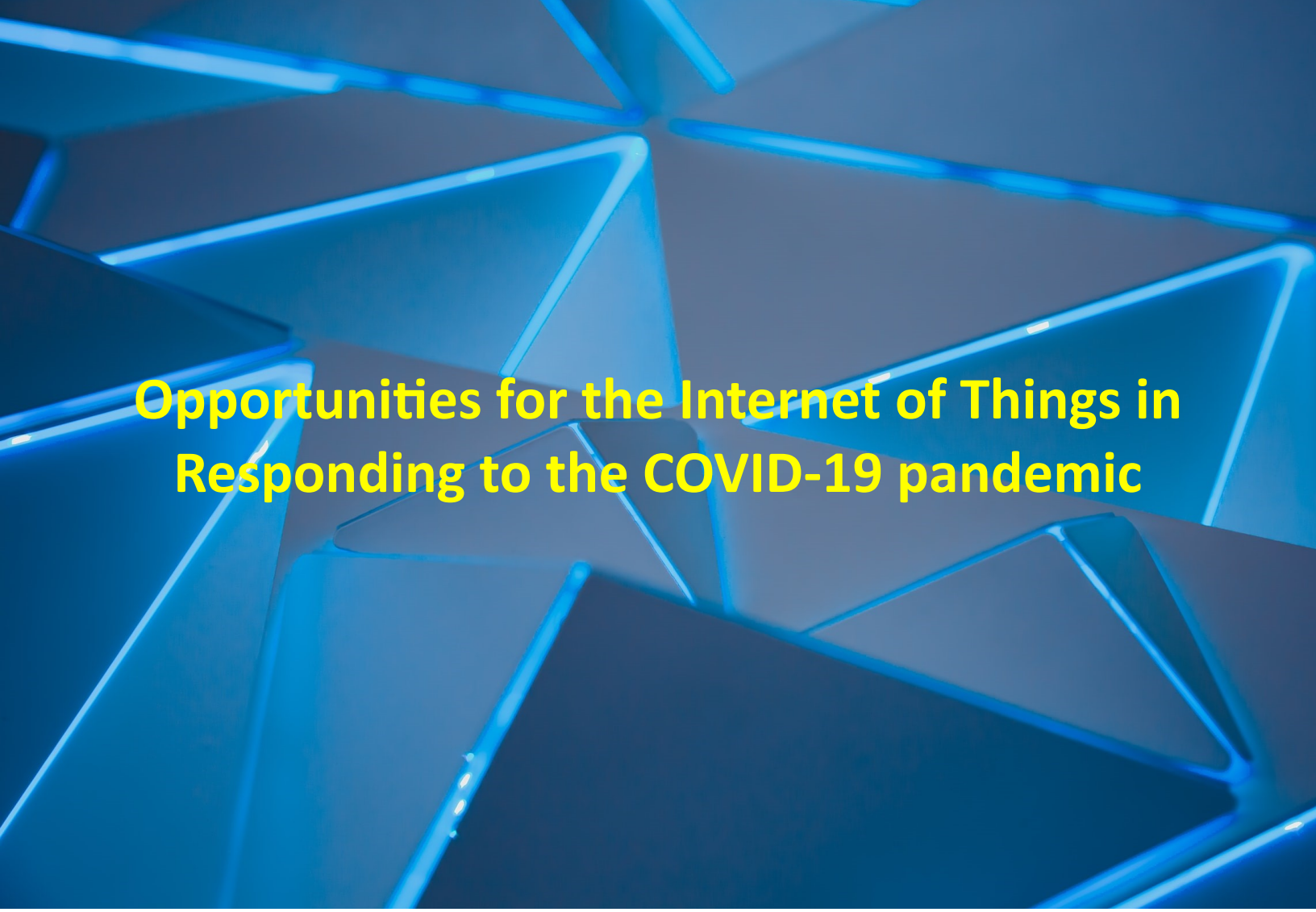

Opportunities for the Internet of Things in Responding to the COVID-19 pandemic

Smart, Responsive and Resilient Cities Insights Series

May 25, 2020

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Target Audience and How to Use this document

This white paper was created with the following objectives:

1. Provide a high level understanding of the COVID-19 roadmap to recovery
2. Provide an understanding and context of the key response strategies
3. Provide solution providers with a holistic structure and framework to identify IoT and technology solution opportunities
4. Provide solutions providers with three example areas of opportunity for IoT

Executive Overview

The coronavirus COVID-19 pandemic has disrupted cities and communities worldwide. Although cities, communities and governments have some emergency and disaster response plans, the scale of the outbreak has strained their resources and capabilities. Smart City technologies, with their innovative digital approaches and impacts, offer the potential to facilitate responses to COVID-19. As a result, municipalities and the public health system have turned to technology companies for help. Many established and start-up technology companies have responded with ideas and proposals. However, the results have been mixed and uneven. Some problem areas get a lot of ideas while other problems get none. Still other ideas are unfeasible. Many respondents lack understanding of how cities respond to public health emergencies.

This white paper discusses the role of the Internet of Things (IoT) in responding to the COVID-19 pandemic. This role is discussed in the context of a smart city-public health emergency collaboration framework. The framework provides a structured way to identify collaboration opportunities between cities, public health systems and the technology community. It integrates typical smart city ecosystem capabilities with the CDC public health emergency preparedness and response capabilities. The framework is then used to identify potential IoT opportunities. Three example areas of opportunity are described.

Introduction

The coronavirus COVID-19 pandemic has devastated and disrupted cities and communities worldwide. From the loss of lives, interruption of essential day-to-day services, to disruption of the global economy, no one person, organization or country is spared. Local, regional and national governments are urgently responding with varying degrees of effectiveness. As the number of infections and deaths surge, governments are turning to technology and innovative approaches for help.

Cities have so far borne the burden of the COVID-19 outbreak. Can smart cities, with innovative technologies such as the Internet of Things (IoT), artificial intelligence (AI), 5G, open data, and analytics, respond more effectively? This white paper provides a framework listing the potential areas of opportunity for the Internet of Things (IoT). Cities and technology companies can use this to structure their own thinking, and to ensure they have considered all the dimensions of the problem. In addition, we provide a sample set of IoT solutions to illustrate the framework in action.

The journey to recovery goes through four stages

When will the COVID-19 pandemic end and we go back to "normal"? This is a commonly asked question posed by many in the communities and business organizations impacted by COVID-19. The answer to the question is ultimately dependent on the discovery of an effective vaccine. Experts predict a vaccine will be discovered in mid 2021, approximately twelve to eighteen months from the emergence of COVID-19. In lieu of a working vaccine, communities focus on containment through exposure avoidance, detection and care of the infected.

The period spanning the start and end of the pandemic is marked by four distinct stages (Figure One). In order to discover the IoT opportunities in responding to COVID-19, it is crucial to understand what the different stages are, and corresponding strategies are employed in these stages.

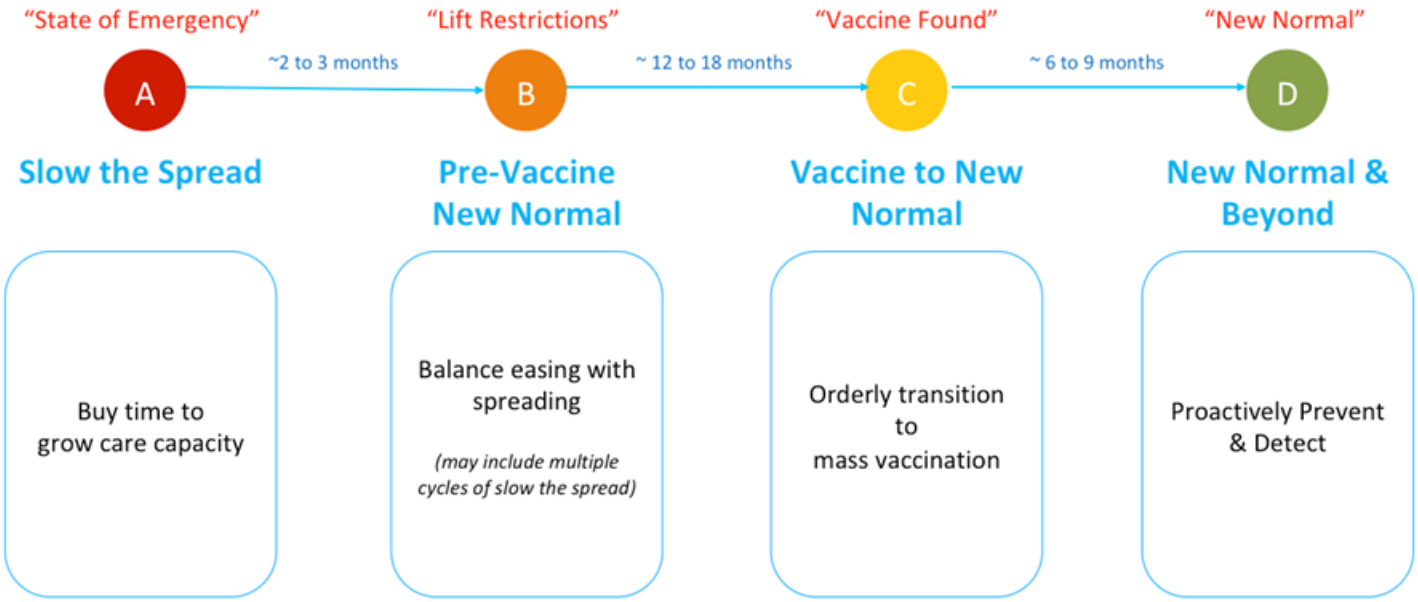


Figure One. The four stages to recovery from COVID-19.

The outset of the pandemic is marked by an exponential surge in the number of infections and deaths. No matter how well prepared communities and public health systems are, the surge will soon overwhelm their ability to respond. A state of emergency is declared and a "shelter in place" is ordered for the general population to stay home. Schools are closed and in-class instruction has shifted to distance and remote learning. Non-essential businesses are closed or operating remotely. Mass public gatherings and events are banned. The main purpose of a state of emergency declaration is to slow the infection rate down such that it won't overwhelm the health system's capacity to manage it. This measure is intended to "buy time" to enable the public health system to build up their response capabilities. This means more testing capacity, hospital beds, ventilators, staff and other resources. Figure Two illustrates the interplay between health care system readiness with the number of new infections across the four stages.

When the number of new infections decrease, and the health system is at a higher state of response capacity, a new stage (B) is entered where restrictions are gradually eased. While an increase in new infections is expected, it is adequately addressed by the public health system, which now has more capacity to treat the infected, and limit its spread. The goals in this stage are to contain the virus in a sustainable way, ease the communities into an "interim new normal", and "buy time" for a vaccine to be developed.

Communities enter stage C when a viable vaccine is developed. However, the vaccine is not available overnight and the community is still vulnerable. It takes time to be manufactured, shipped and distributed to the various communities and health organizations. In addition, there is an orderly transition to the administration of the vaccine. Priority groups within the community are given the vaccination first, including front line workers, healthcare staff, and the vulnerable members of the community. As more people receive the vaccine, the number of new infections in the community begin to drop off rapidly.

A "new normal" state (Stage D) is entered when a certain percentage of the population has been vaccinated and "herd immunity" is achieved. At this stage, formal exposure avoidance practices are halted, and the healthcare system and communities returns to a "normal" state. However, this state represents a "new normal" state that will be different from the normal state pre-pandemic. The community and the public health system must remain vigilant in the "new normal" stage and must begin to plan and prepare for the next pandemic or other health crisis.

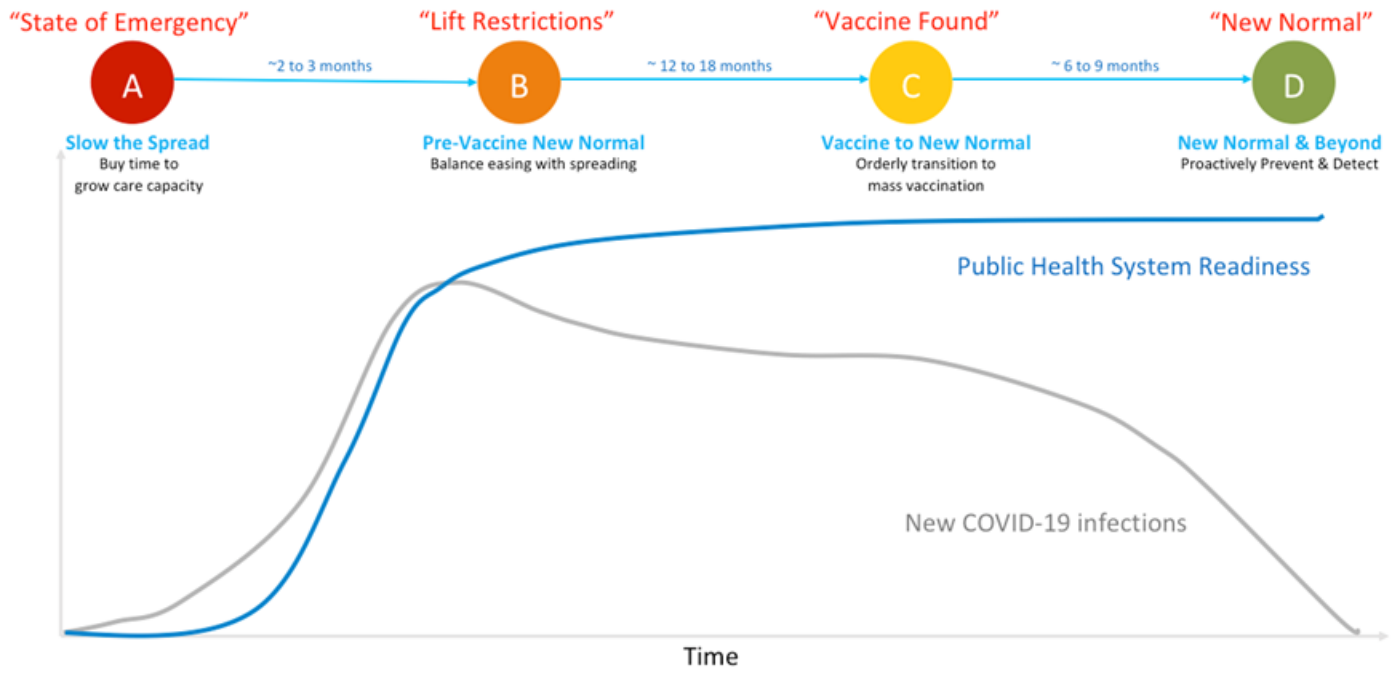


Figure Two. The interplay between the number of new infections and public health system readiness.

COVID-19 responses vary by stage but two core strategies remain constant throughout

Without a vaccine in place, the communities and the public health system's COVID-19 response is based on two core strategies. First, implement exposure avoidance initiatives to prevent new infections in the community. Second, rapidly detect, isolate and treat new infections within the community to limit spread. How well these strategies are implemented will determine whether restrictions can be lifted (Stage B) and the economy can reopen and enter into an interim new normal. Both strategies must be simultaneously effective for a path to recovery to begin.

Figure Three highlights the key strategies and tactics employed in each of the stages. The core strategies of exposure avoidance and public health system capacity readiness are foundational throughout each stage. In stage A (state of emergency), a key tactic was to build up the capacity and capability of the public health system to respond.

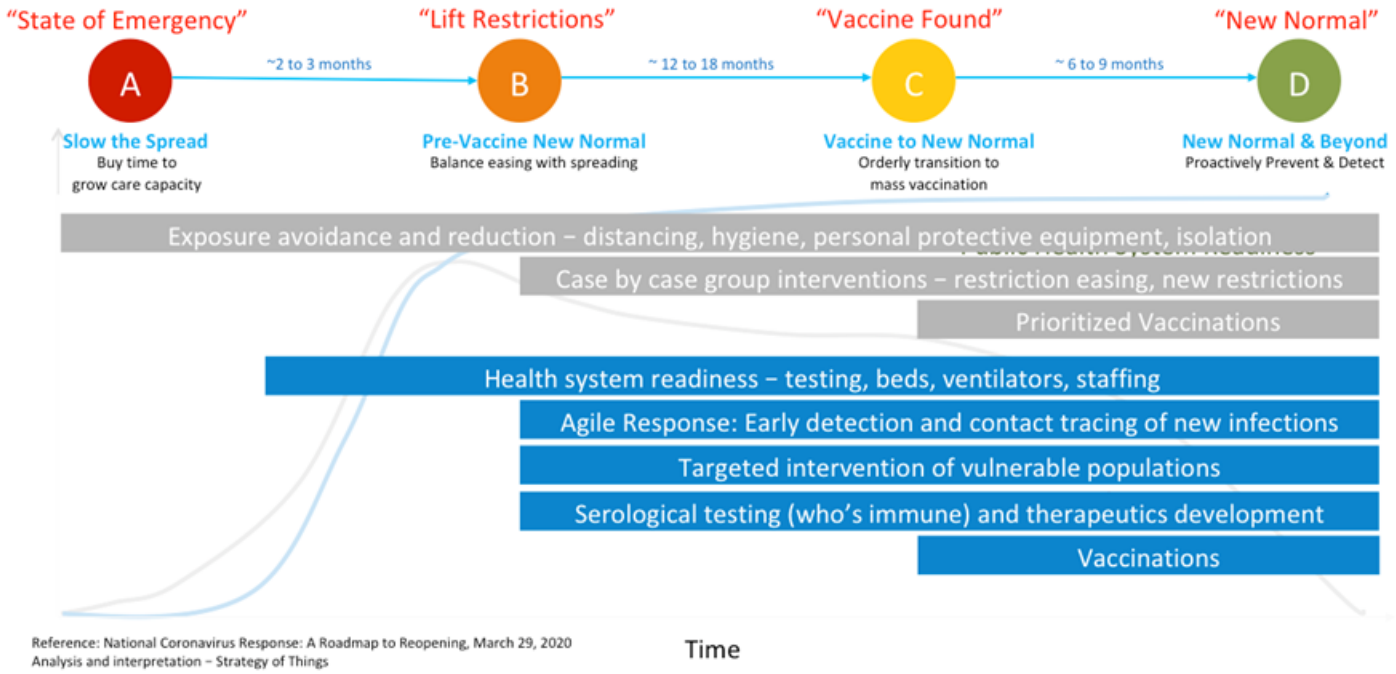


Figure Three. Key response strategies employed during the road to recovery.

As restrictions are gradually eased (Stage B), the core strategies remain in place. In lieu of a vaccine, communities must continue to avoid exposure whenever possible. While schools, some businesses and public venues reopen, preventative and protective measures continue. People must practice social distancing and wear face masks in public. They must continue to practice good hygiene. Large crowds and mass gatherings, such as concerts and sporting events, are avoided. People who can telework should continue. Non-essential travel should be limited whenever possible.

As more public health preparedness and response capabilities become available in Stage B, existing core strategies are supplemented with new tactics. Targeted interventions for specific parts of the community is now possible. For example, initiatives can be developed and implemented for communities or neighborhoods with large elderly populations. Case specific programs and initiatives can be planned and implemented for people with pre-existing conditions. New infections can be detected and responded to immediately. Automated contact tracing tools quickly identify potential infected individuals who are isolated, quarantined or hospitalized. These tactics enable communities and the public health system to "buy time" for a vaccine to be developed.

The discovery and development of a vaccine starts the next stage (C). However, the new vaccine will not be available immediately. It must be manufactured, shipped, and distributed to various communities - and people must find the time an inclination to receive it.. The medical care community must be trained to administer it, as well as understand and be prepared to treat any adverse reactions and symptoms. The administration of the vaccine will be prioritized so that certain parts of the community will get it first, for example front line health workers, others in essential jobs that require face to face contact (retail workers for one), and vulnerable members of the community. The vaccination roll-out for the US is expected to be a six to nine month process. Similar timelines are expected around the world.

During this transition period, the strategies and tactics used in previous stages continue to apply until specified otherwise. This means that those who have not received the vaccine will continue to practice exposure avoidance. The public health system will continue to scan for new infections, and apply countermeasures. Targeted intervention programs and initiatives will continue.

A "new normal" stage (D) is reached when a sufficient percentage of the population has been vaccinated to enable herd immunity. While the core strategies and stage-specific tactics may stop, many lessons learned and practices from these previous stages will be incorporated into everyday life. Office floor plans and furniture layouts reflect social distancing requirements. Teleworking and distance learning will become a permanent part of how people work and study. Hygiene stations become commonplace. Automated contact tracing technologies become standard in public health systems' response toolkits. Public spaces employ practices to ensure the health of its community members.

The role of technology in responding to the COVID-19 pandemic

Communities and government have largely been overwhelmed by the scale of the COVID-19 pandemic. Hospital beds, ventilators and face masks are in short supply in many places. As the number of infections and deaths surge at the outset of the pandemic, governments have turned to technology and innovative approaches for help.

Technology, and in particular the Internet of Things (IOT) combined with data and analytics, is a key enabler and facilitator in the response to COVID-19. This is because:

- Networked sensors of different kinds (for example, temperature sensors, cameras, proximity sensors, air pollution sensors, and not least, the smartphones owned by the public) enable mass surveillance of disease trends and risks. This will of course be subject to privacy concerns.
- Analytics and AI enable patterns and connections to be seen that would miss the unaided human eye and enable predictions to be made that drive pre-emption rather than mere reaction. They also readily enable combinations of IOT data with external data such as air flows or population age groups and locations.
- Analytics, in particular when combined with constructs such as digital twins enable interactions between the disease and other systems to be modelled with live data - for example the impact of transportation routes on disease spread, or assessing disease risk from the incidence of virus loads in sewage.

Thus, the Internet of Things can automate tedious manual processes such as contact tracing. It can analyze vast quantities of data and information to accelerate the vaccine discovery process. It can drive greater engagement and communication between communities and public officials.

In order to discover relevant technology opportunities, it is necessary to understand how cities and the public health systems prepare for and respond to pandemics. In 2011, the United States Centers for Disease Control and Prevention (CDC) defined the Public Health Emergency Preparedness and Response capabilities standards[1]. This set of fifteen capabilities, organized into six domains, (Figure Four), is designed to enable state and local governments to respond to health emergencies like COVID-19. Each of the fifteen capabilities enable a defined set of functions and activities to be performed.

Four smart city capability layers, taken from the Strategy of Things smart city ecosystem model, were overlaid onto the CDC defined domains to create the framework. (Figure Five). This framework represents a holistic way to think about the entire array of potential technology opportunities for responding to the COVID-19 pandemic.

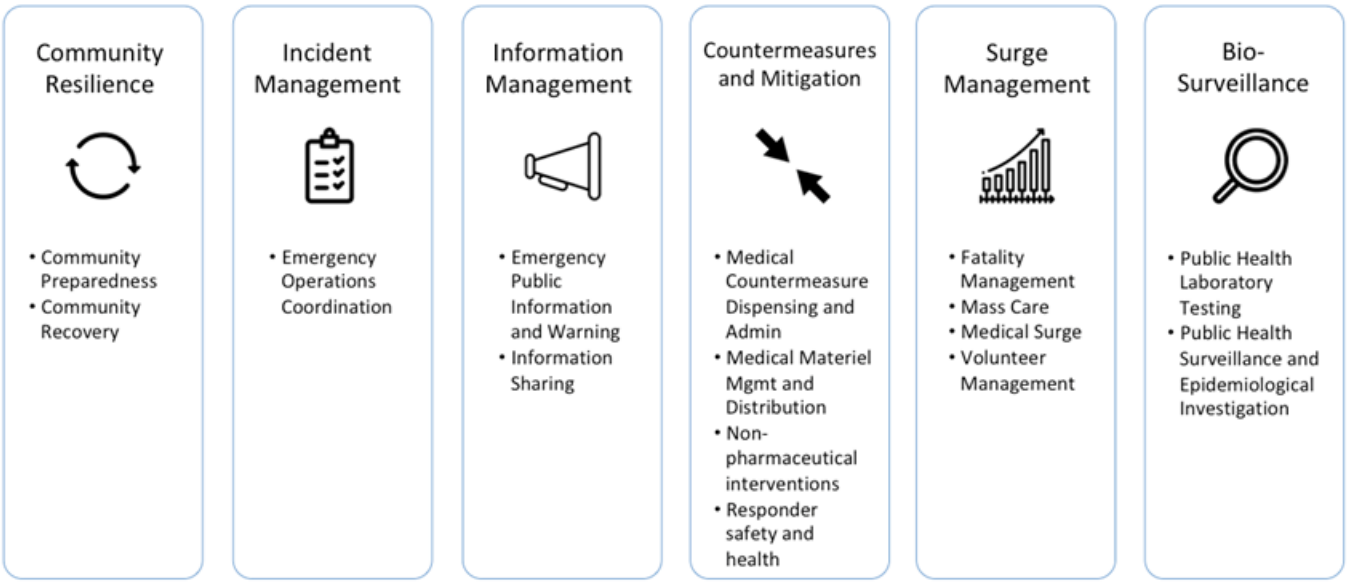


Figure Four. The CDC Public Health Emergency Preparedness and Response Capabilities for Communities.

Challenges in engaging the technology community

Community resilience, health and wellness, and public safety are top of mind with city and public health leaders during the COVID-19 outbreak. Although cities have some resources, capabilities and capacity to respond to emergencies, the scale of the COVID-19 outbreak has overwhelmed many of them. Local and state governments are pushing existing resources and capabilities to its limits with limited effectiveness.

Governments have turned to the technology community in an effort to track the virus, slow new infections, prevent the healthy from falling ill, and to help the infected recover. Technology providers and innovators have responded in a variety of ways. These include manufacturing additional ventilators, 3D printing facemasks and shields for healthcare workers, and using AI to accelerate the development of new cures.

However, current efforts to engage the innovation communities are reactive, piecemeal, and have limited effectiveness. Many technology companies lack context and bombard cities with “solutions” that may not be relevant or complete. Some cities focus on the technology element, but not on equally important elements like community engagement. As a result, some problems get a lot of attention from the innovation community while others go unaddressed. Other problems cannot be addressed because the communities lack supporting infrastructure. Still other solutions have limited effectiveness because they lack community support.

Developing a better way to collaborate

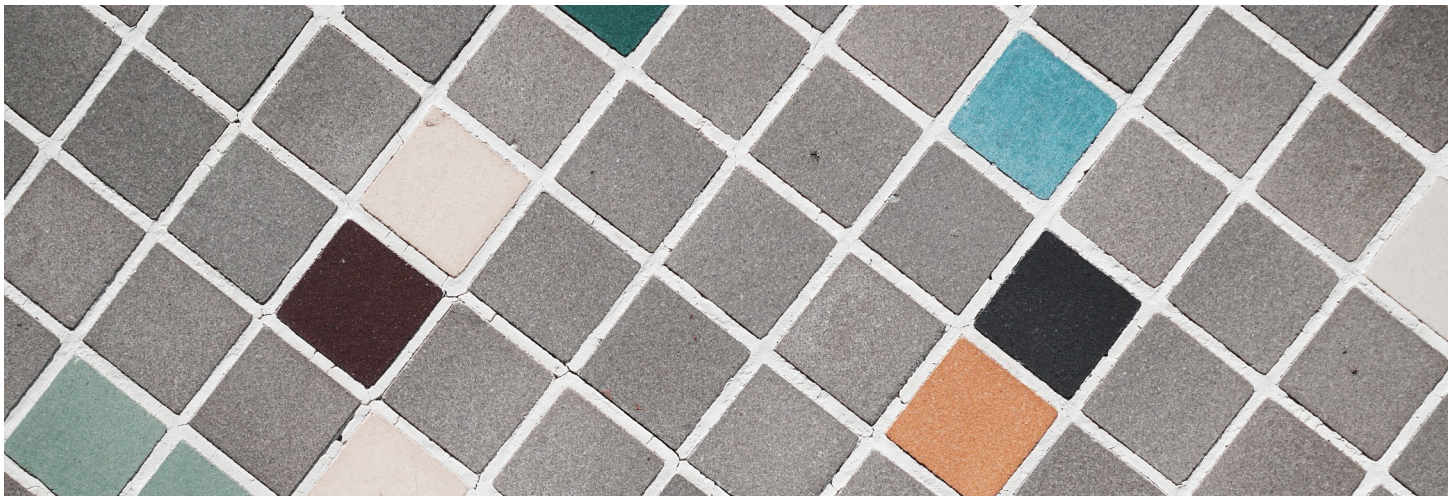
The Smart Cities and Public Health Emergency Collaboration framework was developed with these realities in mind. It is aligned with how public health systems respond to and manage emergencies. The framework was constructed by taking the CDC Public Health Emergency and Response Capabilities standards (Figure Four) and overlaying it with a simplified version of the Strategy of Things smart city ecosystem framework[2]. This resultant framework is shown in Figure Five. Actions and solutions can then be posited at each intersection; indeed, existing responses can also be mapped, enabling possible gaps (aka additional opportunities) in a community’s current approach to be seen. This framework is the basis for identifying opportunities for technology, and IoT, in helping communities and government respond to the pandemic.

	Community Resilience	Incident Management	Information Management	Counter-measures and Mitigation	Surge Management	Bio Surveillance
Innovation						
Community Engagement						
Data and Analytics						
Technology Infrastructure						

Figure Five. The Strategy of Things Smart City-Public Health Emergency Collaboration Framework.

Each intersection in the framework represents a collaboration point where the smart city's innovation ecosystem and digital capabilities can be used to augment the municipalities' public health emergency response needs.

This Smart Cities COVID-19 framework broadly captures and proactively maximizes the full range of collaboration opportunities between cities, public health systems, and the technology community for a public health emergency. The more boxes in the framework that can be populated, the more effective the overall response is likely to be. A detailed explanation of this framework can be found in the white paper "Responding to the COVID-19 pandemic - A collaboration framework for cities and solutions providers"[3].



Using the framework

With an initial understanding of the Smart Cities COVID-19 framework, the following are recommended next steps for municipalities, communities and public health systems:

- Review the framework and understand each of the fifteen capabilities (Figure One) and the associated activities corresponding to each capability.
- Evaluate the current state of the community's response capabilities and activities. Identify the level of activities, as well as gaps in your capabilities.
- Map the gaps and wants into the framework. This becomes a list of challenges that can be used to solicit innovative ideas and solutions.
- Invite the technology and innovation community to review this list. Host various brainstorming and ideation sessions. Create open challenges and invite the community to participate.

For technology and innovative solutions providers:

- Review and understand what each of the fifteen capabilities are, and what activities they enable.
- Review the framework, and identify those areas of current and future potential opportunity for your solution or capabilities. It may be necessary to establish partnerships with other technology companies in order to provide an integrated offering.
- Using this framework as a guide, discuss with public health and emergency operations and response planners their capabilities, gaps, and areas of potential collaboration and opportunity.

As you review the framework, consider IoT opportunities from three perspectives:

- Stand-alone applications, such as air quality monitoring, performing a single function.
- An end-to-end process enabled by multiple stand-alone IoT solutions working together. An example is a fever detection sensor solution working with a keyless door entry solution to keep employees with a fever from entering the workplace.
- An IoT solution embedded into a broader technology solution. The final application may not be an IoT solution. One example is a telehealth and caregiver solution that employs a variety of IoT sensors to monitor patient health.

Opportunities for IoT can directly support a response to COVID-19, or indirectly support the applications that protect and respond to COVID-19. An example of a direct application is a body temperature detection sensor. Indirect applications are those that support the use of IoT applications. For example, an IoT connectivity network within a community, or a platform that integrates various IoT sensors.

This framework is most effective when:

- It is used as a starting point for discovery and collaboration. Cities and health systems bring domain knowledge, while IoT companies bring the digital expertise.
- Cities and health systems use it to plot their existing responses and then identify their capability gaps and needs. They must articulate those gaps and needs to the IoT technology companies.
- IoT companies align their offers to the CDC specified capabilities and activities. It may be necessary to partner with other vendors to offer an "end to end" solution.
- Everyone thinks beyond individual squares. The squares are a starting point. Some needs cross multiple capability domains and require a combination of technology, community engagement, and data.
- Collaboration opportunities are separated into two categories. One for tactical immediate responses, and a separate set for mid-term, longer efforts.

IoT Opportunity—Safe Spaces

A safe space provides peace of mind to its occupants. It is a physical space that enables people to come together to work, collaborate, learn, and socialize in a way that minimizes their health risk.

A safe space **prevents** infected people or things from entering the space. It **protects** its occupants from any infection sources that may have entered the space. It **mitigates** the impact of any possible exposure inside the space. It **responds** quickly and effectively to actual exposure incidents. It **recovers** and returns the workspace quickly with minimal business or occupant disruptions.

Body temperature detectors scan occupants to determine if they have a fever. Those with fevers are prohibited from entering the space and are directed to seek medical attention.

Contactless systems use voice controllers, gesture recognition detectors, sensors and actuators to operate doors, water faucets, towel and soap dispensers, elevators and phones. This reduces exposure risk from touching common objects.

Social distance monitoring systems determine how many people are social distancing, and to notify those who are not in compliance. Individuals can maximize the safety of spaces for themselves using personal alert devices for where safe distance limits are infringed or using personal devices to assist with contact tracing (and thereby getting information for themselves).

Sanitizing and cleaning robots clean surfaces on a regular basis to reduce the possibility of contaminated surfaces which many of its occupants may come in contact with.

Occupant contact tracing is an analytical solution that enable healthcare professionals to determine who any infected people may have come in contact with at the facility.

Occupancy sensing counts the number of people in an area such as a gathering spot, conference room or workspace, and monitors compliance with internal and public health policies.

Asset tracking provides real time awareness of location and quantities of onsite medical and mitigation resources. Ready for rapid deployment. Assets and supplies with a defined shelf life are aged and proactively replaced.

Remote health monitoring and care allows those with potential health issues to receive advice and consultation in onsite isolation or quarantine rooms without having to risk infection by traveling to doctors' offices or hospitals. For example, a visitor found to have an elevated temperature by at the entrance to the safe space is directed to an isolation room for evaluation by a doctor remotely. An occupant feels ill during the day and is directed to an isolation room for consultation. These technologies enable healthcare providers to evaluate large groups of people concurrently regardless of their location. Specialized healthcare personnel can be consulted for potentially infected patients across multiple safe spaces.

Digital signage enables rapid sharing of the latest safe space metrics, health safety alerts, best practices, policies and other relevant information to occupants.

IoT Opportunity—Agile Response to New Outbreaks

An agile response detects new outbreaks early, quickly mobilizes the right resources to affected communities, limits the spread, and effectively treats the afflicted.

Community sentiment detection collects intelligence from residents and businesses. QR codes scanned using mobile phones direct users to complete brief community and health surveys. Data tools analyze comments on local social media and forums. These technologies spot early signs of outbreaks and identify community needs. Early detection limits the spread of new virus outbreaks by directing care and containment resources quickly.

Remote health monitoring and care allow infected, and those suspected to be infected, to be observed in a scalable and safe way. Health sensors are used to monitor people at hospitals, healthcare facilities, and those under quarantine and isolation at homes. In public spaces, body temperature thermal cameras determine how many people have elevated temperatures and use that information to detect early signs and scale of an outbreak. Telehealth allows those with other health conditions to receive advice and treatment without having to risk infection by traveling to doctors' offices or hospitals. These technologies enable healthcare providers to monitor large groups of people concurrently regardless of their location. Specialized healthcare personnel can be utilized to care for infected patients across multiple communities.

Wastewater monitoring enables early detection of COVID-19 in the community. Current research efforts worldwide are underway in detecting COVID-19 in fecal matter in sewage. In the near future, sensors can be deployed at various community locations and at wastewater plants to support early detection and monitoring initiatives.

Asset tracking of medical equipment, supplies and resources enable responders to mobilize and deploy quickly to limit outbreak spread and treat the infected. Responders know exactly where facemasks, ventilators, hospital beds and other supplies are at all times. Available resources and supplies are located in real time, distributed and deployed into the communities of need in a rapid and efficient manner. Assets and supplies with a defined shelf life can be aged and proactively replaced as required.

Tracking of medical and support personnel location and availability enables the rapid deployment of relevant staff. Location sensors on wearables, mobile phones or specialty badges, enable the tracking of available and relevant healthcare and services providers in the field. This facilitates resource planning and enables agile deployment of relevant staff to areas of need.

Location analytics and contact tracing enable healthcare and response teams to automate the identification and notification of those individuals who may have come in contact with an infected person, and those areas where contact occurred. Using location sensors on mobile phones, wearables and e-badges provide location, people density and proximity information. Response teams act on this information to take remediation action on affected sites, including special cleaning, and implement preventative practices to limit the number of people, facilitate social distancing and limiting the time spent in those areas.

IoT Opportunity—Targeted Interventions

Targeted interventions are planned actions undertaken by community and healthcare responders for the specific benefit of select communities and groups.

Example One: Deploying air quality sensor network to identify potential communities for prioritized programs

Researchers at the Harvard University TH Chan School of Public Health discovered a linkage between COVID-19 related deaths and long term exposure to particulate matter air pollution. A minor 1 g/m^3 increase in long term PM2.5 exposure leads to a 15% increase in the COVID-19 related death rate. A study conducted by researchers at Martin Luther University of Halle-Wittenberg in Germany found that 78% of the COVID-19 related deaths in north Italy and central Spain were located in five regions which had the highest NO2 concentrations and a downwards airflow which prevented the dispersion of air pollutants.

IoT Solution

With this knowledge, a network of lower cost air quality sensors can be deployed around the community. Air quality maps are created to characterize pollution patterns and hot spots over time.

Outcomes

Using this information collected, healthcare providers and communities can target specific programs to residents in those areas with high pollution levels. These programs include preventative care services and resources for elderly and other vulnerable residents. Local healthcare facilities can be pre-stocked with extra personal protective equipment, ventilators, and other medical supplies. Early COVID-19 detection and monitoring programs can be implemented for these specific communities.

Example Two: Deploying location analytics to study people movement data to minimize COVID-19 exposure

Shopping centers are public spaces that attract a large amount of people. Many of these shoppers and visitors congregate in stores and other spots throughout the shopping mall. This leads to a high risk of exposure.

IoT Solution

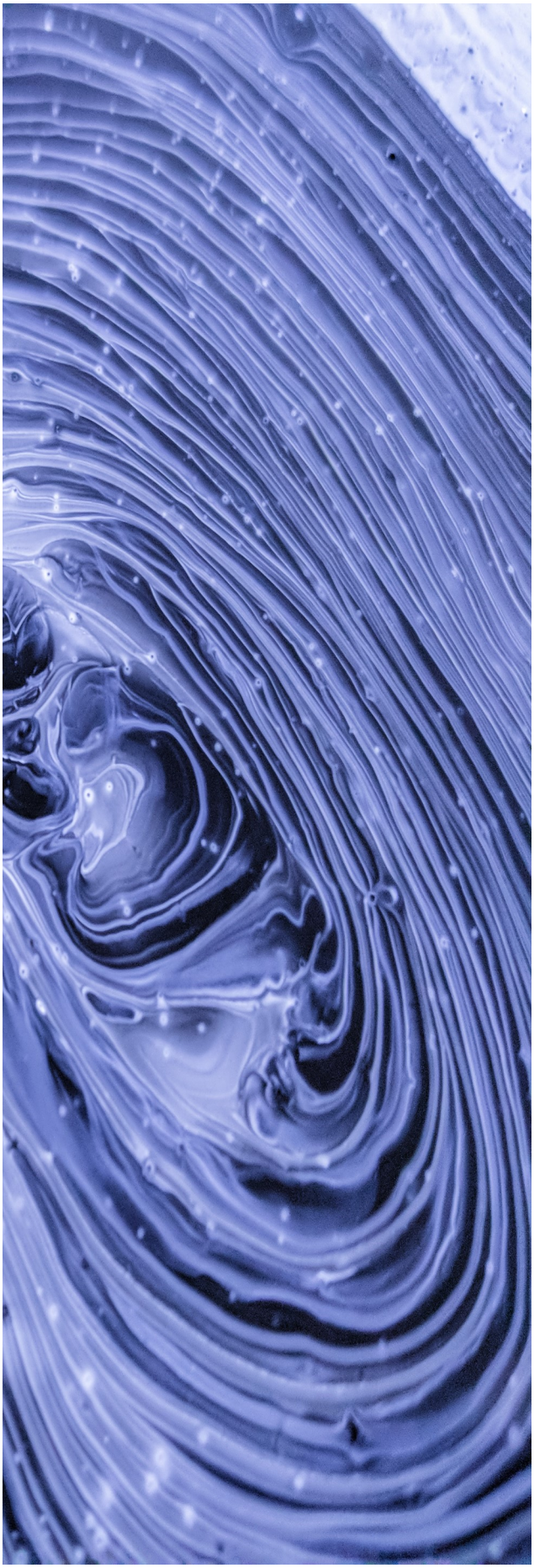
Wireless bluetooth and wi-fi signal detection sensors can be deployed at strategic locations throughout the shopping center. These sensors collect the wi-fi signals of mobile phones throughout the shopping center.

Location analytics algorithms, analyzing the information from the signal detection sensors, create maps that show shopper movement patterns. The information includes specific areas where people gathered, how many people were there, how far apart they stayed from each other and how long they lingered.

Outcomes

Facilities planners use these insights to create strategies that reduce the number of people gathering in hot spots, and alter movement patterns to encourage smooth flow of movement, minimize COVID-19 spread. Using this information, facilities planners can remove furniture in certain spots, add barriers and large objects (plants, artwork, etc.) in other locations, or remove objects in order to widen walking pathways to decrease people density.

Closing and Final Thoughts



The COVID-19 pandemic has disrupted cities and communities worldwide. The journey to recovery will go through four stages, and will lead to a “new normal” in the way we live, work, learn, and spend our free time. Without a vaccine in place, the communities and the public health system’s COVID-19 response is based on two core strategies. First, implement exposure avoidance initiatives to prevent new infections in the community. Second, rapidly detect, isolate and treat new infections within the community to limit spread. These core strategies form the foundation for response throughout the four stages.

Smart City technologies, with their innovative digital approaches and impacts, facilitate the way cities and communities respond to COVID-19. The smart city-public health emergency collaboration framework, which integrates typical smart city ecosystem capabilities with the CDC public health emergency preparedness and response capabilities, was used to identify potential IoT opportunities. Three opportunity areas - safe spaces, agile response to new outbreaks, and targeted interventions, were described. Various individual IoT applications were mapped to each of these opportunity areas.

The framework shared in this white paper provides a holistic structure to think about and discover other IoT opportunities. The Internet of Things (IoT) can directly support a response to COVID-19, or indirectly support the applications that protect and respond to COVID-19. Furthermore, IoT applications can be standalone, integrated with other IoT solutions, or embedded as part of a broader non-IoT solution.

A sense of urgency and a commitment to action is required to limit the disruption caused by the COVID-19 and future pandemics. The Internet of Things brings transformational capabilities in the worldwide COVID-19 response. Readers of this white paper are encouraged to review and use the framework as a starting point for discovering IoT opportunities. Collaboration and partnerships with various members of cities, communities (public and private), health systems, and government is absolutely crucial in uncovering relevant problems and opportunities.

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