The role of digital technologies in the development of *smart sustainable cities. An overview and the potential scenarios*

Il ruolo delle tecnologie digitali nello sviluppo di città intelligenti e sostenibili. Una panoramica e i potenziali scenari

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DOI: 10.14658/pupj-rsld-2023-4-3

Abstract. The environmental impact of smart city projects has not been fully detected yet. The creation of a Smart Sustainable City (SSC) requires the application of digital technologies within the urban context. These technologies can contribute significantly to achieving the sustainable goals set out in the European Green Deal and the UN's Agenda 2030. However, those solutions have a huge impact on the emission of greenhouse gas, the exploitation of natural resources (such as electricity and the so-called 'rare earths'), the democratization of public services and the protection of human rights. This research intends to map the main digital solutions and their applications within the urban context through a review of the existing literature and the most famous case studies in order to verify their real impact on the implementation of a Smart Sustainable City, both from an environmental and a social perspective. The paper also analyzes the potential scenarios of the application of these technologies in designing a Smart Sustainable City.

Abstract. *Il tema del rapporto tra sostenibilità e riprogettazione dei centri urbani in ottica smart appare complesso. La creazione di una Smart Sustainable City (SSC) presuppone l'introduzione di tecnologie innovative all'interno del contesto urbano, le quali possono contribuire in maniera significativa al raggiungimento degli obiettivi stabiliti dal Green Deal europeo e dall'Agenda 2030 delle Nazioni Unite. Tuttavia, quelle stesse tecnologie sono anche causa di una quota importante di emissioni di gas serra e dello sfruttamento delle risorse naturali attualmente disponibili (tra cui energia elettrica e le cosiddette "terre rare") e possono avere un impatto significativo sullo sviluppo sociale dei centri urbani. Questa ricerca intende offrire una mappatura delle soluzioni digitali disponibili e delle loro potenziali applicazioni ai fini della creazione di una Smart Sustainable City mediante una revisione della letteratura esistente e dei più noti case studies. A seguire, verranno ipotizzati anche i possibili scenari relativi all'impatto ambientale e sociale dell'applicazione di tali tecnologie all'interno del contesto urbano smart.*

Keywords: *Smart sustainable cities, Twin transition, Technological innovation, Urban development.*

1. Introduction

The relationship between sustainability and *smart cities* is very actual and still little explored. The "smart city" concept is often associated with the introduction of digital technologies (hardware and software) within the urban context. Such solutions seem to enhance the efficiency of public service, to fix financial problems by reducing public expenditures and to improve the quality of citizens' life.

However, the direction of the relationship between new technologies and the development of a *Smart Sustainable City* (SSC)[1] seems to be uncertain.

On the one hand, people's increased *awareness* about sustainability issues has a direct impact on the smart urban initiatives[2]. It stimulates the adoption of more efficient *data-driven* solutions by the PA as a result of a co-designed project between citizens and the Administration. On the other hand, the digital transition might have negative environmental and social consequences as it may increase pollution[3] - even within the urban context[4] -, imply additional gas emissions, exclude certain people by the decision making process-

[1] *Smart Sustainable City* can be defined as "an innovative city that uses ICT and other means to improve the quality of life, the efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with regard to economic aspects, social, environmental and cultural", due to the definition provided by the United Nations Economic Commission for Europe (UNECE). https://unece.org/housing/smart-sustainable-cities#:~:text=A%20smart%20sustainable%20city%20is,as%20well%20as%20cultural%20aspects). See also UNECE, People-Smart Sustainable Cities (2021), p. 19 ss. https://unece.org/sites/default/files/2021-01/SSC%20nexus_web_opt_ENG_0.pdf in which it is specified that "the creation of "sustainable cities" has been one of the main visions of urban development since, in the early 1990s, sustainable development became a social paradigm in the early 1990s. The sustainable city is considered the one that enhances and balances the social, economic and environmental dimensions. (…) The ongoing digital transitions and the rise of smart technologies have had an impact on the conceptualization of sustainable cities, bringing the "smart" dimension as a new claim of normativity for a technology-enhanced society".

[2] Part of the literature has highlighted: "The greater attention to sustainability in the field of infrastructures of smart cities will have an impact on service provision, transport, food habits and consumption. The factors of well-being and quality of life are directly linked to these areas, as citizens interact with new initiatives and adhere to changes that reduce emissions and carbon footprint. The links between the sense of safety and security and the increased willingness of citizens to switch to sustainability initiatives could be the key factors pushing the authorities of the *smart city* to integrate these aspects from an early stage." See Ismagilova et al., 2022.

[3] Liu et al., 2019.

[4] Cities represent the places of main concentration of people (see Institute for Economics & Peace. Ecological Threat Report 2022: Analyzing Ecological Threats, Resilience & Peace, Sydney) and of ICT technologies. For this reason, they are the main responsible for significant shares of greenhouse gas emissions. On this point, see Croci e Molteni, 2022, p. 375.

es[5], endanger democratic values and deprive public administrations of their sovereignty[6].

Consequently the implementation of new technologies in order to design a smart sustainable city has an ambivalent role and its contribution seems to be mixed.

The objective of this work is to analyze the phenomenon of urban digitization in order to understand if and how new technologies really represent a step forward in the development of smart cities, enabling the transition to a new urban sustainability.

The studies conducted so far offer a wide-ranging perspective, continental[7] or national[8], with respect to this topic. I believe that an in depth focus on specific urban dynamics can offer new answers to the questions posed by the *twin transition*[9], given the fact that the main interactions between technological revolution, environmental and social issues take place within every single city.

Therefore in the following paragraphs I will try to examine the role of digital technologies in the development of *Smart Sustainable Cities* under this perspective.

This study is structured as follows. In the second paragraph I will both analyze the concepts of *twin transition* and *Smart Sustainable City* and specify the methodology I have used. The third paragraph explores the main technologies used nowadays for the development of smart city projects. Each subsection offers a description of the digital solution and a list of its potential urban applications. The fourth paragraph analyzes the social impacts of digital technologies in the urban redesign and their effect on democracy and fundamental rights. The fifth paragraph examines the potential scenarios related to the application of digital technologies for the development of smart city projects in order to measure their impact on the pursuit of sustainability goals. The sixth and seventh paragraphs present the conclusions and the limits of my research, as well as its future developments.

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5 See Shin, S.-Y., Kim, D., Chun, S.A., Digital Divide in Advanced Smart City Innovations. Sustainability (2021), 13, 4076; Caragliu, A., Del Bo C.F., Smart cities and the urban digital divide. Urban Sustainability, 3, 43 (2023).

6 Congress of Local and Regional Authorities, Smart cities and regions – prospects of a human rights-based governance approach, 43rd Session, CG(2022)43-13 / 25 October 2022. https://rm.coe.int/0900001680a861ec

7 Muench et al., 2022; Maucorp et al., 2022.

8 Bianchini, 2022.

9 As defined in paragraph 2.

2. Twin transition and Smart Sustainable City: conceptualization and methodology

The link between new technologies and urban development has been repeatedly examined by scholars[10] and by the institutions[11] under the *twin transition* label.

This concept describes the efforts - promoted above all by public actors - to favor decarbonisation, the zeroing of greenhouse gas emissions and the adoption of digital technologies in a joint and mutually beneficial perspective[12]. This paradigm has been proposed as a synthesis of the commitment of national and international institutions to simultaneously promote the green transition - in compliance with the objectives set by the European Green Deal[13] - and the digital transition.

The "green transition" can be defined as the implementation of new production and consumption models aimed at mitigating climate change, introducing lifestyles that are more respectful of the earth's ecosystem and biodiversity[14]. The objective of this transition is to enable the achievement of climate neutrality and sustainability under the conditions established by European Union[15].

The "digital transition" can be defined as both the large-scale introduction of new technologies and the enhancement of currently existing digital infrastructures, as fundamental elements for the race towards innovation[16]. The goal of this transition is to foster technological growth, mitigate digital divides and reduce the dependence of Europe on foreign suppliers[17].

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[10] Please see, among others, Bianchini et al., 2022; Shaiara et al., 2022; Rosário et al., 2022; Bottero et al., 2021; Bottero et al., 2019; Biresselioglu, et al., 2020.

[11] Please see, among others, Muench, S., Stoermer, E., Jensen, K., Asikainen, T., Salvi, M. and Scapolo, F., Towards a green and digital future, EUR 31075 EN, Publications Office of the European Union, Luxembourg (2022); European Commission, Cities fit for the digital age, Science for Policy Brief, The Future of Cities, Series (2022); European Commission, The European Green Deal, Brussels, Belgium (2019).

[12] According to the European Commission, "the term 'twin transition' does not refer only to two concurrent transformation trends (the green and digital transitions); it also refers to merging the two transitions, which could accelerate the necessary changes and bring societies closer to the required level of transformation. To be successful in the green and digital transitions, a better understanding of the possibilities to connect them is crucial, especially when it comes to knowing what needs to be done most urgently." See Muench et al., 2022.

[13] European Commission, 2019.

[14] Cf. Muench et al., p. 8.

[15] European Commission, 2019.

[16] Cf. Muench et al., *op. cit.*, pp. 8-9. See also Maucorps et al., 2023.

[17] Decision (EU) 2022/2481 of the European Parliament and of the Council of 14 December 2022 establishing the strategic program for the digital decade 2030. https://eur-lex.europa.eu/legal-content/IT/TXT/PDF/?uri=CELEX:32022D2481&qid=1693235077035

The objectives of each transition are clear. Nonetheless, it is still debated whether a synergic intervention on both these fields by the EU could cause an overall slowdown in the pursuit of the respective goals. More precisely, it is unclear if the technological stretch could hinder the parallel achievement of emissions reduction and climate neutrality aims[18].

For sure it is necessary to distinguish among the technologies we are examining, as each solution can have a different impact on the urban ecosystem (as shown in the fifth paragraph). However, the high energy consumption, the huge exploitation of non-renewable resources, the disposal difficulties and the significant amount of *tech-driven* emissions represent common features of all the solutions considered below. These implications might mitigate, or even eliminate, the benefits coming from the green transition. A synchronized approach is therefore essential to obtain a positive net result in both these directions[19]. Synthetically, it is the theorization and the purpose of the so-called *twin transition.*

The urban area represents the backdrop to the main challenges conveyed by the twin transition, as it is the place where the need for technological innovation is most felt and where the highest production of GHG emissions is recorded[20].

But that is not enough.

A second trend is also taking place within cities. It aims to guarantee the protection of fundamental rights, the satisfaction of citizens' social needs and the democratization of decision making processes against technology. This flow is promoted by various institutions too[21] and it would prevent the implementation of digital solutions "at any cost", regardless of the democratic principles.

This trend, as well as the one represented by the twin transition, is equally important for the successful design of a *Smart Sustainable City.*

[18] See Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 11/12/2019, available at: https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0006.02/DOC_1&format=PDF

[19] "The green and digital transitions go hand in hand, but linking them could allow us to benefit from synergies and manage key risks." Muench, cit., p. 10.

[20] Equal to about 75% of the total world quantity. As recently noted, "Cities are key to the energy transition because they account for around three-quarters of global final energy consumption (and a similar share of global energy-related carbon dioxide (CO2) emissions) and are home to more than 55% of the world population, a share that continues to grow". See REN21, Renewables in Cities 2021 Global Status Report (Paris: REN21 Secretariat) (2021) available at https://www.ren21.net/wp-content/uploads/2019/05/REC_2021_full-report_en.pdf

[21] Congress of Local and Regional Authorities, 2021; UN Habitat, 2020.

Many European centers have long been engaged in promoting both these tendencies. From the environmental perspective, I cite the "Covenant of Mayors" promoted by the European Commission in 2008 (updated in 2021)[22] and the *Eurocities* network. These initiatives are based on a commitment among urban centers to achieve climate neutrality by 2050[23].

From the social perspective, I recall the Resolution of the European Parliament of 13 December 2022 on digital divide[24] and the "Citimeasure" program, which intends to provide a set of guidelines for supporting citizen science initiatives[25].

The active role recognized to cities in the fight against climate change and social degradation is confirmed by the 2030 Agenda for sustainable development by the United Nations[26]. It dedicates a whole Goal (Goal 11 "Make cities and human settlements inclusive, safe, resilient and sustainable") to the reduction of environmental impact by urban centers and the creation of inclusive and sustainable settlements[27].

In this context, a primary role is played by the smart urban centers: the so-called "smart cities". Although the literature has not reached a common definition yet[28], we can approximately define the smart city as "a place where traditional public networks and services are made more efficient thanks to the use of digital solutions for the benefit of the inhabitants and businesses that inhabit it"[29]. Under this perspective, the concept ties to a bundle of ini-

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22 European Commission, Covenant of Mayors (2021). https://eu-mayors.ec.europa.eu/en/about

23 Accessible from the website https://eurocities.eu/

24 European Parliament resolution of 13 December 2022 on the digital divide: the social differences created by digitalisation (2022/2810). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52022IP0438

25 https://citimeasure.eu/inclusion-guidelines/#page=1

26 UN General Assembly, 2015.

27 The sub-goals 11.6, 11.7 and 11.b are the following: "Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable.
(...) 11.6 By 2030, reduce the per capita negative environmental impact of cities, paying particular attention to air quality and the management of municipal and other wastes.
11.7: By 2030, provide universal access to safe, inclusive and accessible green and public spaces, especially for women, children, the elderly and people with disabilities.
(...) 11.b: By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans aimed at inclusion, resource efficiency, mitigation and adaptation to climate change , disaster resilience, and who promote and implement holistic disaster risk management at all levels, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030". See https://unric.org/it/obiettivo-11-rendere-le-citta-e-gli-insediamenti-umani-inclusivi-sicuri-duraturi-e-sostenibili/

28 This concept has been defined as "nebulous" by scholars, as underlined by Halegoua G. R. (2020) and Sheldon et al. (2015).

29 https://commission.europa.eu/eu-regional-and-urban-development/topics/cities-and-urban-development/city-initiatives/smart-cities_en

tiatives dedicated to efficiency and sustainability that goes beyond the mere urban technological endowment.

A specific type of smart city is the so-called *Smart Sustainable City* (SSC). It might be defined as an "intelligent" city that offers public services by guaranteeing the respect of the entire urban ecosystem, both from an environmental and a social perspective (e.g. infrastructure and governance, pollution and waste, energy and climate change, social issues, economy and health)[30] (UNECE, 2021; Silva et al., 2018; Höjer and Wangel, 2014).

Its theorization is therefore based on the concept of sustainability which represents the key aspect for distinguishing a smart city from a SSC. The idea of "sustainability" involves each of the sustainable development goals established by the United Nations 2030 Agenda (also known as SDGs)[31]. Among these, the protection of fundamental rights, the improvement of people's well-being and the efficiency of essential public services are foundational elements for the construction of inclusive and resilient urban communities.

A *Smart Sustainable Cities* represents the place where the objectives posed by the green transition, the social demand, citizens' fundamental rights and the digitization have to be synthesized. More efficient urban infrastructures and the use of predictive technologies allow cities to reduce the costs of public services, the unnecessary pollution related to them[32], to increase the quality of people's lives and of their democratic processes[33]. However, digital transition implies some environmental and social costs too.

With respect to the environmental dimension, recent studies (Bianchini et al., 2022; Chen and Lee, 2020) offer empirical evidence about the increase of greenhouse gas emissions caused by the adoption of digital technologies in certain regions. The extension of urban digital endowments could reduce - or even cancel out - positive results obtained from the environmental side, thanks to cities' "green" commitment.

In relation to the social costs caused by urban digitization, the main issues are represented by the protection of privacy and cybersecurity, a lack of control on urban data by Public Administrations and the increase in the digital divide (Allam and Dhunny, 2019; Amini et al., 2019)[34]. The technological race seems to be very costly also under this perspective.

[30] For the definition of the phenomenon, please see note 1.

[31] UN General Assembly, 2015.

[32] It is estimated that, thanks to the installation of cutting-edge ICT solutions, greenhouse gas emissions can be reduced by 10-15% (McKinsey Global Institute, 2018).

[33] Part of the literature has highlighted how urban management and the citizens' quality of life can derive so many benefits from the digital revolution (Valencia et al., 2019; Allam and Dhunny, 2019; Amini et al., 2019; Bibri, 2019; Kharrazi et al. al., 2016).

[34] Some scholars still exclude the possibility that urban centers can be both "intelligent" and sustainable (Akande et al., 2019).

A further complicating factor is represented by the model of smart city we are looking at[35]. Following Halegoua (2020), we can distinguish between *smart-from-the-start cities* and *retrofitted smart cities.*

While the first model (mainly used in Asia) implies an urban digital endowment specifically designed for a given city - in order to make it smart "from zero" -, the second model (frequently applied in US and European contexts) involves the application of technological solutions to pre-existing cities. These urban centers already have "green" and social initiatives ongoing so the digital transition might slow down their additional results. This is the reason why technological solutions are applied gradually within these cities, starting from pilot projects that are later extended. Nonetheless, this asynchronous approach might impede or reduce the success of social ecological pre-existing initiatives.

This analysis mainly focuses on *retrofitted smart cities*, as they are the most common model applied in the European context.

Within this conceptual horizon, in the next paragraph I will examine both technological solutions that are currently applied to SSC and their environmental and social impact, in order to assess how twin transition and urban sustainability evolve in the smart cities context.

2.1. Methodology

This study is carried out by analyzing the related literature and some insightful case studies in order to examine how digital solutions are developed within the smart urban context and their impact on green and social projects.

The analysis of the main literature has been conducted by searching within the Scopus database through keywords such as "smart city", "twin transition", "ICT", "IA" and "big data". The most cited publications that have been published from 2011 to 2023 are considered herein[36].

The case studies cited above are selected by searching within the institutional websites of the most important Italian and European smart cities. In order to select the urban centers I will examine further - whose websites are accessed -, I looked at the most important ranking of smart cities in Europe

[35] Following Halegoua (2020), depending on the role assigned to new technologies with respect to the creation of urban spaces, it is possible to distinguish between two different models of smart cities: the so-called *smart-from-the-start cities* and the *retrofitted smart cities* (whereas the remaining category, as the *social cities,* acts as a *tertium genus* - considering the predominant role assigned to the social dimension of the city -).
These models assume a different direction assigned to the urban regeneration process with respect to the introduction of cutting-edge technological equipment within city spaces:

[36] I selected 2011 as the starting year as it was on 4 November 2011 that the "smarter cities" trademark was registered for the first time (as belonging to IBM). I have also selected 2023 as the final year as my research took place this year.

(es. Global Cities Report[37], limited to European urban centers) and Italy (e.g. ICity Rank[38]; Human Smart City Index[39]), then analyze the initiatives promoted by them and mentioned in their websites.

3. Digital technologies for the development of a *Smart Sustainable City*

The technological dimension represents an unfailing component in the development of a *Sustainable Smart City* project[40]. Hardware devices, sensors and software play an important role in ensuring the success of these initiatives; however, the amount of digital devices is large and various.

In this paragraph I categorize innovative solutions by offering an overview of enabling technologies that are currently used in the smart urban centers in order to highlight their common features. I divide new technologies serving the development of SSC in four categories: (a) artificial intelligence; (b) *urban big data* and *data platforms;* (c) IoT; (d) ICT technologies and infrastructures.

3.1. Artificial intelligence

The first category includes artificial intelligence (AI) systems[41]. They are IT solutions created for enabling machines to perform cognitive processes (similar to logical and predictive capabilities owned by humans)[42].

Within a *smart city*, AI systems might increase the efficiency and quality of public services to improve citizens' quality of life. A recent study[43] high-

[37] AT Kearney, Global Cities Report, 2022.
[38] FPA S.r.l., ICity Rank, 2022.
[39] EY Advisory S.p.A., Human Smart City Index, Milano 2022.
[40] Many definitions of the phenomenon describe the technological components as one of the foundational elements for making up a sustainable smart city (as stated, for example, by the European Commission - see note 2, p. 3). Each definition of "smart city" and/or "sustainable smart city" involves the technological endowment as the unfailing dimension of that urban initiative (cfr. UNECE, 2021).
[41] For an overview of the application of AI systems and their ethical implications please see, among others, Bostrom N., 2017; Cicerone et al., 2022; Coeckelbergh, 2020; Coeckelbergh, 2021; Floridi, 2019; HLEG, 2019; Letouzé e Pentland, 2018.
[42] The Independent High-Level Expert Group on Artificial Intelligence appointed by the European Commission in 2018 defined AI as "systems that exhibit intelligent behavior by analyzing their environment and taking actions, with a certain degree of autonomy, to achieve specific goals. AI-based systems can consist only of software that acts in the virtual world (e.g. voice assistants, image analysis software, search engines, speech and facial recognition systems), or embed AI in hardware devices (for example in advanced robots, self-driving cars, drones or Internet of Things applications)". https://digital-strategy.ec.europa.eu/en/library/ethics-guidelines-trustworthy-ai
[43] Pellegrin et al., 2021.

lighted, for example, how the implementation of "intelligent" IT systems can support Public Administrations in the collection, interpretation and analysis of data for guiding decision-making processes.

AI can be applied in many areas of public policy to promote *Smart Sustainable Cities* projects[44]). Here are some examples:

a. healthcare: diagnostic activities[45], prediction of sanitary equipment failures;
b. governance: urban planning, study of satellite images of peripheral settlements in order to improve the living conditions of poorests (Hofer et al., 2020), city branding, sentiment analysis[46];
c. mobility: optimization of traffic flows (Boukerche et al., 2020) and public transport demand[47], smart parking (Ruili et al., 2018), management of crowds along the streets[48] ;

[44] Their applications also vary according to the type of computer system we use. We can distinguish between (Pellegrin et al. 2021): a) artificial intelligence systems for predictive analysis, whose main function is to predict future results or events (e.g. forecasting of urban traffic and mobility flows, prevention of breakdowns in hospital machinery or other equipment, planning of the delivery of public services); b) artificial intelligence systems for real-time analysis, whose main function is monitoring in order to allow simultaneous intervention with respect to the occurrence of a given event (e.g. urban traffic management in order to avoid congestion, changes topological, the provision of customer assistance activities in real time); c) artificial intelligence systems for almost real-time data analysis, whose main function is to optimize the services provided thanks to monitoring and reporting activities (e.g. optimization of networks and infrastructures, provision of targeted services based on the location of citizens); d) artificial intelligence systems for analyzing historical data, whose main function is to identify patterns in past events or results in order to optimize the delivery of future services (e.g. the creation of public campaigns, network planning and infrastructure, the improvement of customer care services for citizens).

[45] I recall Corti AI, a virtual assistant which aims to diagnose pathologies complained of by patients in a faster and more efficient way, supporting call-takers during emergency calls. The system was implemented by the city of Copenhagen (https://www.corti.ai/newsroom-posts/capital-region-of-denmark-using-ai-to-improve-patient-care-on-the-national-healthcare-system). For further examples of the application of AI systems to diagnostic activities, see the publication of the Superior Council of Health at the Ministry of Health "Artificial intelligence systems as a diagnostic support tool" (9 November 2021). https://www.salute.gov.it/imgs/C_17_pubblicazioni_3218_allegato.pdf

[46] For example, the CivicLytics project which led to the development of an AI system that makes it possible to understand the sentiment of the population by analyzing in real time the manifestations of thought (expressed through social networks, blogs, chatbots) of citizens established in America Latina and the Caribbean by processing the available open data. The aim of the project is to promote inclusive solutions for local and regional recovery. https://bidciviclytics.citibeats.com/en/. A similar initiative was also promoted by the city of Dublin in collaboration withCitibeats.

[47] Since 2017, the city of Shanghai has implemented a facial and voice recognition system that can be used by users of the subway in order to purchase travel tickets. The system is also used for public safety and monitoring purposes. https://www.infinova.com/transportation-surveillance/shanghai-metro.aspx

[48] The city of Amsterdam uses an AI system to collect real-time information about the number of pedestrians for the possible adoption of countermeasures for crowd addressing and public safety. The Public Administration can intervene, for example, by positioning

d. citizen services: efficiency solution for the management of citizens' requests[49], on-demand assistance for citizens and tourists[50];
e. legality and security: tax fraud (Pérez López et al., 2019) and real estate fraud detection[51];
f. waste: optimization of waste collection routes[52] and classification (Bijos et al., 2021); prediction of waste production.

3.2. Urban big data e data platforms

The second type of technological solutions for sustainable smart cities includes urban big data[53] and data platforms.

"Urban big data"[54] corresponds to large amounts of static and dynamic data generated by subjects or objects within the SSC, including individuals (residents or tourists), private entities and urban structures. This data can be generated by smartphones, IoT sensors, cameras, GPS systems, social networks, or during commercial transactions.

In order to define information as urban big data we need the so-called "5V": volume, velocity, variety (Khan et al., 2014), vastness and value (Elgendy et al., 2014; Pan Y. et al., 2016); additionally, information has to be collected within the urban areas.

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digital information panels so that people know which routes to take or by establishing one-way traffic. https://algoritmeregister.amsterdam.nl/public-eye/

[49] For example, the Italian INPS project "Certification and sorting by certified email", developed in collaboration with Accenture Technology Solutions S.r.l., has been created to improve the process of classifying emails sent by citizens and forwarding them to the competent office (up to now carried out manually). The AI system facilitates the automated classification of emails sent by applicants by analyzing the content and context of requests through NPL techniques. https://www.inps.it/inps-comunica/inps-inclusione-e-innovazione/i-progetti-per-i-cittadini/classificazione-e-smistamento-pec

[50] For example, in the city of Helsinki there is a non-stop customer service channel dedicated to housing services. Through chatbots, the system intends to improve the accessibility and experience, both of the customer and of the tourist, during self-service procedures. https://ai.hel.fi/sv/hyresbostadsbot/

[51] We recall the AI system used by the city of Amsterdam to support the investigation and verification activities against tourist rentals promoted without license. The system uses historical data and information collected in real time (e.g. reports from neighbours). https://algoritmeregister.amsterdam.nl/handhaving-illegale-vakantieverhuur/

[52] The town of Darmstadt has equipped the large containers in public places with sensors through which it is possible to know in real time the exact level of its filling, so that emptying takes place only when the containers are full. The AI software also advises collectors on paths to take to increase efficiency. https://www.digitalstadt-darmstadt.de/en/projekte/smart-waste/

[53] About the concept of big data and the related implications from social and ethical sides please see, among others, Allen et al, 2020; Bibri, 2018; DeMauro et al., 2015; Kharrazi et al., 2016; Lane et al., 2013; Lepri et al., 2018; Letouzé, 2015; Cuquet, 2017.

[54] Pan Y. et al., 2016.

Urban big data are used for different purposes:

a. as "fuel" for data-driven products and services that require large amounts of information to perform correctly (e.g. training of AI systems);
b. as a "driver" for decision-making processes conducted by Public Administrations, in order to allocate urban resources properly and to plan public services by improving performance and reducing their costs.

"Data platforms" (or urban data platforms)[55] are digital platforms that bring and integrate data flows from public and private infrastructures in order to make them accessible, interpretable and modifiable in real time, but also reusable. They are often centralized at a local level.

This technology is based on the integration, aggregation and processing of urban data collected through sensors and devices that are in public spaces. Furthermore, through APIs (programming interfaces), it is possible to generate specific datasets which might be used by the municipality for the implementation of urban projects or experimental activities.

According to a recent study, their potentiality in the development of sustainable smart cities is still unexplored - also due to the fact that half of the urban centers still do not have a digital platform whose data are provided by the city itself and/or other urban stakeholders[56].

The implementation of urban data platforms serves for the achievement of different aims within a sustainable smart city:

a. internal goals of the municipality, such as the improvement of decision-making processes, the reduction of public costs, the boost of urban center performance (in terms of public services);
b. external goals, such as the development of entrepreneurship, the co-creation of public services through a bottom-up approach, the increase of citizens' engagement.

Such platforms are often designed together with "control rooms": physical places containing videos and other monitoring devices which enable

[55] About the concept of urban data platforms and their potential uses for goods see, among others, Allen et al., 2020; Badidi and Maheswaran, 2018; Barnes, 2020; Cheng et al., 2015; Hernandez et al., 2019.

[56] According to the Research Study on Urban Data Platforms in Europe published by the Erasmus University of Rotterdam, around 20% of the cities covered by the study keep their data in silos (therefore not accessible through a data platform), 19% have developed an internal data platform provided by the Municipality, 45% have developed an urban data platform that includes both data provided by the Municipality and data provided by other stakeholders (e.g. companies, start-ups), while 16% have developed an external urban data platform that does not include data provided by the municipality. https://www.datavaults.eu/wp-content/uploads/2021/03/2019-Study-on-Urban-Data-Platforms-key-findings-6-3-2020.pdf

real-time control by the Authorities. These control cabins allow timely decisions and targeted public interventions.

Data platforms and the big urban data are two important building block in the creation of a *Smart Sustainable City*[57] and represent an important vehicle for the achievement of SDGs[58].

For example, big urban data might be useful in the following sectors (Al Nuaimi et al., 2015).:

a. transportation: optimization of routes and travel schedules, *in real time* traffic information communication[59], road surface monitoring[60], use of barriers and lights to reduce traffic jam[61];
b. *utilities*: automatic switch off of public lightings when there are no vehicles[62] or pedestrians;
c. environment: real-time monitoring and strategic decisions to improve air quality (Zhang et al., 2022); control and reduction of illegal deforestation (Burgess et al., 2011);
d. governance: measurement of *citizen engagement* (Blasi et al., 2022).

Regarding urban data platforms I recall the following *case studies* (Cheng et al., 2015):

a. environment: real-time monitoring of heat islands, environmental parameters and the rate of crowding within different areas of the city[63] (Garau et al., 2020);

[57] With respect to the latter, Caragliu et al. (2011) highlighted that: "Currently urban performance does not depend only on the endowment of material infrastructures of the city, but also, and increasingly, on the availability and quality of social and knowledge communication infrastructures ("human and social capital "). The latter form of capital is decisive for urban competitiveness".

[58] See https://unstats.un.org/unsd/trade/events/2015/abudhabi/presentations/day3/02/2b%20A-Using%20Big%20Data%20for%20the%20Sustainable%20Development%20Goals%2010222015.pdf

[59] See Transport for London (TfL) project, which uses data collected through the Oyster card system (electronic tickets used in public transport in the Greater London area) to monitor journey times, the number of passengers and the effects of various congestion model situations, such as the impact of mechanical failures on a particular line.

[60] The city of Boston (US) has implemented Street Bump, a mobile app that uses cell phones to map potholes in the city. https://www.boston.gov/transportation/street-bump

[61] The project "Scalable Urban TRAffic Control" (SURTRAC) sponsored by the research group Traffic21 of the Carnegie Mellon University allowed the reduction of traffic jams and waiting times on the urban streets of Pittsburgh, Pennsylvania (US) thanks to the real-time analysis of road traffic data and the use of physical and light sensors. https://www.cmu.edu/piper/news/archives/2012/october/smart-signals.html

[62] It has been realized in the city of Santander (ES). https://www.smartsantander.eu/

[63] This functionality has been implemented, for example, within the data platform used by the Municipality of Cagliari. https://www.comune.cagliari.it/portale/page/it/cagliari_connect_the_intelligent_platform_at_city_service?contentId=VID129301

b. tourism: people counting within a specific area and monitoring of other phenomena, such as tourist spending, number of accommodation facilities, number of visitors in museums, employment data[64];
c. traffic and mobility: centralized information management for improving urban mobility[65], road and water traffic control[66];
d. public health and safety: surveillance of public spaces in real time[67], epidemic containment.

3.3. IoT devices

The third category of technological solutions that enhance the development of SSC includes the Internet of Things (IoT)[68].

This branch involves the installation of sensors (RFID, IR, GPS, laser scanners, etc.) within physical objects in order to enable their interaction with the external context. These devices are web connected so they can exchange information with other online devices (Rashid et al., 2017). For example, IoT devices can recognize objects, people or places, they are geolocated and allow users to monitor the surrounding space remotely, they can interact with other “smart” hardware via WiFi (Kim et al., 2017).

IoT devices that are used in urban contexts the most are RFID and IR sensors, GPS devices, timers, cameras and advertisement panels (e.g. digital signage devices).

Smart Sustainable Cities projects can benefit hugely from the installation of IoT sensors within the urban space. Thanks to their ability to interact with the external world in real time, these smart devices can improve the efficiency of public services, reduce their environmental impact and help prevent natural disasters. Here are some examples of IoT applications within the SSC:

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[64] For example, see the data platform used by the city of Rome. https://www.romadataplatform.it/

[65] For example, the city of Florence has activated a Smart City Control Room (SCCR) as an operations center with Mobility Operations Center (COM) functions. https://www.comune.fi.it/system/files/2022-08/Scheda_2_2_1f.pdf

[66] For example, the Smart Control Room in Venice: the project is based on the implementation of a cloud software platform dedicated to the collection of urban data through systems and sensors distributed throughout the territory. The platform collects and aggregates information from the urban context, making it available through video walls and other devices installed in the control room, for monitoring and predictive analysis purposes, providing both historical and real-time information. https://www.venis.it/it/node/1127

[67] For example, Mexico City promoted the MiCalle project, which foresees the installation of 58,000 cameras in 333 areas with the highest crime rate and additional 16,000 cameras inside public means to guarantee citizens’ safety.

[68] Atzori et al., 2010; Bellini e Pantaleo, 2023; Rajab e Cinkelr, 2018; Rejeb et al., 2022; Syed et al., 2021.

a. waste: monitoring of the filling level of bins to schedule emptying activities (Samih, 2019), measuring the volume of waste produced for the application of punctual taxes[69];
b. mobility: helping people with motor disabilities (Rashim et al., 2017), real-time traffic light regulation[70], signaling of free parking spaces to reduce waiting times and monitoring of urban traffic[71];
c. environment: automatic regulation of switching on/off of public lighting depending on surrounding brightness[72], indoor and outdoor air quality monitoring, creation of charging stations for mobile devices through renewable energy[73];
d. public safety: video surveillance cameras for people detection and critical issues such as thefts, accidents, or floods (Zahir et al., 2019);
e. construction: predictive design and maintenance of buildings and public infrastructures thanks to digital twin models.

3.4. ICT infrastructures

The fourth category concerns ICT infrastructures[74], as 4G and 5G solutions, bluetooth technology, Wi-Fi network, cloud computing (Shafique et al., 2020; El Hendy et al., 2022).

The use of ICT infrastructures within a *Smart Sustainable City* allow Authorities to collect, share and process in real time large amounts of information collected within the urban area (Uribe-Pérez and Pous, 2017). These systems support both the interactivity of urban services and the interaction between citizens and the Administration. Those technologies enable the

[69] For example, the Municipality of Fiesso d'Artico (VE) has introduced the punctual tariff (TARIP) and, for the purposes of determining the amount of the tax, has provided electronic control devices integrated in the waste container (art. 8.2 of the TARIP Regulation - resolution of the City Council n. 828 of 2021).
[70] Thus, for example, traffic lights in Vienna have been equipped with intelligent motion sensors and cameras installed to detect the presence of pedestrians approaching the zebras. Depending on their direction, the system is able to predict whether the pedestrian intends to cross the road so that, as soon as they reach the zebra, the traffic light immediately turns green without the latter having to wait. https://smartcity.wien.gv.at/en/smart-traffic-lights/
[71] For example, the Municipality of Mantua launched the "Smart Parking" pilot project. This project involves the installation of 66 parking sensors in Corso Vittorio Emanuele II, in correspondence with the parking areas. Through an app, sensors are able to detect the closest free parking to users, also indicating the time required to reach it and allowing them to pay only for the effective stop.
[72] See note 30, p.13.
[73] We are referring to the "smart" benches which contain an integrated charging station powered by a mini solar panel, with two USB ports for connecting mobile devices. The devices can also connect to city wireless networks and have been installed in various US cities such as Boston, New York and Washington.
[74] See Attaran et al, 2022; Dameri, 2018; Gade D.S., 2019.

management of data collected by various urban *touchpoints* (e.g. IoT devices), the exchange between centralized and peripheral data centers (e.g. data rooms) but also co-decision processes among civic stakeholders.

Therefore ICT infrastructures serve as an "enabler" for all the hardware and software solutions listed above. In other words, they play a complementary role in connection with the urban technological endowments which need such infrastructures to interact with each other and share relevant information.

In some cases, ICT technologies assume an autonomous role for the development of a SSC. For example:

a. connectivity: Wi-Fi coverage on public transport, installation of free Wi-Fi kiosks[75];
b. security: protection of urban computer systems from cyberattacks (Toh, 2020);
c. governance: electronic voting systems[76], extraction of large amounts of data from social networks for sentiment analysis purposes through cloud computing solutions.

4. Digital technologies, fundamental rights and democracy defense

As I said before, the sustainability dimension of a *Smart Sustainable Cities* is closely linked to the protection of fundamental rights, the improvement of people's well-being and the efficiency of public services, as set by the UN's 2030 Agenda (Del Río Castro et al., 2021)[77].

Although digital technologies are necessary to satisfy population's needs better and faster[78], the relationship between the achievement of sustainabil-

[75] The *smart city* project of Wuxi (China) includes equipping more than 3,000 city buses with free Wi-Fi and establishing nearly 40,000 free Wi-Fi access points with 4G network throughout the city. See Smart cities and infrastructure Report published by the United Nations Commission on Science and Technology for Development (2016).

[76] So in Estonia, where citizens have an electronic ID card with a chip that allows them to vote remotely. The identity card is inserted into a special reader connected to the voter's personal computer which certifies the user's identity (thanks to the digital certificate within the document).

[77] Défenseur des droits, 2022. In this report, the French defender of rights drew attention to the risks deriving from the implementation of the national strategy for the digitization of public services with respect to the three essential legal principles governing the public administration: continuity, equality and adaptability. Such conduct risks jeopardizing the rights of citizens, especially disadvantaged ones such as low-income people, the elderly, foreigners and people with disabilities.

[78] Congress of Local and Regional Authorities, 2022.

ity goals and the urban digital transition is not clear yet (Fukuda-Parr and McNeill, 2019; Goralski and Tan, 2020; Hodson et al., 2023). Indeed, regarding the protection of human rights, we can identify some conflict areas between the implementation of new technologies and the design of inclusive and democratic *smart cities*. The main frictions are related to: (a) data protection and privacy; (b) data governance and sovereignty of Public Administrations; (c) cybersecurity (d) discrimination and digital divide.

First of all, the extension of sensors (e.g. video cameras, IoT devices, bluetooth sensors)[79] installed in the city centers for collecting, processing and storing public information might increase the risks of unwelcome introductions into citizens' private lives (Eckhoff and Wagner, 2018; Dhungana et al, 2015; Leslie et al., 2021; Li et al., 2016). It occurs, in particular, when collection activities take place without the consent of the data subjects[80].

In order to ensure the respect of citizens' privacy, Public Authorities must inform citizens about the installation of control devices in public spaces and, if possible, provide alternatives to the processing of their personal data[81].

Secondly, regarding data governance and sovereignty issues, a lack of technical skills or financial resources by the Administrations often prompts them to outsource the development of smart city's technological solutions. The collection and processing of urban data is delegated to foreign providers consequently. This transfer of functions might strip public bodies of their powers and sovereignty, creating room for technocratic drifts (Bria and Morozov, 2018; Kitchin et al., 2018; Frosina, 2023; Pagnanelli, 2021).

In order to minimize this risk, cities need to equip themselves with democratic models that ensure the control over urban data in the hands of the PAs and/or an active role of citizens in governing processes, according to a bottom-up logic[82].

Cybersecurity represents a central topic in the design of *Smart Sustainable Cities* too. The loss or encryption of information caused by cyber attacks might be detrimental for citizens' personal data[83] or fundamental public

[79] Internet of Things Observatory of the Milan Polytechnic, Internet of Things report (2022).
[80] It happens very often for GPS-based technologies. As an example, I recall the ruling dated 02.05.2020 published by the Court of The Hague which prohibited the use of SyRi system (a government tool used to report profiles of subjects worthy of further investigation to Public Authorities) due to the "impossibility for citizens to protect themselves from it and to resort to its decisions, against art. 8 of the European Convention on Human Rights". https://uitspraken.rechtspraak.nl/#!/details?id=ECLI:NL:RBDHA:2020:1878
[81] In compliance with the principles of lawfulness, transparency and minimization established by Regulation (EU) 2016/679 (GDPR).
[82] As an example, I mention the "DataCités" project developed in France which aims to guarantee the integration, use and sharing of data within urban communities, encouraging collaboration between urban stakeholders. https://www.datacites.fr/?locale=fr
[83] For example, the Municipality of Lviv suffered a cyberattack on 05.13.2022 which

services, whose delivery depends on computer systems[84]. These hypotheses generate extremely serious consequences for the population.

In order to guarantee urban sustainability - in a broad sense -, it is necessary for Authorities to adopt IT security measures that are aligned with international standards and best practices (Congress of Local and Regional Authorities, 2022).

Finally, the implementation of "intelligent" technologies for a smart city project might cause discrimination and marginalization phenomena. These effects depend both on citizens' lack of digital skills and on difficulties in accessing WiFi connection. Citizens who are exposed to a digital divide the most are old people, foreigners and inhabitants of rural areas, who could be excluded from having access to public services[85].

A smart city, in order to be sustainable, must develop countermeasures for bridging the digital divide, providing funds and educational programs reserved to weak citizens, in order to guarantee access to public services for all.

The social problems mentioned above have a significant impact on the success of a *Smart Sustainable City* project. They may reduce the positive impact of smart urban initiatives or, at least, compromise citizens' fundamental rights. Consequently Public Administrations have to go beyond the mere introduction of technological solutions within urban centers by adopting a holistic approach, in order to fix any eventual social implication.

5. Creating a *Smart Sustainable City* through digital technologies: two potential scenarios

The case studies listed in the third paragraph underline the central role of digital technologies in the creation of a *Smart Sustainable City*. Tech solutions promise to have a positive impact by increasing the efficiency of public services, by reducing either GHG emissions or the exploitation of raw materials, by improving the quality of citizens' life.

resulted in the theft of citizens' data and their diffusion on Telegram's channels. https://www.theguardian.com/world/live/2022/may/15/russia-ukraine-war-latest-zelenskiy-victorious-chord-battle-ukraine-wins-eurovision-mariupol-putin-g7-biden-nato-finland-ve?page=with:block-62808f788f083b856379acff

[84] As an example, I mention the ransomware attack suffered by the University Hospital of Brno (Czech Republic) in March 2020 which limited the functioning of the public structure significantly and it caused many damages. https://cyberlaw.ccdcoe.org/wiki/Brno_University_Hospital_ransomware_attack_(2020)

[85] See European Parliament, 2015.

The following table summarizes the main environmental and social benefits conveyed by the application of innovative technologies within the urban context.

Technology	Description	Benefits for SSC development
IA	Training of AI systems	More efficient use of the resources necessary for the provision of public services Reduction of consumption and emissions associated with the provision of these services Pollution level monitoring and support for the adoption of targeted policies Efficiency of the provision of essential public services (e.g. health care, transportation)
Big data analysis	Collection and analysis of a large amount of urban data	Prediction of environmental catastrophes Data-driven response initiatives against environmental events Optimization of decision making processes based on the real needs of citizens Effective allocation of public funds
Data platform	Platform for real-time analysis and control of urban data	Real-time monitoring of urban environmental conditions Prompt response to natural disasters Support for decision making activities Participation of citizens in the democratic processes with the PA Joint governance according to a bottom-up logic
IoT	Sensors and "intelligent" devices installed within the city	Real-time interaction and monitoring of urban environments Measurement of air pollution levels Renewable energy production (small scale) Support for people with motor disabilities Efficiency of public services Public security
ICT infrastructures	Digital infrastructures for information communication and connectivity	Reduction of time windows for information transmission Speed of response during emergencies Widespread access to the network Democratization of technologies and reduction of digital divide

Table 1: The main environmental and social benefits ensured by digital technologies in the development of Sustainable Smart Cities.

However, as highlighted above, environmental and social impacts deriving from the use of digital technologies might be negative too.

In particular, from the environmental side:

a. most digital technologies cause high environmental pollution, as highly energy-intensive technologies, which translates into a higher rate of GHG emissions[86];
b. the use of connected devices (e.g. IoT) also leads to high environmental pollution[87];
c. moreover, an increased production of technological devices (which is related to a higher demand rate) determines a greater exploitation of the so-called "rare earths" as well as a greater use of plastic materials (e.g. for the creation of external components, for packaging, etc.). These resources are consumed very fast, so the Nature cannot replace them, and their recycling is challenging; it leads to a further increase in greenhouse gas emissions (Bianchini et al., 2022);
d. a further critical phase in the life cycle of technological products is represented by their disposal, given the difficulty of recycling raw materials.

At the same time, from a social perspective:

a. the implementation of new technologies - especially AI systems and IoT devices - undermines citizens' right to privacy whenever their personal data is processed without prior information or without allowing the individuals to avoid such violations (e.g. alternative routes are not available);
b. the complexity of these solutions requires Public Administrations to delegate data governance and sovereignty to private entities without any supervision;
c. the risk of cyber attacks could detriment citizens' data protection;
d. discrimination and marginalization phenomena against old or rural populations.

The negative impact of such technologies represents the main obstacle to the creation of *smart cities* that are truly sustainable.

The table below summarizes the main environmental (Bond and Dusik, 2020; Bianchini et al., 2022) and social (Caragliu and Del Bo, 2022; Congress of Local and Regional Authorities, 2022; Cuquet, 2018) risks connected to each technology:

[86] Joppa and Herweijer (2018), in particular, have estimated that the share of greenhouse gas emissions caused by the use of digital technologies has grown from 2.5% in 2013 to 4% in 2020.

[87] "Internet generates between 3% and 4% of the world's carbon dioxide emissions" (McKinsey, 2018).

Technology	Description	Environmental impact	Social impact
IA	Training of AI systems	High energy consumption High levels of greenhouse gas emissions	Discriminations Breach of Confidentiality Data protection
Big data analysis	Collection and analysis of a large amount of urban data	Highly energy-intensive computational activity High levels of greenhouse gas emissions	Cyber attacks Discrimination Loss of sovereignty
Data platform	Platform for real-time analysis and control of urban data	Use of "rare earths" Difficulty in materials disposing at the end of products' life cycle	Cyber attacks Digital divide Loss of sovereignty
IoT	Sensors and "intelligent" devices installed within the city	Use of "rare earths" Difficulty in materials disposing at the end of products' life cycle	Cyber attacks Breach of Confidentiality Data protection
ICT infrastructures	Digital infrastructures for information communication and connectivity	Large use of physical areas Large use of semiconductors Difficulty in materials disposing at the end of products' life cycle	Discriminations Digital divide Loss of sovereignty

Table 2: The main social and environmental obstacles to the development of a Sustainable Smart City.

To evaluate the net impact of each tech solution, it is necessary to carry out a risk assessment for measuring their potential impact on the development of a *Smart Sustainable City*. Therefore I suggest evaluating the impact of these technologies under two different scenarios.

In relation to social risks, the best scenario relates to the implementation of all the related countermeasures (as mentioned in paragraph 4) by the Public Administration. At the same time, the worst scenario ties to the failure of the implementation of such remedies by the Authority[88].

With respect to environmental risks, I adopt a quantitative approach instead: I consider the harm caused by the implementation of each technology within the urban context, as measured by the previous literature (Dusìk et al., 2018; Garau et al., 2020; United Nation, 2022)[89].

The impact of digital solutions is measured on a scale from 1 (significantly positive impact) to 5 (significantly negative impact) while their overall effect on the urban ecosystem - as indicated in the final column - is calculated as the sum of values indicated in the previous columns.

[88] The classification criteria follows the one offered by Dusìk et al. (2018).

[89] I consider the quantity of greenhouse gas emissions and the use of energy required for the proper functioning of these technologies, as well as the quantity of raw materials that are used.

Best scenario				
Technology	Greenhouse gas emission and energy use	Use of natural resource	Social impact	Net effect on the urban ecosystem
IA	2	1	2	5
Big data analysis	3	1	1	5
Data platform	3	1	1	5
IoT	4	4	2	10
ICT infrastructures	1	3	1	5
Worst scenario				
Technology	Greenhouse gas emission and energy use	Use of natural resource	Social impact	Net effect on the urban ecosystem
IA	4	1	5	10
Big data analysis	5	3	4	12
Data platform	5	3	3	11
IoT	5	5	5	15
ICT infrastructures	1	5	3	9

Table 3: Possible scenarios regarding the social and environmental impacts of the implementation of digital technologies within the urban context for the development of a Sustainable Smart City.

Regardless of the scenario we consider, the implementation of IoT devices seems to have the greatest impact on the urban environment, both from an environmental and a social point of view.

AI systems are functional to the development of a *Smart Sustainable City* due to their lower environmental impact, although they present considerable risks for citizens' rights even if Authorities adopt all the countermeasures available nowadays.

The collection and processing of big urban data - also through specific data platforms - assume an intermediate position in the face of the adoption of appropriate countermeasures against social risks while they present a significant environmental impact.

Finally, the development of ICT infrastructures has modest social and environmental consequences and they seem to be the least risky solution for the development of a *Smart Sustainable City.*

6. Conclusions

The contribution of digital technologies in the creation of a *Smart Sustainable City* is huge when they ensure the efficiency of public services, reduce raw materials consumption and greenhouse gas emissions, support democratic approaches to decision making processes and protect human rights.

At the same time, these innovations can have significant negative implications both from an environmental and a social perspective.

To assess the real risks underlying the implementation of smart urban projects, it is necessary to consider both these aspects: the adoption of a sectoral approach, limited to the analysis of only the environmental or the social side, might generate misleading and conflicting results. It creates the illusion of a successful urban project while its sustainability dimension is completely deceived. In order to evaluate the impact of a *Smart Sustainable Cities* project in the proper way it is necessary to consider these two dimensions jointly.

This study aims to offer a guiding tool dedicated to Administrators and decision makers for comparing different technologies and their potential impact under two possible scenarios, in a holistic perspective. I hope it will help them to address the effort of Public bodies in a proper direction: given the central role played by urban centers in the fight against climate change and the protection of fundamental rights, it is necessary for cities to consider the consequences of implementing innovative urban projects more deeply and broadly.

In my opinion, this shift is necessary in order to promote a twin transition that is effective and complete and a shared effort towards achieving SDGs objectives.

7. Research limitations and future developments.

This research has at least two limitations.

The first one depends on the fact that I have divided digital technologies into four homogeneous groups. This approach is requested for simplicity and systematicity reasons. However, practical knowledge of the urban phenomenon suggests that this subdivision is, in some ways, artificial.

We can think about the various AI systems currently available and how they are designed and "trained" (e.g. facial recognition, natural language processing or NLP, and so on). These differences from the design side ties to important differences in terms of energy demand, GHG emissions and so on. A linear approach - as the one I adopted - could alter the results of my comparison significantly.

Secondly, the distinction among technological solutions carried out in the fifth paragraph is not based on a *dataset* referred to all the smart urban centers: most of the environmental data have been collected within large geographical areas and the social risk assessment is carried out arbitrarily. This approach is forced by the lack of disaggregated data on the net environmental and social impact of individual technologies within each urban context. However, it reduces the potential contribution of my research in understanding the effective relationship between the technological development and the planning of a *Sustainable Smart City.*

Future studies might fill this gap by collecting precise information at the urban level regarding the environmental and social impact of each digital solution. It could identify the greenest and most sustainable solution that can be used for supporting the development of urban projects in a more precise way.

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