Technologies Helping Smart Cities to Build Resilience: Focus on COVID-19

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Abstract. Sustainable development goal #11 (SDG#11) deals with making cities inclusive, safe, resilient, and sustainable. SDG#3 deals with "Strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks" So, the COVID-19 pandemic can be included within the targets of SDG#11 and #3 targets. It is reiterated the necessity of disaster and emergency health risk reduction and the building of resilience within the context of sustainable development concerns. Resilience is a concept also contemplated within the paradigm of smart planning and smart cities. The urban domain is selected to explore the tools used to cope with the current COVID-19 pandemic and that contribute to building resilience. Innovation and the relevance of SDG#9 are clear since the urgency of improvements in general and domestic technology and access to universal and affordable internet have to be guaranteed to achieve the objective of building resilience. A categorized vision of the main technologies, applications, and functionalities within the Smart City domain are discussed to identify the way those technologies support COVID-19 and integrate with the three SDGs fundamentals for resilience building. We hope that this work will contribute for practitioners, policymakers, academics, and citizens to be better prepared for future outbreaks.

Keywords: COVID-19, Smart Cities, SDG, Resilience, Resilience Building, Disrupting Technologies.

1 Introduction

The United Nations' Sustainable Development Goal #11 (SDG#11) deals with turning cities inclusive, safe, resilient, and sustainable. It is a fact that urbanization is exerting pressure on the living environment (fresh water supply, sewage discharge) and public health. In the current situation of the coronavirus pandemic, the high demographic density in urban environments is acting as an enabler for virus dissemination.

Due to the lack of consensually effective drug therapy and incomplete vaccination, interventions in terms of virus spread prevention are mandatory. The measures to prevent the dissemination of viral infections in communities include maintaining social distancing combined with different degrees of lockdown [1]. According to Shoruzaman et al. [2], the social distancing protocols include country wide lock downs, travel bans, and limiting access to essential businesses. People face the challenge of meeting the needs in total or partial isolation whereas the continuity of essential services is ensured.

Among the targets included in SDG#11, two are explicitly applicable to the current situation of the pandemic. In this way, target 11.5 deals with reduction of the number of deaths and the number of people affected by disasters and target 11.B deals with increasing the number of cities adopting and implementing integrated policies and plans towards resilience to disasters in line with the Sendai Framework for Disaster Risk Reduction (SFDRR) [3]. The SFDRR reiterates the necessity of disaster and emergency health risk reduction and the resilience building within the context of sustainable development, being resilience defined as "The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management" [4].

As stated by Wright et al. [5] the SFDRR recognizes health at the heart of disaster risk management. Thus, target 3.D of SDG#3 dealing with "Strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks" [6] is aligned with the SFDRR. So, the COVID-19 pandemic can be undoubtedly considered a matter of concern of SDG#11 and #3.

The transboundary characteristics of the pandemic lead to a multilevel necessity of management, at the global, national, regional, and city levels. The approach of SDG#11, more specifically its focus on resilience, offer the approach to explore the tools used to cope with the COVID-19 pandemic at the urban level and consequently, to help in building resilience.

Resilience is a concept also contemplated within the paradigm of smart planning and smart cities [7] [8]. The smart city (SC) concept although broad and still open to new approaches, converges into two fundamentals: new technology-based applications (based on information and communication technologies (ICT) and data-driven smart applications) providing an added value to the human/environment binomial.

The main function of innovation is related to the role to develop, test, and implement new solutions through the building, sharing, and continuously enhancing practical knowledge in response to the goals, strategies, policies, and visions of the city [9]. The relevance of SDG#9 is evident since the urgency of improvements in technology and access to universal and affordable internet have to be guaranteed to achieve the objective of building resilience.

The present paper aims to discuss how the information and communication technologies within the smart city environment could contribute to building resilience during the COVID-19 pandemic in an integrated way with SDG#11, #9 and #3. There is little discussion on smart city technology devoted to support urban resilience in the context of Sustainable Development paradigm. It is expected this paper will shed light to identifying ways of operationalizing the SDGs (in this case, three of them) with a well-focused goal of resilience construction within pandemic. We hope discussion will help practitioners and academic researchers.

2 Literature Review

This brief review organizes literature according to three classes. Some papers deal with technologies adopted to fight against pandemics without identification of the domain of action and application. Others explicitly express the focus on SC. And it is found an incipient research approach which deals with SC network.

Among the first class of papers in mitigating the spread of COVID-19 [10], cover the role of smart technology with specific focus on advancement in the field of drone, robotics, artificial intelligence (AI), mask, and sensor technology [11] explore three initiatives: COVID-19 focused datasets; Artificial intelligence-powered search tools and contact tracing based on mobile communication technology [12] analyses the different technological response to control the transmission of the pandemic adopted by China and Western democracies, concluding that the impact of smart technologies is potentially moderated by the social and political contexts in which they are implemented. Among the research explicitly concerning technologies within SC domain [13], discuss extensive use of SC technology in South Korea [14] discuss the heterogeneous impact of smart cities on COVID-19 prevention and control from different phases and city population size in China. The relevance of SC networks is represented by Allam and Jones (2020) [15] who address how smart city networks should work towards enhancing standardization protocols for increased data sharing in the event of outbreaks or disasters, leading to better global understanding and management.

3 Methodology

3.1 Bibliographic Research

Instead of engaging in an orthodox systematic review, a review at different levels was conducted, searching for representative cases of technologies within the smart city approach showing the current or potential use in building resilience during the pan-demic. Journals retrieved from the World Health Organization open database were used to identify representative technologies. Some combinations of keywords were adopted.

In addition to COVID-19 or coronavirus, these other terms were included: ICT, “smart cities”, “smart city”, IoT, Artificial Intelligence, Bigdata, traceability, tracking, Cloud, technologies, disrupting technologies, apps, among others. A subsequent stage of filtering was conducted to retrieve only those initiatives related to the urban environment. As the pandemic is still in course the sources consulted also include, when necessary, divulgation journals or media. Cases dealing with specific medical applications such as drug therapy, artificial intelligence to develop the synthesis of novel drugs, or vaccine development, were discarded since they do not belong to the research scope.

On the other hand, health-related technologies that integrate ICT are included if they deal with the following tasks: allow communication between patients and health staff, remote support to diagnose, and distant provision of care since they support measures that minimize virus spreading.

3.2 Outlining the Smart City Approach Adopted

It was mentioned above that SC presents various definitions and that two principles are extracted as fundamentals to define SC: i) adoption of ICT technologies and, ii) inhabitants/environment improvement through identifying and solving problems.

In the present paper, the services delivered by ICT contribute to the containment of the pandemic, thus contributing at different levels to building resilience. To organize and categorize the representative technological applications, the structural model of SC defined by Calvillo et al. [16] and Chamoso et al. [17] is adopted. The structure of a SC is composed of different layers and it can be represented as a three-level platform, where hardware is the base, the communication mechanism represents the middle layer and the top layer is represented by the intelligent software [16]. This structural approach based on the necessary layers to support and allow technologies operationalization (and consequently service delivering to citizens) was chosen as the framework to discuss and categorize the technologies. The technologies are classified within the specific layer based on the service that is currently delivering to society.

3.3 Outlining the Approach of Resilience Adopted

In the present case, the selected approach is not focused on its definition but on the stages necessary for its building. To build resilience the technological-based interventions have to fulfill abilities capable of contributing at one or more of the following stages:
1) Planning or anticipation to mitigate or prevent risks.
2) Preparedness in order to further ensure that capacities are in place for effective response.
3) Responsiveness in order to ensure a rapid and effective reaction. to the occurrence of a catastrophic disaster or emergency.
4) Recovery in order to restore critical community functions.
5) Strengthening of resilience capabilities: continuous improvement.

3.4 Line of Thought Adopted

The technologies against COVID-19 relevant to building resilience are explored through two aspects: the layer they belong to, as discussed in section 3.2 and at which stage, they support building resilience (section 3.3). Figure 1 shows the line of thought in an illustrative way. The collection of data that feed the first block is extracted from considerations explained in section 3.1.

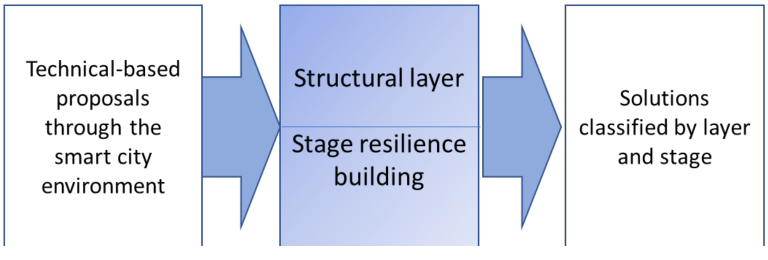

Fig 1. Line of thought adopted and the relationships among the different elements and blocks. The first block represents the technical-based solutions inherent to Smart city; the second represents the two classification criteria explored, whereas block 3 displays the results classified according to block 2.

4 Results

Results are organized according to the structural layer.

Layer 1. Infrastructure.

The first or lower layer (here termed the infrastructure layer) is represented by the city infrastructure. It corresponds to both the connected objects of the city and the sensor network in addition to the technology used to gather or exchange information. In this case, equipment and devices play the role of substituting a person or acts as an enabler to turn a function more efficient and effective with less risk and without human intervention. Among them, robots and drones were used to clean and disinfect, measure patient's temperature, deliver medicine and food [18]. Robots can measure patients' parameters and allow communication between patients and medical staff, reducing direct contact [19]. In the transport domain, according to Kanda and Kivimaa [20], electric vehicles (EV) will decrease health risks by reducing human contact in the absence of human drivers.

Robots and drones also are used to disinfect [21] [22] avoiding workforce mobilization and decreasing exposure risk to personnel.

Robots with the ability to track or detect high-risk areas are gaining importance in busy public areas as well as playing an important role in tracking the disease, say the researchers [21]. Tables 1 show in a categorized form the main contributions.

Table 1 - Main applications at the infrastructure layer, functions, benefits and relation with SDGs and stage of resilience

Layer	Functions	Benefits		
Infrastructure	Substitute humans	Decrease risk More efficient More effective		
	Acquire data/collect data	Aid in decision-making after proper analysis (in upper layers)		
	Application	**Examples**	**SDG integration**	**Resilience stage**
	Health care	Robots with biosensors	Contributes to SDG#3. Aligned with SDG#9	Response
	logistic	Robots/drones/EV	Contributes to SDG#3/SDG#11. Aligned with SDG#9	Response
	Capture of geolocation (risk area/crowds)	drones	Contributes to SDG#3/SDG#11. Aligned with SDG#9	Preparedness
	Community services	Disinfection robots/cleaning robots	Contributes to SDG#3/SDG#11. Aligned with SDG#9	Response
	Sensing	Heterogeneous sensors	Aligned with SDG#9	Necessary for posterior Planning.
	Physiological data sensing	Biosensors/ Biometric terminals	Contributes to SDG#3. Aligned with SDG#9	Response

Layer 2. Communication

The data collected at layer 1 has to be exchanged with the system and the functionalities used to configure the sensor networks integrated into the objects located in the middle layer, namely Communication Layer. Tables 2 show in a categorized form the main contributions supported by this layer and their functions, benefits, alignment with SDGs, and at which stage they support resilience building.

Table 2 - Main applications at the Communication layer, functions, benefits and relation with SDGs and stage of Resilience

Layer	Functions	Benefits		
Communication	Allow exchange data	Ensure real time exchange among devices		
	Ensure remotely communication between persons or persons/devices	Allow establishing real time communication among people. Allow information integration Allow real time communication among devices (robots, platforms) and people.		
	Application	**Examples**	**SDG integration**	**Resilience stage**
	Health	telemedicine	Contributes to SDG#3. Aligned with SDG#9	Response
	Contact tracing	Apps (supported by Bluetooth, internet, GPS)	Contributes to SDG#3/ SDG#11. Aligned with SDG#9	Response
	Real-time exchange data/information	IoT network/internet/ 5G	Contributes to SDG#3/SDG#11. Aligned with SDG#9	Preparedness
	Care	tele-care services for elderly people	Contributes to SDG#3. Aligned with SDG#9	Response

Layer 3. Intelligence

The third layer is associated with data analysis and managed to deliver to the citizens/city/institutions/governmental the most appropriate information and services. Results from this layer allow more accurate decision-making and provide information from prediction models.

AI-supported robots can perceive emotional states and can aid when isolation is imperative [23]. AI technologies, as well as Big Data analytics, are the main supportive technologies of this layer's functionalities. The alignment with innovation and the necessity of real-time transference of data and information is imperative to support proper outcomes from this layer, namely the adherence to SDG # 9 is imperative. Table 3 show in a categorized form the main outcomes, their functions, benefits, integration with SDGs, and at which stage they support resilience building.

Table 3 - Main outcomes at the Intelligent layer, functions, benefits and relation with SDGs and stage of Resilience

Layer	Functions	Benefits		
Intelligent	Data treatment and processing	Simplify decision-making Enable autonomous decision-making Enable anticipation/prevention Perception of existing patterns and relations		
	Delivering of applications for citizens/city/institutions	Improvement of services.		
	Application	**Examples**	**SDG integration**	**Resilience stage**
	Health	Chatbot/socially assistive robots	Contributes to SDG#3. Aligned with SDG#9	Recovery
	Disease surveillance	monitor trends in the disease where human-to-human transmission occurs	Contributes to SDG#3/ SDG#11. Aligned with SDG#9	Preparedness
	Mask wearing recognizing	Intelligent drones/intelligent robots	Contributes to SDG#3/SDG#11. Aligned with SDG#9	Response
	Contagious prediction	Algorithm identifies hotspots for exposure and vulnerability	Contributes to SDG#3/SDG#11. Aligned with SDG#9	Preparedness
	virtual reality for training purpose	Virtual platforms	Contributes to SDG#3/SDG#11. Aligned with SDG#9	Preparedness

5 Discussion

Some questions arise from the results and although they are not addressed in the present paper, they deserve some comments. The identification and organization of technologies according to their contribution on different stages of building resilience, will help practitioners and policy makers to decision making in administration, organization and planning. However, the paper does not address the challenges and barriers, legal, normative or even due to societal and cultural differences among countries and cities. It is worth noticing that vulnerable sectors are not expected to benefit from the technologies (depending on which one) at the same level. Or elderly people who are less familiar with apps or internet access. These niches may serve as starting points for future research.

Present results show alignment with results from other papers, although the models of SC or the organization of technologies differ. Thus, comparison with Bragazzi et al (2020) [24] shows points in common with the categories they defined as a) Short-Term Applications and b) Long-Term Applications. SC technologies classified by Costa and Peixoto (2020) [25] in solutions for detection, alerting, mitigation shows points of adherence with our results. The paper of Jaiswal et al. (2020) [26] classifies solutions into smart technology, smart healthcare, and smart delivery system. Our results, although having adopted other approach show alignment with theirs.

6 Conclusions

An overview although categorized, of the main technologies, applications, and functionalities within the SC domain is discussed to identify the way they support COVID-19 and integrate with three SDGs that were considered fundamentals for resilience building. Results show a starting point to define and implement an accessible strategy of defensive measures against COVID-19 and/or other types of natural disaster situations within the Agenda 2030 and focused on turning the cities more resilient. We hope that this work will contribute to governance systems and citizens to be better prepared for future outbreaks. Some challenges arise from the technologies proposals among them the individual rights related to personal data. However, it is undeniable that pandemic accelerates innovation thus strengthen the role of SC against COVID-19 spread.

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