# Handbook of Smart Cities

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# Smart Cities: State of the Art and Future Challenges

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**Abstract**
This chapter concludes the Handbook of Smart Cities. It provides an overview to the organization of the volume and explains the technical content of the various chapter which form the Handbook.
The chapter also contains an overview of the area of Smart Cities which emerge from the whole volume. This includes identified common threads, discussion of challenges and bottlenecks, and possibilities for further development of the area.

Keywords: smart cities, human-centric systems, sensing, data, energy, e-government, sustainability.

## Introduction

There are many definitions of Smart City, broadly speaking here we take it as "*a city where technology is deployed and effectively used to improve the life experience of its inhabitants*". Technology being a necessary but not sufficient component. Hence the definition above emphasises that the city can be considered a smart city when the technology is effectively achieving the aims of enhancing people's life experience.

The Handbook of Smart Cities has been organized around three main parts:

- Part 1: understanding the basics and the holistic concept, emphasis on what has been done so far
- Part 2: understanding its components, with more emphasis on current challenges
- Part 3: understanding how to evolve the concept, emphasis on the future

Connecting these there are vertical threads which refer to important basic and pervasive concepts or pillars. There are various ways to highlight which are the main building blocks in a Smart City. In this volume the following main frameworks are highlighted and given prominence: Humans, Energy, Technology, Data, and Institutions. Of course more can be added and these can be further split into subcategories at any level of conceptual granularity.

## Part 1: understanding the basics and the holistic concept, emphasis on what has been done so far.

The *Basic Concepts and Frameworks* section provides a state of the art view and a high level view of essential building blocks. It starts with an area overview (James et al., 2021) which provides a state of the art on the field in general as well as a focus on the five main frameworks or pillars we highlighted in this handbook and also includes a specially commissioned glossary of technical terms which the community can adopt as a reference. The chapter opening the consideration of humans in Smart Cities, highlights the necessary importance of humans, individually and collectively, as creators and recipients of the Smart City benefits. (Costa, 2021) The chapter focused on energy in Smart Cities highlights the strategic role of smart grids and at a higher and strategic level supports a more distributed

polycentric administration of energy for resilience and democratization in the handle of such key resource. (Nyangon, 2021) The chapter on technological infrastructure in Smart Cities focuses on the sense-analyze-actuate cycle and how each of these stages can be realized. This is a core component of any Smart City as the concept was born actually from the gradual and incremental enabling of services provided by the ever evolving digital technologies. (Bouroche and Dusparic, 2021) The chapter overviewing the role of data in Smart Cities highlights the opportunities and the challenges. Millions of sensors provide and incredible amount of data, which can support a wide range of potentially useful decision making. There is also a potential for misuse and there is also the issue of accuracy of the summary automatically projected out of that data. (Bilal et al., 2021) The chapter analyzing institutions in Smart Cities, highlights the key role of these as clustered repositories and catalysts of innovation and benefits which should aim to provide maximum societal benefit minimizing the cost to produce it. (Wiesmeth et al., 2021)

This volume also has a section on *Examples of Smart Cities* from around the world. Of course there are many at various stages of development and we cannot include them all. Our selection includes cases at different level of development in different regions of the world: Edmonton (Hayes et al., 2021), Racine (James and Martin, 2021), Curitiba (Spinosa et al., 2021), Taipei (Lee et al., 2021), Canakkale (Benli et al., 2021), Stockholm (Landahl, 2021), Wien (Madreiter et al., 2021), NEOM (Madakam et al., 2021), Tehran (Fartash et al., 2021), Umhlanga (Erwee et al., 2021) and Bandung (Arfiansyah et al., 2021). This diversity of samples is very representative of the different levels of progress which the concept of Smart Cities is being embraced around the world. Different needs are being prioritized, different speed of progress based on each country regulation and investment availability. In some cases governments are providing the main investment and in others they focus on creating the conditions for the private sector to develop the final product.

**Part 2: understanding its components, with more emphasis on current challenges.**

The material in the *Humans Dimension* section emphasizes on the need for Smart Cities to be conceived with humans at its core and taking care of the diversity of citizens, and their diversity of preferences and needs. Concepts such as Interconnected Public Spaces where virtual and physical environments cooperate to provide special services to humans with special needs are starting to be explored and trialled. (Padron et al., 2021) The emerging concept of ICT-enabled citizen coproduction is considered and pros and cons highlighted. (Rodriguez Müller, 2021) It also provides a case study of a country where the concept of smart citizenship can act as an enabler for cultural cohesion and nation-wide national policies. (Boon et al., 2021)

The *Energy Dimension* section considers specific cases of energy administration in the context of Smart Cities. This includes a focus on energy autonomy and related strategic, methodological and technological tools as well as their societal impact. (Meleti and Delitheou, 2021) There is a description of some technologies and derived products used to harvest energy innovatively through daily life activities and by citizens at a society wide scale. (Chew et al., 2021) There is also a discussion on the role of Smart Cities as important agents in the reduction of green-house gases, which not only look inwards to the city use and generation of energy, also provides a global and interconnected dimension to energy from a planetary perspective. (Astoria, 2021)

The *Technology Dimension* section explores a diversity of technological options. It covers the essential element of interfaces, their variety, and the need for them to be simple enough and effective enough to provide a benefit worth the effort of adjusting our lives to yet another piece of technology. (Hopkins et al., 2021) It presented a vehicle system architecture supported by IoT infrastructure , including different types of protocols, standards, and technologies applied to vehicle networks, as well as highlighting several challenges related to movement and security in a vehicle network. (Tamariz-Flores and Torrealba-Meléndez, 2021) It includes the guidelines for the development of a transportation ontology which can support digital smart transportation services representation and support services development in that sector. (Yazdizadeh and Farooq, 2021) It explores the wider opportunities provided by the abundance of IoT, and the diversity of services which can be covered when these are used to support new systems based on human invention and progressive development. (Prabaharan, 2021) One important sector where technology can have a high beneficial impact is health care. This open up also issues of privacy and confidentiality and relates to important transnational initiatives such as GDPR. (Enler et al., 2021) Another delicate issue included is that one of citizen identification, it has obvious advantages in security and obvious disadvantages in privacy, the material in this topic analyses system design where the advantages are kept, minimizing disadvantages. (Bezukladnikov et al., 2021)

The *Data Dimension* section considers the phenomenal amount of data being generated and which will only augment exponentially. Some contributions looked at the technical challenges inside the Big Data layer of the system and considering the different levels of abstraction, the multitude of data sources, including virtual and real. (Abdullaziz et al., 2021) Examples of data-driven services included applications in healthcare and vehicular networks. (Ponnaganti et al., 2021) Some content more directly addresses current challenges. One such challenge is interoperability which has slowed down progress for several years in smaller areas such as healthcare, due to the barriers for equipment from different companies to interact. (Delgado, 2021) Another challenge is data privacy and the subtle interplay of the benefits of data sharing and the dangers of some of that data being misused. (Vojković and Katulić, 2021) It also include contributions which highlight the need to shift from a passive collection of data to a more active and well-intended collection of data, data collected and processed to proactively help humans, positively looking after our species in a proactive way; detecting danger, preventing, providing help. (Nowaczyk et al., 2021)

The *Institutions Dimension* section highlights how the current Smart Cities under development have not yet taken citizens into account, or at best their addressing of citizen needs is very uneven and this is identified as the main challenge for the Smart Government development (Roberts, 2021). There is also an analysis of Smart Cities dynamics as a complex system with rich interactions amongst cells (individuals, groups, organizations) within the city which is considered through a Generative Emergence Model (Rochet and Belemlih, 2021).
A chapter provides a very important analysis of the consequences of using Big Data wrongly, be it because of a failure in the process of gathering outcomes or because of the interpretation of those outcomes. It also provides a way to assist decision-makers through these processes addressing these potential risks. (Choenni et al., 2021)

**Part 3: understanding how to evolve the concept, emphasis on the future.**

The *Smart Cities Infrastructure Ecosystem* section includes contributions revisiting the traditional ways to produce and distribute food. (Lodge, 2021) As different critical resources

get more closely related to digital technologies  security becomes more important, and this material includes as an example a case study on using blockchain technology to secure agri-food supply chain.  (Hou et al., 2021)  Blockchain technology will also increase security for a more general range of Smart City interactions and transactions and alternatives such as Smart Contracts will require investigating and perfecting as a safe base for entrepreneurship (Bhagavan et al., 2021)

Transport is another key building block in any society.  There are very pedagogical descriptions of the benefits that technology-driven transport solutions bring in comparison to traditional infrastructure investment brings. (Dia et al., 2021)  New infrastructure is based on softer and more flexible resources, such as the use of data-driven models to help citizens and also to support more efficient decision-making from government. (Rosa et al., 2021)
A challenge which arises in environments with a diversity of coexisting technological platforms as in a Smart City is the one of interoperability, by which each technology vendor tends to worry mostly about compatibility and facilitating information exchange amongst products only from the same company.  Smart Cities will still be able to operate as have smaller smart systems (smart healthcare, smart transportation).  However, any progress in addressing this debilitating issue will help benefits to combine and multiply.  It is not an easy problem to solve and will require specific solutions and support to be created.  Most likely a definitive and practical solution does not exist and what will be achieved is a mix of ameliorating measures.  (Buchinger, 2021) It is important that within all this complex technological jungle individuals rights are preserved and here they are discussed in association with the concepts of Self Sovereign Identity and Cold Places (van Kranenburg et al., 2021)

There is an example of how technology can be used to support safer communities.  The case study based on stormwater management is very representative of the current state of the art, including the hard and soft infrastructures, citizens involvement in services design, the possibilities and the challenges. (Barthelemy  et al., 2021)  A complementary case study in terms of technology, services and citizen participation focuses on crowdsourcing and the combination of mobile and static infrastructure to provide services for citizens in a way that stimulates their cooperation (Aihara and Imura, 2021)

Planning, designing and developing Smart Cities involves many challenges, and a layered-based reference model has been developed which explains how cities can be developed in a holistic way connecting the needs and services related to the different groups of stakeholders. (Bök et al., 2021)

The *Ethical Challenges* section includes examples of ethical concerns as well as proposed way forward in terms of bringing ethics as a more important driver in Smart Cities implementation.  There are examples of cities under development where technology is used for surveillance in a way which is worrying, an emerging pattern especially in countries where citizens have less of a say on how government runs the country affairs.  (Purandare and Parkar, 2021)  There are also calls for the cities to be more open, flexible, diverse and participatory and to prioritize participation, communing, and citizenship.  (Galič and Schuilenburg, 2021) There have been developments in the legal front with the introduction of regulations in various regions of the world to protect citizens rights, for example GDPR in Europe, although there are still weaknesses and some of these are highlighted through scenarios which involve robotics and modern home technology.  Privacy by design methods

are advocated as one of the tools which may help addressing these problems. (Gültekin-Varkonyi et al. , 2021)

The *Bottlenecks and Potential Enablers* section consider some of the perceived barriers for progress and how we should go around them, including the discussion of innovative ideas on how to support progress in this area.

Smart Cities combine an unprecedented number of citizen needs, potential solutions and resources constraints decision makers how to juggle with. Science has been studying strategies to solve complex problems of this nature. We include work that shows one possible way to support decision making with science through the use of optimization. (Fada et al., 2021) There is also content which provides a more technology based view of how to integrate various relevant resources such as big data, artificial intelligence, data analytics and visualization, internet of things, cloud, edge and fog computing; and they can be combined to produce different levels of beneficial input to decision-makers: data, information, knowledge and wisdom. (Fonseca et al., 2021) This is complemented with the presentation of virtual reality technology which helps track key performance indicators in a way that supports a more positive engagement of stakeholders and decision-makers. (Wiberg et al., 2021)

Significant content is devoted to the key question of the best way to design Smart Cities. An invitation to a more holistic analysis is made linking the smart cites concept in time, how they offer a transition from their past to the future vision their inhabitants expect from it, and in space, how the smart city influences and nourishes from the more rural region is embedded in. (Ianoş et al., 2021) There is also an creative invitation to imagine the different possible "journeys", whether physical or virtual, through the Smart City services as citizens would like to experience them. This is a flexible and powerful design strategy which can inspire and unlock the thinking of the world to come. (Callaghan et al., 2021) The concept of openness is explored on three directions: transparency, participation and collaboration. Highlighted vehicles for collaboration are inclusiveness, interoperability and open innovation. (Oktay et al., 2021) There are proposals suggesting not only the tecno-centric views are insufficient, so are the human-centric approaches to city design, in the sense that the vision has to take into account a wider concept which goes beyond the most immediate and direct human concerns and considers their environment at large and the projection of decisions through time. (Wolff et al., 2021) Finally, an analysis is provided on the connection between the desirable sustainable development goals and the quality of life that citizens expect to improve, and some content advocates for cities to take public policies based on a strategic use of technologies which support the sustainable development goals in urban areas and had a direct connection with the desired quality of life. (Rodríguez Bolívar, 2021)

## Concluding Remarks

The content above is very representative of the richness and diversity of Smart Cities. Although there is a technological level, it also extends and reaches out to all aspects of urban life and experience. The collection of chapters that makes this volume the largest published in history about this topic, it has contributions from the Americas, Africa, Oceania, Asia, and Europe, as well as including authors from a large number of disciplines and backgrounds. All this diversity provides the richer multi-disciplinary mixing pot of views which are needed for

projects of this nature which are intended for the bigger group rather than to specific individuals. Given the multidirectional diversity of the material there are some meaningful take away messages we can adopt with confidence.

One emerging thread is the understanding that Smart City projects should be strongly human centred. Although technology and the data it generates, play an important role, ultimately these projects are not for technology and humans have to be the definitely at the centre. These projects are driven by citizens and they should not forget they have that privilege because other humans entrusted them with this opportunity to create good for other fellow humans. This echo expectations in other areas where powerful smart technologies which have capacity to directly influence daily life affairs. (Augusto et al., 2013) How this is achieved is being debated, a move from a the Triple Helix of innovation: University – Industry –Government into the Quadruple Helix of innovation: University – Industry –Government – Citizens is a necessary step most agree on. There are actually several sides to citizen involvement. One is as expressed above, being the natural recipient of services and benefits. Another important role is that of producer of services and active contributor to services, for example by supporting green policies through daily life behaviour or by producing data which allows positive decisions to be made based on the data emerging. This citizen creation of knowledge brings new challenges, such as curating the data and the results of the analytics performed on them, as well as the issues of individual and collective authorship. Another important role is perhaps that of monitor getting involved with the decision-making of which services are designed, how, to what extent their work and connecting the most passive citizens and those with higher influential power.

A very important aspect is that of sustainability, not only how the Smart City contributes to global or national sustainability, also how they made themselves self-sustainable by which the benefits and savings are retro-fed into the system for a long term operation. On one hand it is a fantastic opportunity to attract private innovation and business, on another hand there is a need not to become fatally dependent on those.

One challenge of Smart City systems and their need to work on a multitude of citizens is the importance of considering all humans, these are massively multi-user services. (Jones et al., 2015) In relation to the human beneficiaries there is also concern about people access to the benefits and that all users have access to the benefits, for example, one issue with technology is that it requires certain investment from each human (for example a ‘smart’ phone) to access the benefits, so there are ‘equality’ and ‘inclusion’ issues at stake (Jones et al., 2015). The involvement of citizens from the beginning and throughout the process (Augusto et al., 2018) is important so that they understand the services are for the common good and sometimes users will have to sacrifice individual specific preferences in favour of supporting something that benefits more citizens.

Popular topics revolved around the supporting technology (‘internet of things’, ‘smart’ technologies, ‘cloud’ services, mobile computing) their by-products (data and digital services) and some concerns associated with them (privacy, security, interoperability, sustainability) and there are good contributions not only on capturing the state of the art, also proposals to advance it. Other important threads emerged from this material on the roles of Smart Cities in development, on the social dimension of a city, on the handling of fundamental resources such as energy, water and green-house gas emissions, as well as in the resilience of a society (for example to face pandemics). Again, this went beyond

pedagogically capturing what has been done and there are interesting fresh proposals on how to improve in various directions.

One of the main paradoxes of modern data dependent systems is that for systems to serve better they require access to more private information however user's privacy and their fear of data misuse goes against that so this is one of the main bottlenecks society needs to address and agree on. Scientists and innovators can propose possible solutions however governments and citizens ultimately decides adoption.

A recurrent and expected issue is one of scales, the catering for the big and the small, for the general and the specific, the public and the private. There will be a need to provide services for the general population, for example on energy, water, and air management. Also a need to provide for citizens with special needs. There will be services run by government-related organizations and others by private initiatives. Systems which work for bigger number of citizens will have to harmonize and be able to connect with systems for families and individuals. To what extent this will be left to some sort of "evolution" of the artificial systems "ecosystem" or will be planned and directed?

One other embedded challenge is that systems at this scale take significant time to be realized. It is the reaching the agreement that is needed, the planning, the finding of the resources, the building of it. Timescales are measured in years. Meanwhile, the population for which it was conceived changed, and the assumptions in which the project was set up, and indeed perhaps the whole world would have changed.

There is a harmony dimension which will have to be carefully cherished between the Smart Cities technological ecosystem, enjoying the benefits of interconnectedness, and the requirement to protect citizens' rights to experience their humanity, being privately away from technology (see P1-P9 principles in (Augusto et al., 2013)). There is certainly a noticeable understanding that the power of technology is its very weakness, protective measures proactively and timely secured will be the key for the adoption of these ambitious society wide projects. So far legislation and law have been catching up with IT developments, this will either have to change from reactive to proactive or citizens and governments will have to compensate for this tardiness through cooperative action.

On a bigger global scale one consequence of the many opportunities and challenges arising from these big scale initiatives is that it will require collaboration amongst various groups of humans, not only amongst companies, also amongst companies and governments and amongst governments themselves. The world is drawn to bigger interconnection, to the Global Village, the internet already weakened geographical and political barriers, Smart Cities will build on that, there will be more of a digital experience of life and citizens in different cities will share more of their lives digitally within their own city and between different cities, regardless of where they are in the planet. The path of widespread digital technologies adoption by humanity seems an irreversible trend, all we can do is to work to make it as effectively beneficial as possible.

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