economic, institutional, physical and natural dimensions*[4,57]. The social dimension addresses health and well-being issues to minimize human vulnerability and to effectively safeguard human health and life. In this regard, a standard of living, which goes beyond mere survival, is necessary and must be accompanied by the existence of integrated health facilities and services as well as responsive emergency services. These frameworks recognize the importance of learning and future planning to ensure that public health practices – such as prevention through education – are appropriate for the social and physical context of a given city. Additionally, a diverse network of medical practitioners and facilities in cities can ensure the availability of additional resources (redundancy) that can be deployed immediately in case of public health emergencies[57]. The indicators that measure how resilient a city is in terms of health include:

a. Public health systems
b. Quality healthcare
c. Medical care
d. Emergency responses

5 Case study and examples

5.1 Seoul, South Korea

South Korea flattened the curve of rising coronavirus cases in the country within two months of the outbreak. It did a remarkable job of fully curing 92 per cent of the more than 15,000 infected citizens, keeping the death count at just 305 nationally. In the capital, Seoul, there were 1,841 confirmed cases with 13 deaths as of 15 August 2020[61]. South Korea, like the United States, saw its first case on 20 January 2020. However, the death toll in the US reached 170,000, with the number of confirmed cases at 5.4 million. A year later, by August 2021, the number of Covid-19 cases in the United States had risen to an estimated 36.5 million with 620,000 fatalities. In South Korea, the case numbers for the corresponding period stood at 220,000 with 2,144 recorded fatalities.[62,63] These disparities have attracted much attention. South Korea may seem like one of a number of Asian countries, including Singapore and China, which have so far managed to successfully flatten the curve. However, it is the only country that did not suspend everyday activities. According to the late Park Won-soon, Mayor of Seoul, Korean success lies in the "promptness and transparency" applied by the Seoul Metropolitan Government (SMG) in conducting tracing, testing and operating 24-hour quarantine countermeasures from the early days of the Covid-19 pandemic as well as by the role played by its citizens, whom he described as "Seoul's Vaccine". How did "promptness and transparency" turn South Korea, and Seoul specifically, into the poster child for state officials and policy-makers fighting this global crisis, and what role did the smart city endeavours play in controlling this virus?

Promptness in tackling the virus is a result of years of preparedness since the Middle East Respiratory Syndrome (MERS) outbreak in 2015, preceded a year earlier by the sinking of the Sewol Ferry in 2014. The impacts of both were worsened by the lack of government transparency, making both speed and communication key to facing future crises. The result was an evolving three-pronged approach to combating Covid-19, consisting of an extensive social distancing and public hygiene campaign, a comprehensive medical strategy, and public-private partnerships. This was enabled by an advanced infrastructure and innovative economy forming the basis of the smart city. Notwithstanding the fundamental role played by technology and speed in testing, tracing and treating, it was an underlying trust in leadership combined with the centralized mode of governance that proved critical to the handling of this pandemic. Though this modus operandi remains unchanged, the number of confirmed Covid-19 cases spiked in the second half of August 2020, forcing the government to sound the alarm and revert to stricter social distance measures. It is not clear whether this was attributed to the long predicted second wave of the virus, or to the effect of the change in leadership (following Park Won-soon's suicide in July 2020) and consequently of the changed relationship between the government and the people.

Building trust in leadership and advanced technology in post crisis era

Trust in government, shaken by repeated political and public health crises, had been in short supply well into the second decade of the 21st century. Korea's hard-won battle for democracy, achieved by the late 1980s, continued to be a struggle for trust in government, the core of the relationship between the state and the people. Over-the-top policing of demonstrations and police raids on a military scale to arrest trade union agitators indicated that the Korean government lacked trust in the citizens[64]. The populace was equally distrustful of their government, articulated by Korean "netizens", the nation's tech-savvy Internet users, who flood online forums with organized responses to government activity, opinions and theories, conspiratorial or otherwise. These watchdogs, ever mindful that their nation was a dictatorship just a quarter-century earlier, are on constant watch for any hint of trouble threatening their hard-won democracy. Since the election of Mayor Park in 2011, The SMG has been focused on improving the nature and form of communication between government and the citizens, making public-private participation central to the governing of smart sustainable Seoul. The "listening mayor", as the late Mayor was known, was responsible for making open communication the cornerstone of his administration. He had many smart city tools and services at his disposal, such as the Open Data Plaza (2012), Seoul's big data store as well as an advanced communication infrastructure, which enabled the promotion and implementation of various citizen participation programmes to boost economic growth and to improve public services. These were all instrumental in regaining public trust in government[65] and in his leadership.

Since at least early 2000, ICTs have been the main driver of South Korea's economic growth as well as managing its cities nationwide. Subsequent national governments continued to make technology paramount in the creation of new economic growth engines designed to lead the country into the 21st century; the latest in 2014, labelled 'creative economy', was designed to drive innovation. Seventeen innovation centres were set-up in cities across the country, including Seoul, becoming the basis for a new ecosystem enabling the formation and growth of start-ups. According to the mayor, the key to the success of this new economy was regaining the people's trust and securing their happiness and safety through innovation and governance in "order to transform Seoul into a global model for innovative cities". Meanwhile the late Mayor turned his focus to "safeguarding the lives of Seoul citizens by focusing on growth, jobs and welfare". In his 2016 New Year's address to citizens of Seoul, he promised that the lessons learned during the MERS crisis like "better too early than too late" and "the magic bullet is information disclosure" would continue to determine the measures his administration would take in the form of proactive policies. That year, on 21 November 2016, Mayor Park joined 100 or more mayors from around the world in the *Healthy Cities Mayors Forum* at the 9th Global Conference on Health Promotion in Shanghai. The forum reached a Healthy Cities Consensus that emphasized promoting health at the neighbourhood and community levels for all groups, highlighting the importance of local leadership and citizen engagement in achieving this goal. Furthermore, the forum attendees stressed the role of health and well-being in sustainable development, consequently satisfying the United Nations Sustainable Development Agenda. Joined by government representatives and heads of UN agencies, the participants also released the *Shanghai Declaration on Health Promotion"* advocating "improved governance for health at all levels, development of healthy cities that are inclusive, safe and resilient, and health literacy[66]", overlapping with the recommendations which had resulted from the MERS investigation into the response of the Korean government to that epidemic.

'Flattening the curve': 24-hour emergency citizen prevention system

Preparedness for this current health crisis began in South Korea prior to the identification of the first case on 20 January 2020. In fact, it started as soon as the MERS epidemic was declared over in 2015, and an investigation into the government's handling of the outbreak was launched. Much emphasis was placed on inter-organizational cooperation and risk communication. These two aspects facilitated a swift and transparent response during the current pandemic through the sharing of both general and targeted real-time information delivered by all three governments – central, metropolitan and local – using smartphone apps as well as websites of governments and ICT companies (WISEnut).

Social distancing and hygiene guidelines backed by real-time information along with rapid intervention through testing, tracing and treating formed the basis for an evolving 24-hour emergency citizen infection prevention system. A few days after the Chinese government reported the coronavirus cluster in Wuhan on 31 December 2019, the central government responded via the Korean Centres for Disease Control and Prevention (KCDC) while the SMG relied on its Disaster and Safety Countermeasures Headquarters. They enacted the four-tiered national crisis management system and launched a public hygiene campaign and social distancing guidelines. Operating almost in unison, they raised the alert level to blue (level 1), publishing cautionary measures to individuals travelling to Korea from China and vice versa. This, however, started to change fast when the first case was confirmed on 20 January, raising the alert to yellow (level 2) and moving to preventative measures, especially recommending behavioural guidelines on public transit. As fears of the virus spreading became real and the WHO declared Covid-19 a global pandemic at the end of January, the alert level was lifted further to orange (level 3). Fourteen-day strict social distancing was enforced, restricting movement and use of public spaces, and issuing recommendations for businesses on how to transform the work environment. Meanwhile, a special facility was allocated for quarantining infected individuals and those exposed to them. The city carried out disinfection of facilities, including bus-stops (4,081 in total) and bus interiors, designating them as "clean zones". All these measures were plotted on the smart map of Seoul, which citizens could access on their smart devices to learn about their neighbourhoods, medical facilities, etc. and to create individual maps. All foreign travellers who had been to China, especially to Hubei Province, were banned from entering Korea. Social distancing measures and hygiene guidelines kept pace with the evolving situation. The death of a local, coupled with a jump in the number of confirmed infections, which reached triple digits exactly a month after the first case was confirmed, raised fears of loss of control among government officials, who responded by raising the crisis alert level to red (dangerous – level 4). The SMG restricted gatherings by shutting off all public facilities, followed by a campaign of social distancing in which citizens were asked "to take a break from social life". It created a dashboard including daily updates, a timeline of events and countermeasures, presented through a visual platform for Seoul citizens to quickly track a fast-moving situation. Various media outlets were used by SMG to keep the public informed. These were the key for securing trust in the actions taken by officials as they worked on helping to create a safe and secure environment.

Rapid intervention through early testing, often and safely as well as contact tracing, isolation and surveillance became the basis for *Covid-19 Smart Management System* or Korean SMS. Each of these actions relied on different modes of collaboration between different levels and agencies of government, private organizations and the public. Supported by Korea's smart city technology, manual processes subsequently became digital. New methods and approaches were introduced to confront the challenges posed by this virus. Collection of real-time data became the basis for a "new digital surveillance system". Following the first confirmed case in Seoul, a state of emergency was declared, and an evolving strategy was devised both to contain the virus and protect the economy and society. It included the early and widespread adoption of temporary testing sites, such as the drive-through, the testing booth and the use of diagnostic test kits that produced quick results. This enabled moving more quickly to tracing and detecting infection hotspots, and equally swift in alerting the public both through the various government websites and phone applications. Tracing and tracking in particular relied largely on data already collected from phone records, credit card transactions and CCTV sources. This data was repurposed for use during the coronavirus pandemic by government and the general public, as mandated by the 2013 Act on *Promotion of the Provision and Use of Public Data*. Seoul citizens have played an instrumental role in designing apps (Corona Map, Corona 100, Self-diagnosis and Mask Apps[67]), which have enabled real-time tracking of the virus by creating maps of hotpots with regular updates of the number of infected, quarantined and expired. Despite the fact that Korea has a universal health care system with high hospital bed capacity, the government stepped in to quickly control the situation to avoid putting pressure on the hospitals and established a patient management system based on triage in line with a dual-approach system to treatment (C40)[68]. The nature and severity of the symptoms determined whether the patients were sent to a secure emergency centre or to a temporary treatment public facility. In either case, patients were supported by state-of-the art treatment technology and monitoring Apps using artificial intelligence services.

Seoul's smart city vision focus on smart infrastructure has always been geared towards the application of the latest technologies, both to develop an innovative economy centred on improving people's well-being and to address rising challenges. It is supported by public-private-partnerships (PPPs), a world class health care system coupled with trusted government-citizen relationship, which are all key components to understanding the forces shaping the South Korean Covid-19 countermeasures.

5.2 Fighting the Covid-19 health care challenge leveraging technology - Arogya Setu App

The Covid-19 pandemic is posing a major challenge to a large number of countries in managing their health care infrastructure to save lives. Efforts are on to leverage technology to effectively fight this pandemic. A number of Apps from different countries are in place:

1. *TraceTogether*[c] from Singapore

2. *GH Covid-19*[d] Tracker App from Ghana
3. *CovidWatch*[e] from Stanford University
4. *HaMagen*[f] from Israel Ministry of Health
5. *Corona DatenSpende*[g] from German Watch co.
6. *Covid Symptom Tracker*[h] from King's College, London and others
7. *NHS Smart Phone App*[i] from NHS, UK
8. *Let's Beat Covid-19*[j] from MedShr , London
9. *PeduliLindungi*[k] from Indonesia
10. *Kwarantana Dommowa*[l] from Poland
11. *Arogya Setu*[m] from Government of India (GOI)

The effectiveness of these tracking applications is still arguable compared to real time tracing and physical tests. Efficient scientific evidence is missing and the existing studies show that regardless of the usefulness and the acceptance of the contract tracing Apps[69], given the uncertainty of their committed use, policy-makers should be cautioned against overreliance on such Apps[70].

6 A Smart Public Health Emergency Framework: the role of SSCs

The findings elucidated in the previous section synthesize a unified framework for public health epidemic management. They involve public health stakeholders, including a leading working group, a control centre team, data collection organizations (research labs and hospitals) and public health organizations in other countries and/or WHO, who draft plans, collect and analyse data and proceed with decision making over several measures. The framework addresses *preparedness* and *mitigation* as short-term phases of the previously summarized disaster-resilience model (Figure 2). Public health does not deal with policies that support the community's *adaptation* to changes, which are brought on by an epidemic. Adaptation is highly related to the community's resilience, and in this regard the community's preparedness with training, economic and social support measures

[c] https://www.tracetogether.gov.sg/.
[d] https://www.moc.gov.gh/launch-gh-covid-19-tracker-app.
[e] https://www.wehealth.org/arizona.
[f] https://govextra.gov.il/ministry-of-health/hamagen-app/download-en/.
[g] https://corona-datenspende.de/.
[h] https://covid.joinzoe.com/us-2.
[i] https://www.nhs.uk/nhs-services/online-services/nhs-app/.
[j] https://letsbeatcovid.net/.
[k] https://pedulilindungi.id/.
[l] https://www.gov.pl/web/koronawirus/kwarantanna-domowa.
[m] https://www.mygov.in/aarogya-Setu-app/.

are part of this phase and are beyond the public-health frameworks. According to the framework, the corresponding efforts during the pre-crisis phase address the establishment of a network of educated people and professionals, the strengthening of social coherence and continuous social networking and support along with the development of government-community cooperation. During the post-event phase, continuous data collection and monitoring are combined with surveillance systems and community protection under a secondary and a tertiary level.

In terms of data generation and access, the aforementioned unified model suggests a process that consists of the previously defined steps requiring access to specific repositories:

i. The *interventions* that store the public health measures planned or undertaken for the community's safety.

ii. The *incidents,* where the information that is being collected by the research labs, the hospitals and the surveillance systems is stored.

iii. The *KPIs* that collect processed data for the measurement of the crisis size and sprawl (e.g., the epidemic curve).

iv. The *civil protection repository* that stores corresponding data (e.g., source allocation, activities, events).

And the representative information systems that should collaborate:

i. The national public health *control centre's dashboard* where all the collected and processed data will be depicted.

ii. The *national e-health system* – which is potentially different when comparing research labs and the hospitals.

iii. The *civil protection system.*

iv. The external *WHO/others' dashboards* that belong to other countries' national public health systems or the WHO.

With respect to smart sustainable cities (SSC), both the above framework and data flow requirements utilize smart infrastructure, smart services and crowdsourcing in cities. For instance, the IoT SSC infrastructure can detect operational changes when an emergency occurs. It can interact with existing safety systems, while supporting rescue procedures during disasters. These processes could also include alerting and evacuation[71]. More specifically, the IoT-based transportation safety management aims to anticipate disasters and mitigate transportation damage, and consists of four phases (Figure 4):

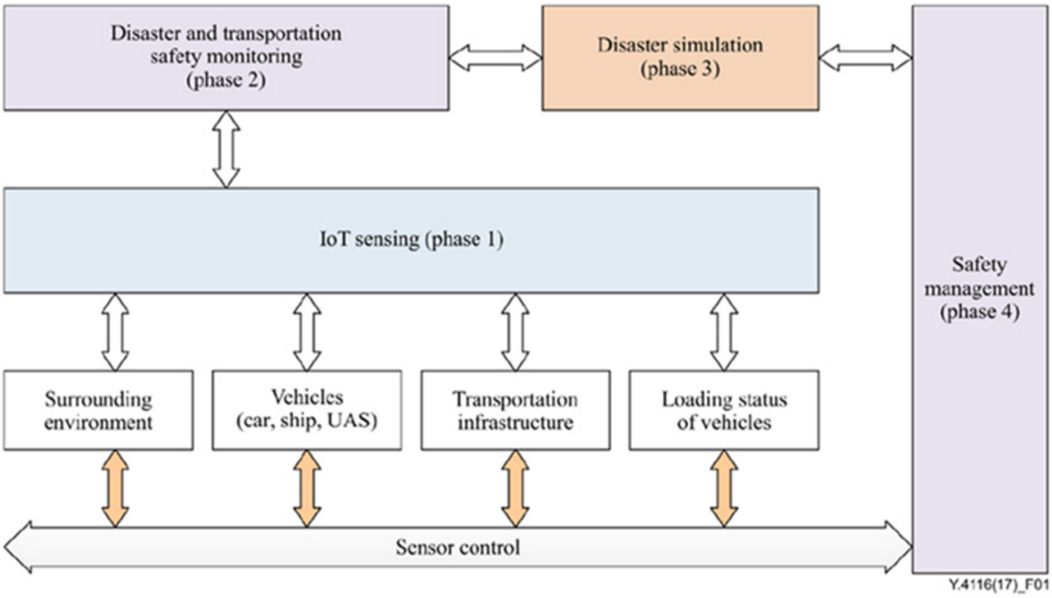
i. Phase 1: Uses vehicle sensors to predict environmental disasters, while monitoring traffic and the safety status of transportation infrastructure after a disaster (e.g., bridges, tunnels etc.).

ii. Phase 2: Analyses real-time collected data from various IoT devices (e.g., vehicles, streets, environmental sensors etc.) to estimate the crisis size.

iii. Phase 3: Safety simulation – the disaster-affected area is estimated by multidimensional data analysis to mitigate the damage from disaster.

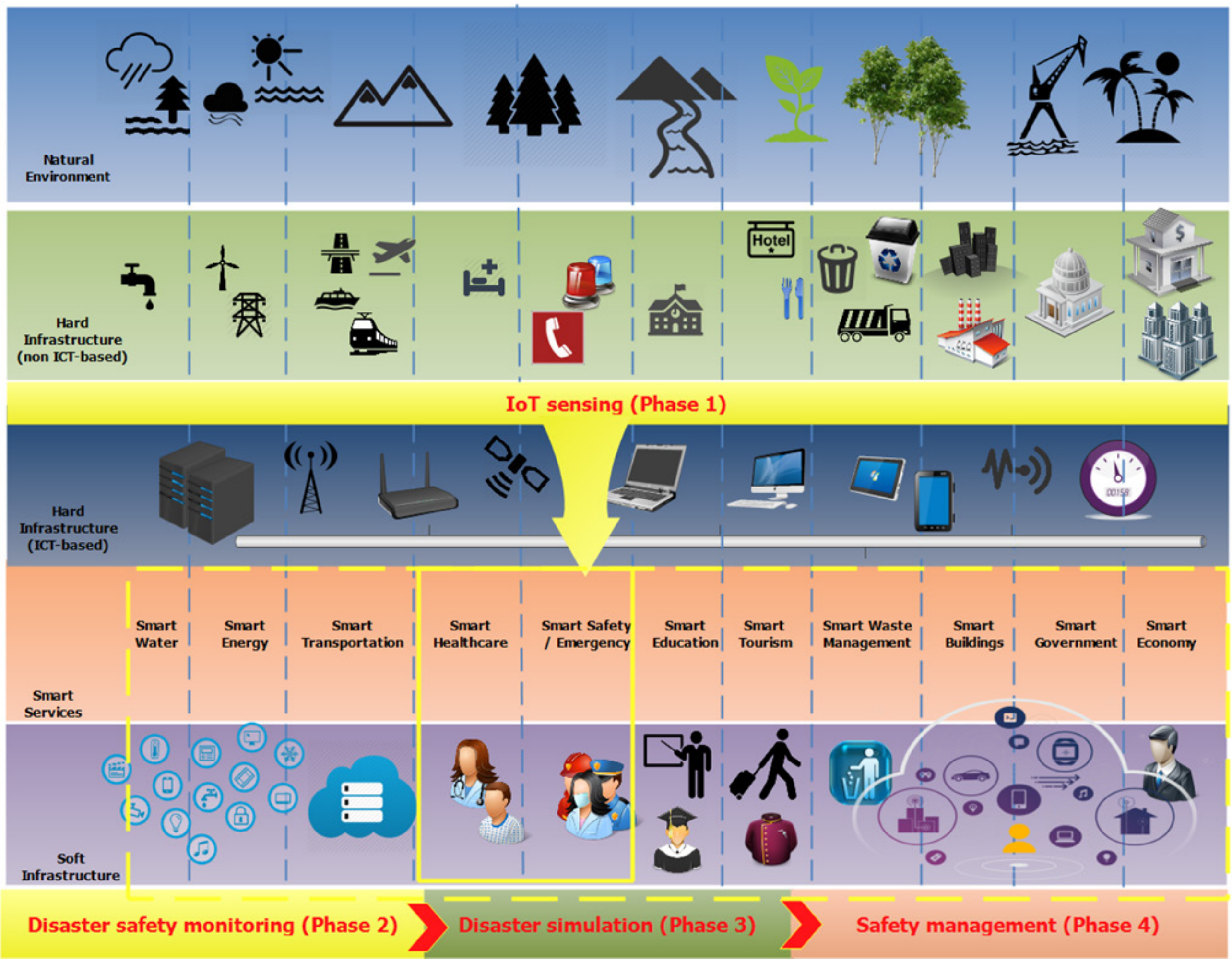
iv. Phase 4: Safety management determines the countermeasure activities (e.g., alert signalling) when a disaster has occurred to mitigate transportation damage.

Figure 4: IoT-based transportation safety management[60]



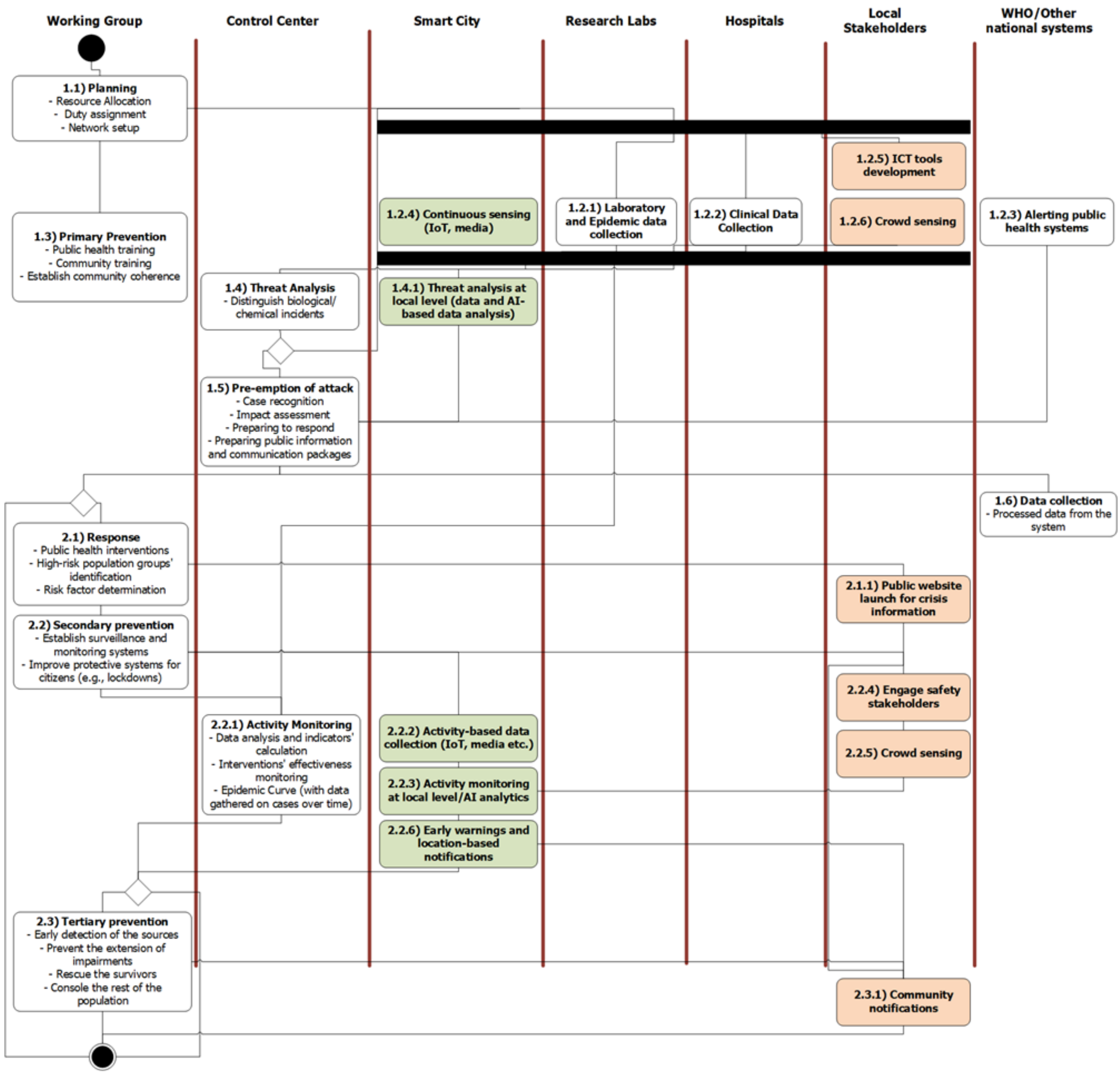
Similar synergies can be considered to exist between the SSC, the SSC platform and all the local operational sub-systems that are based on utilities (e.g., water, energy, waste etc.) or on typical services (e.g., health, training etc.) that are affected during a crisis. Accordingly, the following Figure 6 depicts how an SSC architecture can follow these four phases during a disaster. The local physical environment and infrastructure are being sensed by the local IoT layer, which triggers the safety management phases (2, 3 and 4) with the support of the medical and safety teams (soft infrastructure), enabling information to flow across the entire SSC ecosystem. Phase 1 could include artificial intelligence (AI) applications to support early warnings for known or unknown hazards. The existence of IoT and AI influences (Figure 5), which are being transformed to the SSCs (Figure 6 and Figure 7), taking into account the involvement of local stakeholders. More specifically, SSCs host control centres in most cases, which consist of a local dashboard that monitors IoT collected and processed data[71]. Pandemic-related graphs can be depicted on this dashboard, while the local IoT can communicate with the rest of the information systems that belong to the national public health system. However, although this architecture is focused on generic safety management in SSCs, similar processes were not observed during the first wave of the Covid-19 pandemic in aspiring SSCs.

Figure 5: IoT-based safety management in SSC[60]



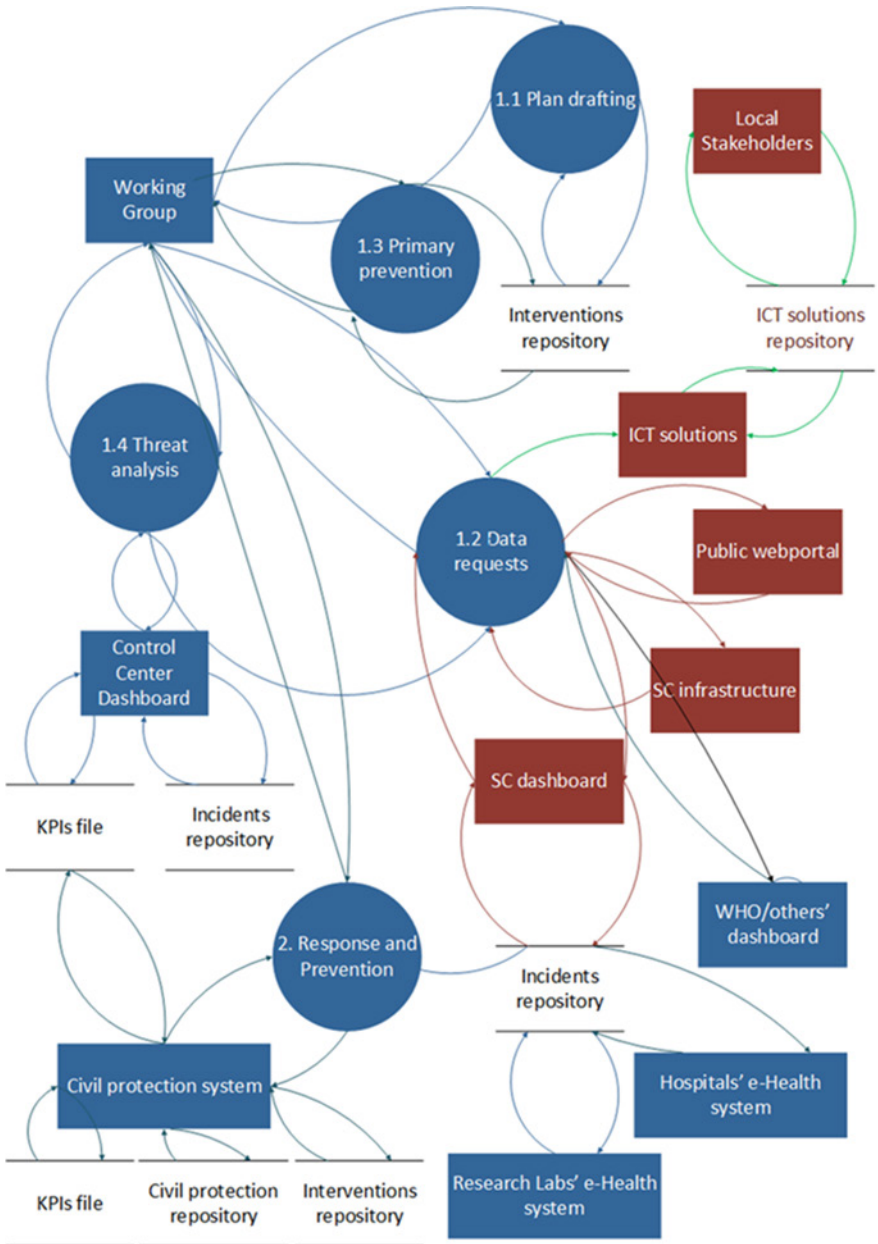
In this regard, the public health emergency management framework has to be extended to include the SSC infrastructure as well as to incorporate the local stakeholders that appeared to play a crucial role during the pandemic (Figure 6). The SSC hard infrastructure can be used to continuously collect data from the local environment (sensors and even text, voice and video from local media) and contribute to the national public health control centre, together with the data from the national research labs and hospitals (process step *1.2.4* of Figure 6). This SSC role can be included in national planning (process step *1.1*). The collected data can be processed and analysed and perform threat analysis at local levels (process step *1.4.1*). The SSC infrastructure can contribute with the release of a public website that will post corresponding information (process step *2.1.1*) as well as support the national surveillance system with activity-based data collection from sensors, cameras and even media (process step *2.2.2*). Activity monitoring, analytics and AI-based predictions at the local level (process step *2.2.3*), either with the use of local control centres or independently (sewage analysis etc.) can also contribute. Additionally, the SSC infrastructure can support the submission of notifications to the safety stakeholders (police, hospitals etc.) to engage them in case of curfew violations or emergencies (process step *2.2.4*) as well as to submit location-based alerts (notifications on crowded areas and/or spaces to be avoided owing to incidents, busy bike lanes, etc.) (process step *2.2.6*). Local stakeholders can also start developing or sharing ICT tools and solutions after the early appearance of a crisis (process step *1.2.5*) and these tools can be used for crowdsensing (process steps *1.2.6* and *2.2.5*), as was observed in Seoul. Additionally, early notifications can be submitted and received via these solutions (Corona Map, Corona 100, Self-diagnosis and Mask Apps, etc.), something that appeared to be crucial due to the particular role that location played during the pandemic, where different sizes of outbreak were observed in different areas of the same big city or country.

Figure 6: A proposed UML use-case unified framework for public health management in SSC



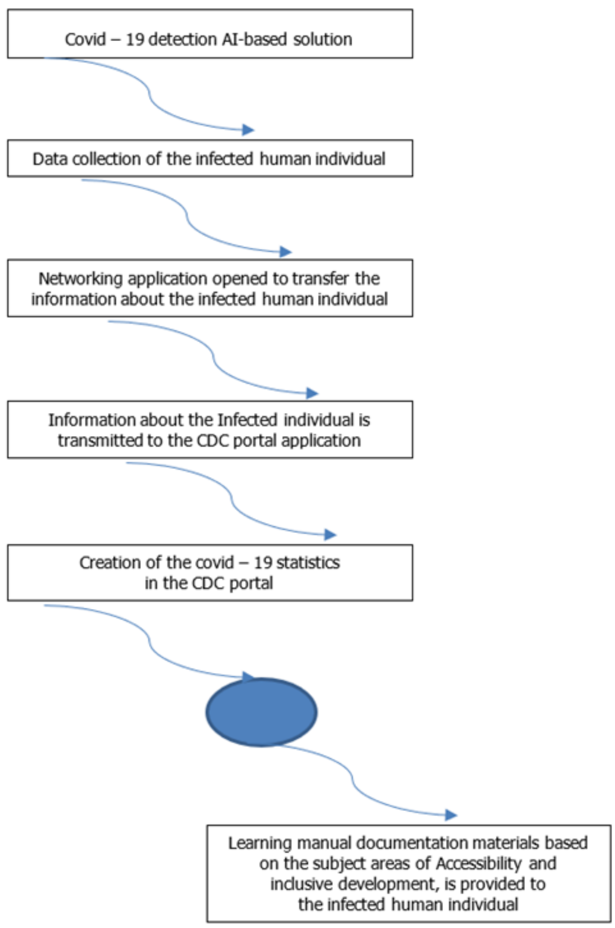
With regard to data flows, the corresponding UML diagram (Figure 7) involves the local entities (local stakeholders, SSC infrastructure and SSC dashboard for local monitoring) and the ICT solutions repository, where the applications will be delivered and accessed by the community. Corresponding requests and flows are simple, since ICT solutions contribute to the repositories. However, they also collect data and notifications. The potential local SSC dashboard also interacts with the rest of the data sources and analyses and depicts information, while it performs threat analyses that can be submitted both to the Apps and to the national public health control centres.

Figure 7: A proposed UML data flow diagram of the unified framework in SSC



AI and IoT-based solutions are created to detect the occurrence of a health condition in an individual. When the Covid–19 pandemic is observed to have entered a city, residents are advised to utilize the artificial intelligence solutions. The various health conditions and parameters of the particular human individual is collected by the artificial intelligence mechanism. If the input conditions which are entered into the AI-based solution is computed, verified and validated to be Covid–19, then the confirmation message is displayed to the concerned individual. Subsequently, this positive Covid–19 information is forwarded to the CDC portal via the networking application. The networking module application within the AI-based solution transmits the patient's name, the address, phone number and the ailment information to the CDC portal module application. These details are then inserted into the database management system within the CDC portal application. This addition to the database management system increases the Covid–19 infected count by one. Monthly, quarterly and yearly statistics of the Covid–19 pandemic is measured via this CDC portal application's database management system. The learning manual documentation materials based on the subject areas of accessibility and inclusive development are then supplied to the Covid-19 infected individuals (Figure 8).

Figure 8: The role of an AI-based solution during Covid-19 pandemic



7 Conclusions: Requirements for ICT implementation and integration with the SSC platform

The analysis in the previous sections indicates that the following (Figure 9) ICT infrastructure, based in the Reference framework of a smart city platform Recommendation ITU-T Y.4201 (02/18), is engaged in the implementation of the proposed smart public health framework:

1. *City IoT infrastructure*: This includes cameras, environmental sensors, new types of sensors (e.g., for sewage analysis) and biosensors. It collects information from the urban space (*process step 1.2.4* and *process step 2.2.2* in Figure 6) and feeds into the public health threat analysis system (*process step 1.4* e.g., the SIR functions) and the crisis curves (*process step 2.2.1*).
2. *City Apps:* These collect information from the community (outbreak tracing; public space use etc.) and submits location-based notifications (e.g., to the Corona App) (*process steps 1.2.5, 1.2.6* and *2.2.5*).
3. *City dashboard and public website*: They visualize outbreak data and other indices that measure the size of the crisis, while a central point of access by the public is launched to post information for public consumption (e.g., guidelines) (*process steps 2.1.1* and *2.2.3*).
4. *Smart services:* This involves ICT-based services (custom-triggered, AI-based etc.) that generate alerts when needed (e.g., call the social or the security services in the city to respond to an incident), which can be location-based or focused on specific groups (e.g., social services to elderly people to avoid visiting specific areas) (*process steps 2.2.6* and *2.3.1*).

Figure 9: Requirements for ICT implementations

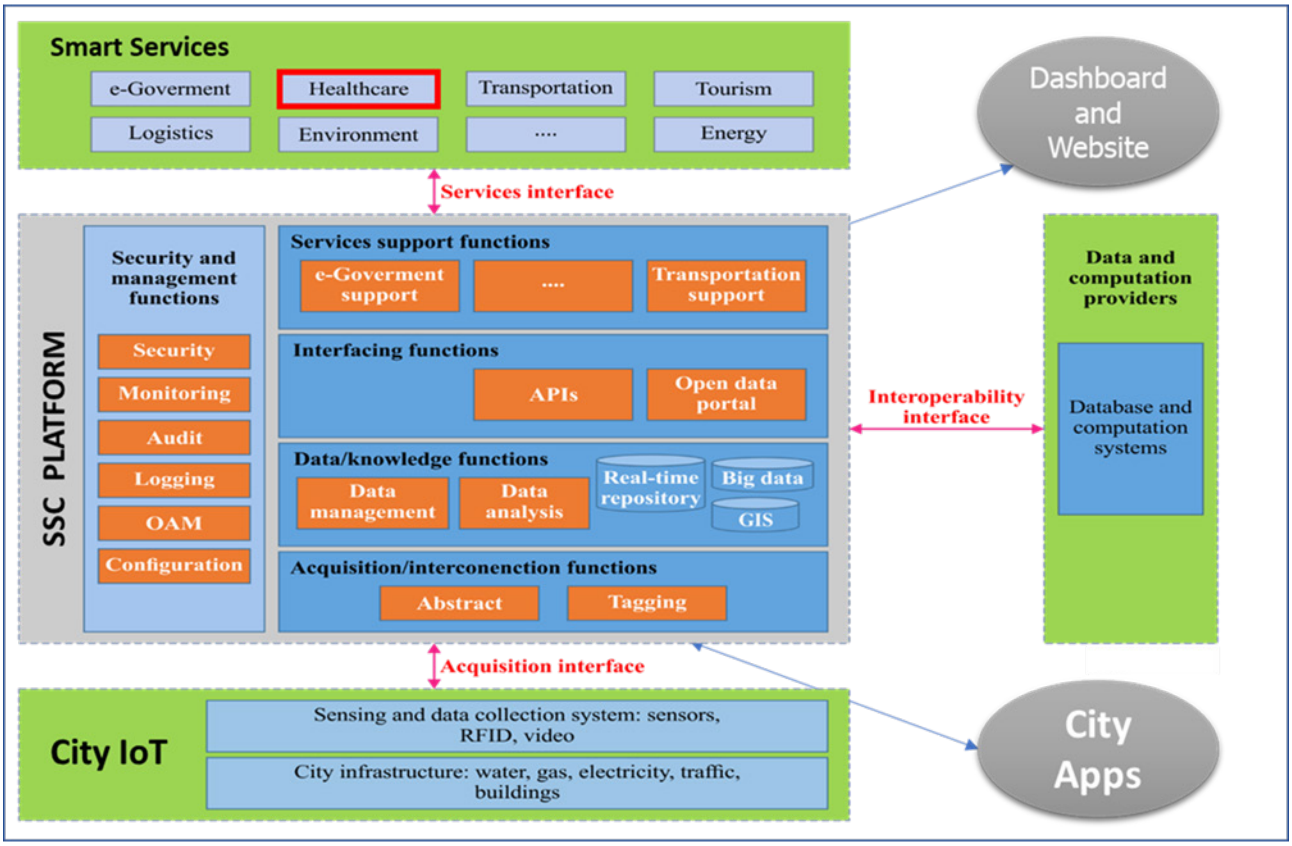


Figure 9 shows that the proposed framework introduces the utilization of the existing SSC infrastructure (IoT, networks, facilities, SSC platform, other dashboards and Apps) during a public health emergency and complies with the reference framework of a smart city platform[72]. The smart public health management framework does not introduce novel facilities or Apps, but it encourages the integration of the SSC components under specific process flows, which interact with external systems (national public health system; WHO's etc.).

Moreover, the UML use-case diagram (Figure 6) clearly shows when mass surveillance with ICT is triggered (*step 2.2: secondary prevention*) and when it ends (*by the end of step 2.3: tertiary prevention*). Corresponding policy-making that adopts this introduced framework can prevent communities from continuous mass surveillance from continuing to exist even after the end of a pandemic or other public health emergency.

Interoperability (organizational, semantic and technological) among the SSC stakeholders via the SSC platform needs to be established to support a city when it faces pandemics or other public health crises. Moreover, the importance of city platforms is highlighted as the point to have a holistic view, multi-domain integration and ecosystem orchestrator with an integrated city management objective. The introduced framework should be identified as a basis for semantic interoperability.

There are also other factors that could contribute to overall smart city resilience. While dealing with health-related emergencies, a smart city infrastructure must be able to sustain itself against hazards. Cascading disaster events or emergencies triggered by other natural hazards and disasters, such as tropical storms and landslides, which, if not considered during the preparedness and mitigation phases, can cause massive disruption of smart city infrastructure (telecom networks, data centres etc.) and adversely affect the entire health care system and services.

APPENDIX I – A simulation of crisis generic three-step management process: city watering system's pollution

The following simulation specifies the generic emergency management process (Figure 3), which consists of the following steps:

1. Preparatory step – before the crisis
2. Operational step – after registration of the event
3. Concluding step – elimination of the consequences.

More specifically, the second process step is analysed further into five phases (Table 2):

Table 2: The different phases of managing an emergency (in the context of water pollution)

Phase	Focus	Example
1	Identify the inflection point between the normal and crisis situations.	Two facts became obvious: 1. The city's entire water supply is from the Loire, and 2. The water in the Loire may be contaminated
2	What makes the risk acute?	A reaction is needed and cannot be delayed further without endangering people's health
3	Possible decisions are considered and the effects that will be triggered are identified.	If, for example, the city's water supply is stopped, then alternatives will be needed to get water to the people.
4	Resources are assessed.	The means to get water to the people are assessed and the available resources measured.
5	The decision is evaluated.	With the collected information, it is now possible to evaluate the impact of the decision and possibly suggest different options.
6	Action is taken and the collective system retracts against the crisis.	The water supply is stopped and alternative water supply measures are initiated. The scenario plays out

According to the above analysis, the generation and size of the crisis situation is first estimated from the decision-makers' points of view. In the case of the water supply to a city becoming polluted, decision-makers need to specify what caused the pollution and its source – the river, underground sources etc., or from the network.

- Right after the appearance of a crisis, risk perception is sharpened: we would see an "extension" of the crisis. For managers, it is now clear that a "combination of factors forces intervention". The parameters characterizing the crisis situation are such that it is necessary to react "for the whole community and not only for the plant staff" directly involved.
- A decision is then made in line with previous decisions using precedent to partially justify it. And the effects of the decision have a direct and immediate impact on the evolution of the crisis.

- (The two previous steps are repeated in the same sequence with each new decision).
- The decision-making is followed by an evaluation of the available intervention options. Simultaneously, the decision-makers shall evaluate the means to unlock the implementation of their decision as soon as possible. In the example of water contamination, the decision to stop water supply via the conventional network based on health concerns cannot be done immediately without an alternative means to supply water, according to the member of the crisis cell of the municipality of Tours, France. Because of this concern, it is necessary to put in place the means to counter the potentially harmful consequences of a decision at the earliest.
- The selected interventions are monitored and evaluated. It is sometimes presented at the same time as the previous one, but the decision-maker makes a quick assessment of the appropriate course of action. This is the purpose of the previous step. But, at best, this assessment is done at the same time as the decision is being made.
- Finally, a retraction of the system (positive outcome) or to a new series of destabilizations are performed. The crisis, at this stage, may result in the following:
    - In terms of training, a resolution with the acquisition of new skills to deal with crises in general.
    - Inadequate adaptation, with poor resolution of the causes that led to the crisis in the first place and the reactivation of past crises.
    - Finally, a major disorganization

In these last cases, the organization is trapped in a looping process.

APPENDIX II – An exemplar of Covid-19 tracking App

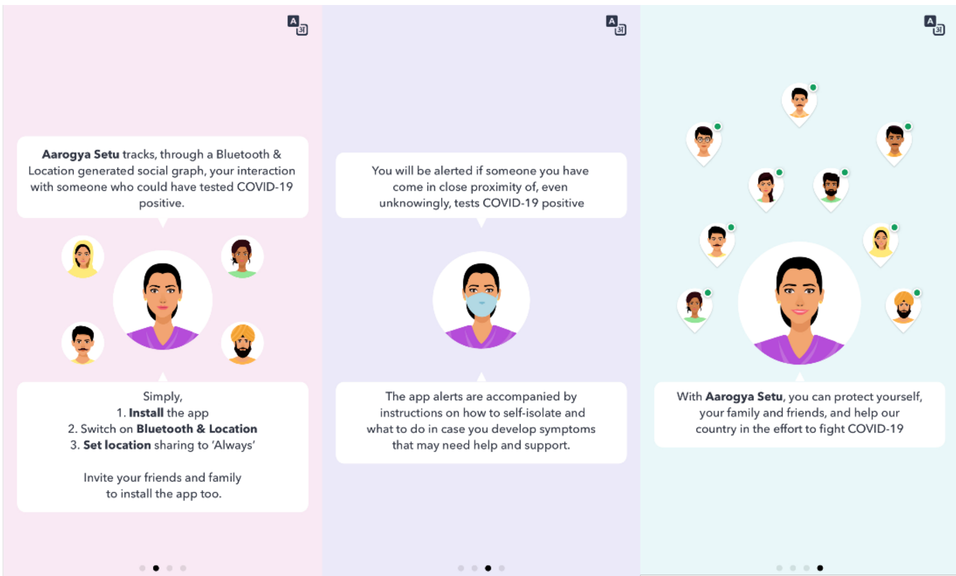
While all the Apps are basically aimed at mitigating some challenge or the other posed by Covid-19, the most downloaded App – more than 96 Million – is *Arogya Setu*[73,74,75,76,77].

The additional feature that Aarogya Setu has is *self-assessment*, which makes it quicker for a user to be detected and remedial measures taken, including a team of designated health care professionals coming to the user's place to test him/her for the virus. Also, it makes use of GPS location to make it easier for the authorities to take action in identifying the hotspots.

The Aarogya Setu mobile App, developed by the ministry of electronics and IT, has been adopted by the Government of India. It provides a way of managing the pandemic, more so in a dense urban environment. This can be a cost-effective way of handling this invisible enemy in smart cities. The same App can be modified for future applications for managing other diseases/pandemics as well.

Aarogya Setu – literally meaning *Bridge to Health* – is an App-based solution to contain the Covid-19 pandemic. Available both on Google Play and the Apple App Store, the App is available in 11 languages, including English and ten regional languages of India. It is designed to keep a user informed in case she or he has crossed paths with someone who has tested positive or if there are cases in the neighbourhood. The tracking is done through a Bluetooth and location-generated social graph, which can show one's interaction with anyone who has tested positive. Thus, other people susceptible to the virus can also be tracked and traced.

AAROGYA SETU APP



Aarogya Setu, designed to help citizens identify their risk of contracting Covid-19, notched up more than 127 million downloads as of July 2020.

The World Bank has described it as an important voluntary initiative to combat the pandemic. It uses GPS and Bluetooth technology to alert a user who may have come in contact with a Covid-19 positive patient. The Aarogya Setu digital App is set up for:

- Coronavirus tracking
- Contact tracing
- Connecting people to health services

What does it do?

The *Aarogya Setu* App does three things. When a user downloads it and first installs it, it will ask a few questions to get a person's profile, which is relevant to Covid-19. The App encourages users to get a self-assessment, which determines if they are fine for now or may need some help.

The self-assessment is something users can take at any time, when they are feeling uncomfortable, and/or not feeling well to ascertain if they need to do something or if somebody needs to reach out to the concerned individuals.

The App also takes the users' permission and starts recording their Bluetooth contact history once every 30 minutes. The GPS location is used for those who are infected. The users of the App get an alert from the authorities in case they are near an infected person or area.

When the Indian Council of Medical Research (ICMR) notifies that a particular user is infected, their GPS location data is taken and used to trace all the places they might have been to, inadvertently contaminated or contracted the infection from, so that those areas can be contained and sanitized.

The Bluetooth contact history also is used when somebody is infected. This information helps trace who else they might have spread it to. A more advanced model is capable of figuring out who the user might have been in contact with, for how long and where, and that information is used to determine if the person has to be self-isolated or who they need to reach out to.

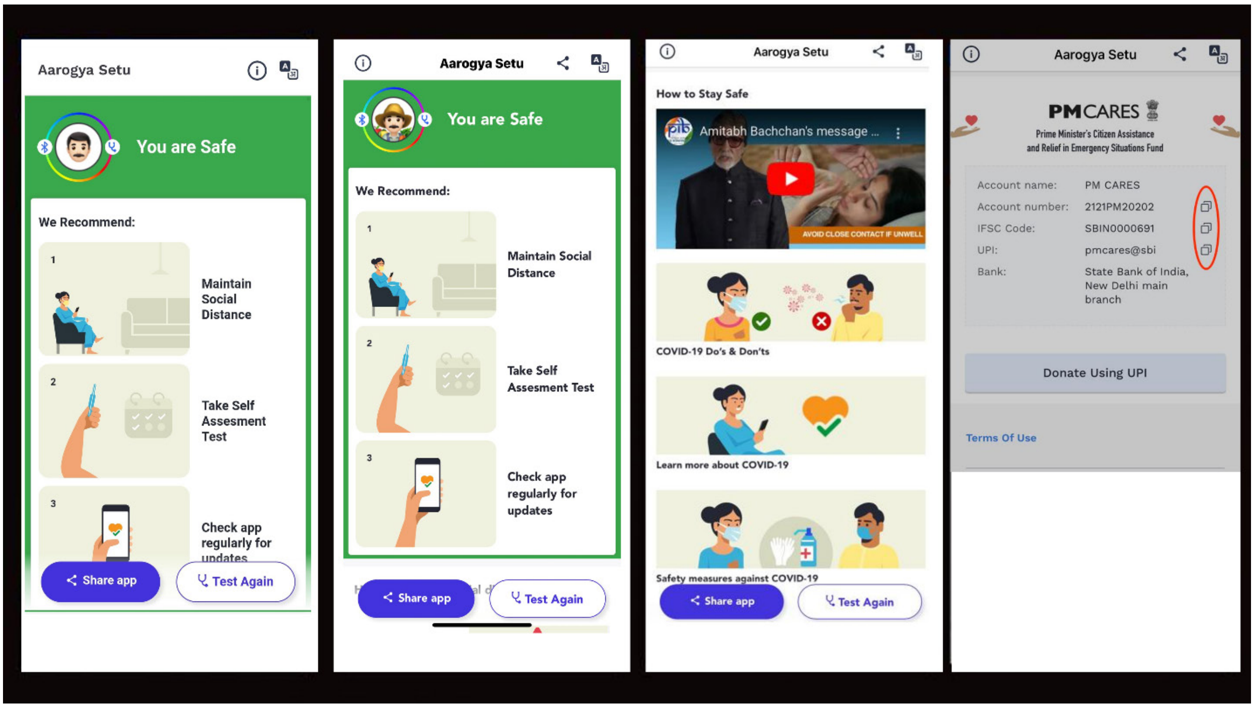
The steps required to use the App are as follows:

1. After the user has run the App, it is permitted to access their device's location, as prompted.
2. The user gets an OTP (one-time password) and enters it to sync the App.
3. The user has to choose their gender from the options given.
4. The user's full name, age and profession are requested.
5. The user is asked about their foreign travel history.

Once an appropriate answer is given regarding the foreign travel history, the answers will be matched with the ones provided by individuals who have tested positive. This process is carried out with the help of the ICMR database. The App then asks the user whether or not they are ready to volunteer in times of need. In case an affirmative answer is provided, a 20-second assessment test is initiated.

After the user has installed *Aarogya Setu* on their phone, it will detect other nearby smartphones that also have the App installed. It can then figure out the risk of infection based on sophisticated parameters if any of these contacts tests positive.

The smartphone user's interaction with others is the basis for this calculation – which is done using Bluetooth, specific algorithms and Artificial Intelligence.



Storage of data

The data is stored on the cloud using open-sourced technologies. The database is under the control of the National Informatics Centre, which is part of the Ministry of Electronics and IT (MeitY), Government of India.

GOI is planning to incorporate all Covid-19-related information and services within the application. The plans include making it a single point of access for food shelters, night shelters as well as *Suraksha retail stores* – sanitized corner stores – that are being launched across the country.

A *National Telemedicine Platform* may also be integrated within the App so that people with any illness can consult a doctor remotely and limit visits to medical facilities during the pandemic. The App could also become the single interface for all curfew passes as the government seeks to make sure that no person who is at risk is allowed to travel anywhere once the lockdown is lifted to prevent the risk of infection spreading exponentially.

The main SDGs related to Aarogya Setu include:

- SDG Goal 3 – Promote healthy lives and promote well-being for all (at all ages).
- SDG-11– Make cities and human settlements inclusive, safe, resilient and sustainable.

Why is this simple and smart?

Aarogya Setu is simple and smart because it is easy and quick to implement and does not involve much expenditure, either for the authorities or for the citizens. Given the simplicity of the App, similar Apps could be implemented in any smart city in the world.

Where has it been implemented?

Aarogya Setu has been implemented at the country level in India. It provides information alerts in blocks of 500 metres, 1 Km, 2 Kms, 5 Kms and 10 Kms. It can therefore be easily used in any city.

Benefits realized

There are early signs that the App is effective in different ways. By using the self-reported information, it is possible to correlate areas where the incidence of infections is increasing as well as confirming the areas of emerging infection as the source of early evidence.

This App has helped the Ministry of Health, Government of India in getting alerted to about 650 hotspots in the country, besides helping to identify about 300 emerging hotspots (as of 8 May 2020). The App has played a major role in effectively controlling the pandemic. It has helped the Health Ministry in identifying whom and where to test, thus saving time and limited resources in random mass testing.

Apart from being a health challenge, the Covid-19 pandemic has also damaged the economies of the world. Efforts to mitigate the health challenge and restoring economic activity would help prevent economic collapse.

Other consequences and considerations

1. There have been concerns in India that, by virtue of this App, the government can spy on citizens and that privacy would be compromised. Though these are apprehensions and may or may not exist, when the choice is between saving millions of lives and privacy, the choice is obvious. *The data is shared only with the government*. The App doesn't allow user-names and numbers to be publicly disclosed.
2. Since users are supposed to fill in all details concerning their health, any serious flu-like symptoms can be interpreted as Covid-19, triggering false alarms and people overreacting when a case is reported in their neighbourhood. Yet, it is better to err on the side of safety in the interest of the community as a whole. A test in such cases would clarify everything.

Keys to success

The project can be deemed to be successful since a large number of citizens – more than 127 million people – downloaded the App as of July 2020. It gives confidence to the user that they are in a safe zone, freeing them of undue apprehension due to this pandemic. This intervention can be used in all types of cities, big or small. Only the dimensioning of the system would vary.

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