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Understanding City 4.0: A Triple Bottom Line Approach

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Abstract: Rapid urbanization and population increase, along with remarkable technological advances, have accelerated the speed of digital transformation, or at least the need for it, in our cities. Whilst being smart and sustainable is seen somewhat as an ideal city quality globally, a new city concept has emerged—the so-called City 4.0—that combines Industry 4.0 and Society 4.0 in the context of smart cities. While there is growing literature on the topic, there is limited understanding of City 4.0. This communication piece aims to bring clarity to City 4.0 by elaborating it from three diverse but interrelated perspectives—namely, societal, environmental, and economic lenses or domains (also know as the triple bottom line approach)—and highlights the key City 4.0 themes—namely, circularity, adaptability, livability, accessibility, authenticity, and responsibility. The methodological approach includes a thorough appraisal of the current City 4.0 literature. This communication paper informs researchers, local and regional authorities, and urban planners on the rising importance of the notion of City 4.0 and its prospective research areas.

Keywords: City 4.0; Industry 4.0; Society 4.0; smart city; sustainable development; knowledge-based development; urban innovation; responsible innovation; platform urbanism; digital transformation

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1. Introduction: Defining City 4.0

At present, way over half of the world's population resides in urban localities, making cities undoubtedly the epicenters of socioeconomic activities [1]. In some countries, the urbanization rate surpasses the 90% mark, such as Australia, the Netherlands, and the UK [2]. Along with cities being the primary generators of gross domestic product and innovation, rapid urban growth also brings challenges related to sustainability, quality of life, productivity, and urban management [3]. More specifically, we face the daunting task of ensuring that the urban centers of tomorrow do not exacerbate environmental degradation, social inequalities, and resource scarcity but rather serve as catalysts for progress toward a more sustainable, livable, and equitable world.

The major challenges we face today include, but not limited to the following: (a) The need to offer solutions to anthropogenic problems that cities have been causing; (b) The need to respond to the increasing socio-technological and infrastructural needs of growing urban regions; (c) The need to address the anthropogenic climate emergency; (d) The need to cater to the aging population's needs by using state-of-the art planning, design, construction, and management; (e) The need to offer cutting-edge and innovative solutions to improve the quality of life of residents; and (f) The need to prepare for digital transformation and technological disruption [4–6].

City 4.0 is the response to such challenges [7,8]. In a nutshell, City 4.0 is a city that utilizes technological developments and digitalization to transform local public services and the local economy to produce sustainable and desired urban, environmental, and

societal outcomes for all [9]. It represents a vision where cities are smart, sustainable, inclusive, well-governed, and resilient [10,11]. As our planet undergoes an unprecedented wave of intense urbanization processes, the concept of City 4.0, following the smart city's popularity and foundations, has emerged as a beacon of hope on the horizon [12]; it is becoming a vision for many cities in the 21st century that integrate technology, innovation, and sustainability to address the myriad challenges of rapid urbanization [13,14].

City 4.0 envisions urban environments where technology enhances resource efficiency, connectivity improves quality of life, and data-driven decision-making transforms governance. It represents the convergence of urban development and the digital age, offering innovative solutions to age-old urban problems [5,15,16]. By integrating various technological advancements like Internet-of-Things (IoT), artificial intelligence (AI), big data, and sustainable practices to manage resources, transportation, energy, and services within a city, City 4.0 aims to create smarter, more sustainable, more efficient, and more livable and prosperous cities [6,17].

In terms of the differences between smart city and City 4.0, both refer to urban development concepts, but each of them emphasizes different aspects and stages of technological advancement within a city. In essence, while smart city focuses on using technology to improve specific aspects of city life, City 4.0 represents a more advanced stage, encompassing a broader and more deeply integrated innovation and technological ecosystem aimed at creating a highly connected, intelligent, and efficient urban environment. City 4.0 is often seen as the next phase of smart city development, incorporating more advanced and disruptive technologies to transform urban living and governance [5,18].

As a result, the concept of City 4.0 represents a paradigm shift in urban planning and development, "leveraging the power of engaged and connected citizens, digital technology, and data to ensure and enhance the quality of urban life, productivity, and sustainable development" [9,19]. Although such a paradigm shift is occurring at the moment, there is a knowledge gap regarding what City 4.0 is and what its key characteristics are. Tackling this issue is the rationale behind this communication piece.

This is a communication paper, as opposed to a research article, we aim to contribute to the efforts in bridging this knowledge gap by sharing our views on the topic thorough an appraisal of the current City 4.0 literature and our extensive experience and expertise in the field of smart and sustainable urbanism. In this communication piece, we explore City 4.0 from the perspectives of societal, environmental, and economic lenses (a triple bottom line approach), and also introduce the six prominent themes—circularity, adaptability, livability, accessibility, authenticity, and responsibility—of City 4.0.

2. City 4.0 from the Societal Lens

The societal lens of City 4.0 delves into this new city type's societal benefits and challenges, and the transformative potential it holds for urban societies, including the rapidly growing aging population. City 4.0 brings profound societal benefits, influencing various aspects of urban life through the adoption of various digital technologies and data-driven decision-making [20].

First, City 4.0 enables active citizen engagement, since digital platforms, mobile applications, and participatory mechanisms enable citizens to provide feedback, report issues, and actively participate in local initiatives to shape and better control their urban environment [21]. This active involvement fosters a sense of ownership, belongingness, accountability, and community cohesion among citizens, maximizing their contribution to community development and generating more sustainable solutions [9,22].

Second, City 4.0 promotes inclusive governance and community, where decision-making is transparent and responsive to the diverse needs of stakeholders, particularly for community citizens. This inclusivity ensures that marginalized and underrepresented groups, especially those vulnerable and disadvantaged populations in communities, have a voice in urban development, leading to more equitable outcomes [23].

Third, City 4.0 enhances the delivery of public services and infrastructure for the improvement in the quality of urban life. With data-driven insights and support from AI, governments can optimize services and infrastructure provision such as transportation, healthcare, education, and public safety, leading to a smart society that benefits all residents with improved efficiency and effectiveness [24]. To improve these deliveries, it is necessary to have good data to work on.

While City 4.0 holds immense promise for our current and future society, it is not without its challenges and considerations, including, but not limited, to the following:

Privacy and Cybersecurity: The extensive data collection and analysis required for City 4.0 raises concerns about privacy and cybersecurity. Safeguarding citizen data and ensuring data privacy regulations are adhered to is crucial to maintain public trust. Additionally, as cities become increasingly interconnected, they become more vulnerable to cyber threats. Robust cybersecurity measures are necessary to protect critical infrastructure and citizen data [25]. Robust rules and regulations, such as the General Data Protection Law, must be implemented to ensure that citizens' rights are protected [26].

Digital Divide: While City 4.0 envisions a connected and engaged citizenry, it also highlights the digital divide that exists within our societies because not all citizens have equal access to digital technology or possess the necessary digital literacy. Addressing this divide is crucial to ensure that City 4.0 benefits all segments of the population [27]. This is to say, technology must be accessible and beneficial to all citizens, regardless of their socioeconomic status, to avoid deepening social inequalities.

Public Acceptance: The changes brought by City 4.0 may not find universal acceptance among all residents. There may be resistance to new technologies, concerns about job displacement, or resistance to the disruption of established routines. In addition, urban citizens from different cultures and societies may have varying levels of acceptance and readiness for digital transformation [28].

Keeping these issues in mind, City 4.0 initiatives should be sensitive to all these factors to ensure successful implementation. It is worth mentioning that City 4.0 brings great opportunities and innovative solutions for addressing issues related to the rapidly growing aging population. The aging population is a demographic trend that is reshaping societies worldwide. By 2050, it is estimated that over 22% of the global population will be aged 60 or older [29]. This demographic shift poses unique challenges for urban planners and policymakers, but City 4.0 offers promising solutions.

For example, the emphasis of City 4.0 on data-driven decision-making can lead to the creation of age-friendly infrastructures, which include well-designed public spaces, accessible transportation options, and smart homes that cater to the specific needs of older citizens. In addition, digital technology in City 4.0 facilitates telemedicine and remote healthcare services, making it easier for older adults to access medical care without the need for extensive travel [30].

Additionally, given that loneliness and social isolation are significant concerns for the aging population [31], City 4.0 platforms can foster social connections by facilitating virtual meetups, providing information about local social activities, and encouraging intergenerational interactions. Finally, considering that older adults often face challenges with transportation and mobility, especially in sprawling urban areas, the smart transportation systems of City 4.0 can offer on-demand, accessible, and personalized transportation options, ensuring that seniors can remain mobile and independent [32].

To summarize, the emergence of City 4.0 carries a range of important societal implications, all of which are significant and multifaceted, influencing various aspects of urban life and society. On the one hand, it offers opportunities for enhanced citizen engagement, improved governance, sustainability, and better quality of life. On the other hand, it also presents challenges related to concerns regarding privacy, cybersecurity, the digital divide, and public acceptance. Meanwhile, it is worth noting that City 4.0 has profound implications for an aging population, the majority of which will age in cities. By building age-friendly infrastructures, improving healthcare access, promoting social inclusion, and

enhancing transportation options, City 4.0 can significantly improve the quality of life for older citizens, although it is also crucial to address those similar issues like the digital divide, privacy concerns, and digital literacy to ensure at City 4.0 truly benefits all members of society, regardless of age.

3. City 4.0 from the Environmental Lens

City 4.0′s environmental perspective has a strong sustainability and sustainable urban development focus. As outlined in the UN's Sustainable Development Goals (SDGs), sustainability encompasses environmental, social, and economic well-being [33,34]. Within this framework, we examine how City 4.0 contributes to achieving these global objectives.

Technology and Innovation: City 4.0 adopts advanced technologies such as AI, IoT, and big data analytics to create more efficient, sustainable, and resilient urban environments. In addition, the adoption of these technologies can optimize transportation, energy consumption, and waste management, contributing to sustainable resource use and reduced emissions in cities [35].

Smart Infrastructure and Services: An essential aspect of City 4.0 is the development of smart infrastructure and services, such as intelligent transportation systems, renewable energy generation, waste reduction strategies, and other urban services [36]. These innovations not only enhance the livability of cities (as discussed in the Society Lens of City 4.0) but also significantly reduce their environmental footprint [37].

Data-Driven Decision-Making: In the context of City 4.0, the emphasis is on the environmentally responsible collection and analysis of extensive data to enhance the sustainability of urban services and the efficient allocation of resources. This highlights how data-driven approaches in urban planning can lead to more eco-conscious governance, offering insights into the environmental challenges and opportunities associated with this approach [38]. In City 4.0, data will promote innovation and technological ecosystems and governments can include the smart mind society to contribute to solve city problems and to have more transparency in the process [39].

Environmental Benefits: City 4.0 can mitigate environmental degradation, given that sustainable urban planning can enhance green spaces, preserve biodiversity, improve air quality, and promote climate resilience. The objective is to understand how City 4.0 contributes to sustainability within city boundaries and on a global scale [40,41].

Social Equity and Inclusion: Sustainable development encompasses social dimensions, and our special edition recognizes their importance in the context of City 4.0. We delve into the role City 4.0 plays in providing affordable housing, bridging the digital divide, and ensuring community engagement. The vision of inclusive, equitable, and diverse cities is explored in detail, emphasizing the significance of balancing technological advancements with social progress [42,43].

Therefore, City 4.0 supports sustainable development because cities can reduce their environmental footprint, lower energy consumption, minimize waste and mitigate the impact of climate change by harnessing data and digital technology [44]. Regulating the carbon emission trading policies and promoting innovation in green technologies is crucial for City 4.0 in addressing the climate emergency [45]. This not only benefits the present generations, but also contributes to a more sustainable future for urban societies.

Effective policies and regulations are pivotal in guiding sustainable urban development and governments at all levels must play a central role in incentivizing and regulating the transition to City 4.0. Public awareness and community engagement will be equally vital, as informed and engaged citizens are instrumental in driving the transition to more sustainable, equitable, and resilient cities.

In summary, viewed through the lens of sustainable development, the concept of City 4.0 offers both a vision and a roadmap toward a brighter and more equitable urban future. With this communication piece, we hope to stimulate conversations, inspire action, and provide a platform for knowledge sharing among researchers, policymakers, and practitioners as we collectively embark on the journey to City 4.0, a vision where our cities

will not only flourish, but also be the cornerstones of a more sustainable and inclusive global society.

4. City 4.0 from the Economic Lens

The economic lens of City 4.0 adopts urban innovation principles where, in this regard, knowledge-based collective platform urbanism paves the way for a more economically sustainable, resilient, and inclusive urban future [39]. Knowledge-based collective platform urbanism, a key component of City 4.0, proposes a revolution in the way cities manage their development [46]. At the heart of this strategy is the establishment of an innovative environment that values cooperation between diverse actors—from government entities and the business sector to academia and citizens. This confluence of visions and expertise makes it possible to create solutions to complex contemporary urban problems.

The concept of City 4.0 expands the traditional idea of urbanism by emphasizing the importance of technology and the use of data in improving urban infrastructures. It focuses on capturing and analyzing real-time data to improve urban systems such as transportation and energy management, as well as human resource development, smart marketing, and smart technology adoption [47]. This is complemented by knowledge-based collective platform urbanism, which highlights the role of collective knowledge in solving complex urban challenges. Both approaches agree on the centrality of data, but while City 4.0 focuses on optimization and efficiency, knowledge-based collective platform urbanism sees data as a public resource that must be democratized to foster innovation [48].

The importance of entrepreneurship and innovation in knowledge-based economic development is undeniable. To promote this integration and economic development, cities must have universities that train a specialized and entrepreneurial workforce, as well as support infrastructures such as incubators, accelerators, and technology parks [49]. Legislation and public policies must also favor the growth of these emerging companies, whether through investment funds or tax incentives. Furthermore, political ties, environmental regulations, and corporate innovation should be considered in combination [50].

In the context of City 4.0, creating a robust innovation ecosystem requires a holistic approach that integrates the UN's three pillars of sustainability: "economic development, social development, and environmental protection" [51]. This ecosystem must operate in four main domains: socio-cultural, spatial, institutional, and economic. Each domain has its pillars; however, when we look at the economic-domain-emphasizing aspects, such as knowledge, creativity, fostering, innovation, and competitiveness, we see cities being able to generate economic development that is both sustainable and knowledge-based [52,53].

A crucial pillar of this vision is the emphasis on open data. By making this data accessible to a wide range of stakeholders, a stimulus is created for the development of new applications and services aimed at improving the quality of urban life. These innovations can cover areas as diverse as transportation, energy management, public safety, and health [54].

Data management plays a central role in this ecosystem, providing the necessary stimulus to drive innovation [55]. These data, seen as commons or common goods, have immense power in society and can be used to reorganize cities in more efficient and just ways. These commons also include other natural or cultural resources and are fundamental to sustainable development.

Promotion, whether through favorable tax policies, subsidies, or support programs for entrepreneurs, plays a crucial role in the development or transformation of City 4,0. Cities can foster an environment where startups flourish and innovation is valued by encouraging them to generate innovations. This approach does not just benefit companies; it creates a dynamic where all citizens benefit from technological advances and innovative solutions. Especially when fostered by open and big data, the intelligence of the collective is used to contribute and bring invaluable solutions to cities.

Therefore, the union of City 4.0 with knowledge-based collective platform urbanism, and the importance of entrepreneurship and innovation, offer a transformative paradigm

for the future of urban development. These are not just theoretical concepts, but a call to action that demands a radical reimagining of how cities function and meet the needs of their inhabitants. The possibilities are endless and, even in the face of significant challenges, these approaches point towards more resilient, inclusive, and innovative cities.

5. City 4.0's Prominent Themes

When elaborating on City 4.0, it is also important to present the prominent themes this new city conceptualization comprises. Thus, this section concentrates on this issue. In City 4.0, which aims to utilize technological developments and digitalization to transform local public services and local economies to produce sustainable and desired urban, environmental, and societal outcomes for all, the following six themes become prominent—circularity, adaptability, livability, accessibility, authenticity, and responsibility [56]. These interrelated key themes are briefly introduced below and a framework with some of the exemplar approaches to these key themes are graphically presented with some examples in Figure 1.

Figure 1. Framework of City 4.0's prominent themes.

In the core ring of Figure 1 sits City 4.0; the middle-ring contains prominent themes of City 4.0, while the outer-ring includes some project examples for a clearer understanding of each theme. The six themes are concisely explained below.

Circularity: This theme focuses on economic, social, technological, and environmental systems that aim to eliminate waste, maximize the reusing of resources, and contribute to the sustainable development efforts of City 4.0.

Adaptability: This theme focuses on boosting the ability to make necessary adjustments in ecological, social, technological, and economic systems in response to actual or expected climatic stimuli and their effects or impacts on City 4.0.

Livability: This theme focuses on enhancing the conditions of a decent life for all inhabitants of cities, regions, and communities, including their physical and mental wellbeing, in City 4.0.

Accessibility: This theme focuses on informing the practice of making information, activities, opportunities, and environments sensible, meaningful, and equitably usable for as many people as possible in City 4.0.

Authenticity: This theme focuses on forming and maintaining spaces, places, and communities that are genuine and distinctive and contain recognizable social–cultural and natural characteristics and identities in City 4.0.

Responsibility: This theme focuses on informing governance decisions, including in technology adoption and utilization, through ethical, accountable, trustworthy, explainable, and equitable frameworks in City 4.0 [56].

The presence of each of these six prominent themes as successfully applied projects in a city (see the outer ring of Figure 1 for project examples), at scale, will initiate the transformation journey of that locality into a smarter and more sustainable city and will thus pave the way to the emergence of City 4.0.

6. Concluding Remarks: City 4.0's Prominent Research Areas

This communication piece aims to bring clarity to City 4.0, which is seen as the next phase of smart city development, by elaborating on it from the three diverse but interrelated perspectives—namely, the societal, sustainability, and economic lenses or domains (also known as the triple bottom line approach). The piece also highlighted the prominent themes in City 4.0—circularity, adaptability, livability, accessibility, authenticity, and responsibility.

Despite our communication piece shedding some light on the notion of City 4.0, the notion is still in its infancy. We hence call for in-depth research, effective implementation, and thoughtful consideration of the societal, environmental, and economic implications to realize the full potential of City 4.0, while tackling its associated challenges.

Additionally, we advocate and encourage collaboration among academics, governments, communities, business, and industry professionals to ensure that our future cities are smart, inclusive, sustainable, and responsive to the diverse needs of urban populations. A concentrated effort is needed to reach the potential of City 4.0 in shaping the future of our urban centers and to transform the vision of City 4.0 into a tangible reality. This also means fostering global collaboration to address the challenges of urbanization and climate change. As cities continue to evolve and embrace the possibilities of the digital age, City 4.0 represents a promising vision for the future of urban life, one that is smart, sustainable, inclusive, well-governed, and resilient.

Global collaboration for urbanization and climate change is imperative to justify the vision of City 4.0. As urbanization accelerates worldwide, and the impacts of climate change become more pronounced, cities must unite to face common challenges. By fostering global collaboration, cities can share best practices and innovative solutions that transcend geographical boundaries. This collaborative approach enables the exchange of knowledge, experiences, and technological advancements, paving the way for the development of smart, sustainable, and resilient cities. In a world interconnected by shared environmental concerns, collaboration is the most important management tool for City 4.0, allowing cities to collectively navigate the complexities of urban growth and climate resilience.

Furthermore, City 4.0 needs to use collective intelligence to solve existing problems, bringing citizens closer. From this perspective, collaborative intelligence—where humans and AI join forces—is critical [57]. Moreover, data are the new oil and, hence, through open data, City 4.0 can promote entrepreneurship through hackathons, contributing to digital transformation and responsible innovation [58]. Furthermore, cities have the challenge of promoting education and inclusion for this new world—facing many societal, economic,

governance and environmental problems— and, to do so, they need to provide digital network infrastructure and cybersecurity [59,60].

In this communication, we also propose public policy recommendations for achieving City 4.0. From the societal perspective, policies should be centered on safeguarding citizen data and ensuring data privacy, giving different groups of citizens equal access to digital technology and improving public acceptance of City 4.0, especially regarding readiness for digital transformation. From the perspective of the economic lens for City 4.0, it is important that there are regulations for opening up data through public policies, and that these data are clean and clear. As a public policy factor, guaranteeing a quality and secure internet connection is fundamental for achieving City 4.0 status. In a nutshell, urban policies should concentrate on initiating the transformation towards human-centered cities, focusing on social, economic, and environmental aspects, seeking transparency in management and utilizing technology and collective intelligence for city development.

To achieve the ideal state of City 4.0, we hence call for in-depth research, effective implementation, and thoughtful consideration of the societal, environmental, and economic implications in order to realize the full potential of City 4.0 while tackling its associated challenges. In addition, we advocate for and encourage global collaboration among academics, governments, communities, business, and industry professionals to ensure that our future cities are smart, inclusive, sustainable, and responsive to the diverse needs of urban populations.

We also strongly advocate that, with all above-mentioned factors—along with a sound and balanced triple bottom line approach (societal, environmental, and economic) with a focus on the circularity, adaptability, livability, accessibility, authenticity, and responsibility aspects of our cities—City 4.0 (utilizing digitalization as a disruptive force in cities) has the capacity to generate development based on knowledge and sustainability, whilst offering smarter and more sustainable, livable, and prosperous futures. We also believe that the shared ideas in this communication paper will inform researchers, authorities, and urban planners on the raising importance of the City 4.0 notion, and will encourage the uptake of projects concentrating on increasing the circularity, adaptability, livability, accessibility, authenticity, and responsibility of our cities.

Lastly, we conclude this communication piece by advocating for the importance of prospective research on City 4.0, and mapping some of the relevant and important research areas—as shown in Figure 2—that would be of interest to researchers dedicated to investigating sustainable, healthy, and digital transformations and their disruptions in and implications for our cities, communities, industries, and the environment.

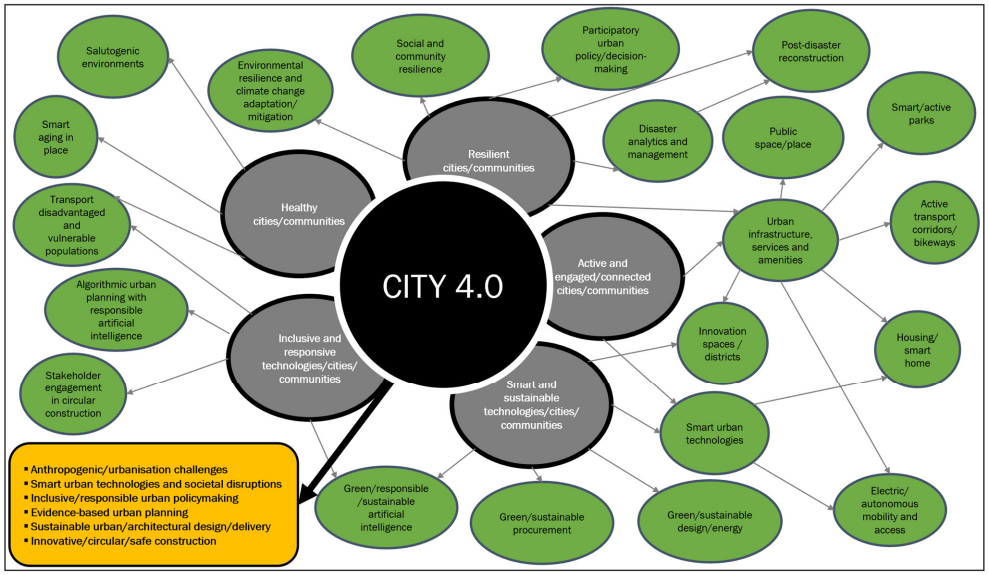

Figure 2. City 4.0's prominent research areas.

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