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Global warming, ageing of population, reduction of energy consumption, immigration flows, optimization of land use, technological innovation

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Contents

REVIEW NOTES

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From smart city to artificial intelligence city. Envisaging the future of urban planning

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Abstract
The paper emphasizes the need to advance both theoretical and methodological understandings to reflect the theoretical-methodological evolution of urban planning, considering the vast potential of Artificial Intelligence (AI). Specifically, the paper aims to chart an innovative path for the discipline of urban planning by adopting a systemic approach to studying urban phenomena and envisioning how the intentional integration of AI can lead to a completely new way of managing urban transformation. The study seeks to provide a fresh perspective on AI's potential impact, especially within fields overseeing urban and territorial changes. It begins with an analysis of the relationship between technological innovation and urban transformation, which is crucial today due to the opportunities AI presents. The paper particularly focuses on the relationships among urban sub-systems, which are essential for city survival. Historically, from the inception of urban planning to the rise of smart cities, the integration of technology and urban environments often lacked a cohesive theoretical framework to guide the deliberate adoption of technological innovations. The primary aim of the paper is to highlight the urgent need to build a theoretical and disciplinary foundation that recognizes AI's creative capacity and effectively utilizes its capabilities to design sustainable future urban configurations in harmony with existing resources.

Keywords
Artificial Intelligence; Urban Planning; Smart City; Complex Systems.

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1. Introduction

There is no doubt that we are witnessing one of the epochal transition moments among those that have thus far shaped the history and evolution of humanity. The relationship between humans and technology is undergoing an acceleration probably never observed in the past. The discovery of the possibility to extend the physical capabilities of human beings through the creation of technical tools - from flint, used to build axes and arrowheads, to silicon for the development of computer microchips (Giovannini, 1984) - now experiences an epochal turning point with the introduction, diffusion, and utilization of Artificial Intelligence (AI). We are likely facing an entropic watershed (Rifkin, 1980) that will determine new organizations and social structures on the planet and new ways of acting and interacting within human settlements where the future of humanity will be decided: the city.

This paper, agreeing on the need to develop theoretical and methodological insights, proposes an innovative interpretation of the role that AI can play, particularly in the disciplines managing urban and territorial transformations. In the past, from the birth of urban planning to the spread of smart cities, the relationship between technology and cities has generally involved the introduction of technologies, more or less advanced, into urban systems but outside a theoretical framework capable of guiding conscious processes of technological innovation adoption. Some scholars, always attentive to the modifications that new technologies often invisibly produce within the city (Balducci, 2023), have initiated interesting reflections on the current technological revolution and the impacts it will have on anthropic contexts. In this crucial condition, it is vital to surpass all previous interpretative models that indicated technology as the foundation of urban configurations; the smart city is giving way to the emergence of a new "system" of the city in which the network, and therefore the production and transmission of information, remain vital for new urban economies. It should also be noted that the term "smart city" has taken on different meanings depending on the various stakeholders involved in urban development processes (Papa et al., 2015). However, with the advent of AI, an innovative processing mode is spreading, whose speeds, potentials, and effects on the city are still unexplored. Starting from the analysis of the relationship between city and technology and adopting a renewed proposition of the holistic-systemic paradigm for interpreting urban and territorial transformations, this paper describes the possibility and necessity of constructing a new dimension of urban planning capable of consciously utilizing the enormous, yet not entirely known, potential of the new artificial reasoner. In particular, it emphasizes the AI's ability to analyze and formalize systemic connections and interactions rapidly. The point on which this contribution intends to prompt reflection within the community of scholars of urban phenomena, in this particular moment of "technological singularity", is the need to define a new dimension of urban planning using approaches well-known in the discipline, such as the systemic one.

2. City and technology: a diachronic literature review

Throughout its evolutionary history, humanity has consistently witnessed the development of technological changes that have impacted its evolution to varying degrees. However, as previously emphasized, we are now facing a groundbreaking shift in the relationship between cities and technology, unprecedented in history. Scientific literature is rich with reflections and in-depth analyses of the relationship between cities and technology, considering the systemic approach as an interpretative reference. The exploration of this theme dates back to the 1960s and 1970s with studies on the network city, initially rooted in a sociological approach (Barnes, 1972). However, applying algebraic analysis methods (Craven & Wellman, 1973) reflected the contemporaneous development of urban modelling and the systemic approach. In Italy, notable reflections on the systemic approach and its adoption for analyzing the relationship between technology and cities can be traced back to the studies of the Turin groups (Bertuglia et al., 1987) and the Neapolitan group led by Corrado Beguinot (1989). The 1990s witnessed an interesting evolution in the international debate, reflected in studies on the informational city (Castells, 1989), proposing a new approach for innovative analysis, methodologies, and research in economic innovation, urban development, and new media. Particularly noteworthy is the fundamental contribution of Graham and Marvin regarding the relationship between telecommunications and cities (Graham & Marvin, 1996). In Italy during the same period, scholars of urban phenomena produced an interesting collection of reflections in 1991 (Gasparini & Guidicini, 1990), emphasizing how a new urban order and structure can be considered the final stage of innovation produced by technology. A significant leap in the literature on the relationship between technological innovation and cities is represented by Bill Mitchell's book "City of Bits," which highlights how the city constructs its structure not based on the distribution and intensity of traditional urban functions but entrusts its survival to the ability to produce, process, and transfer information. Bits represent the new atoms of the urban organism and the basic elements of recombinant architecture (Mitchell, 1995). The 2000s were characterized by the construction of the concept of the smart city, primarily developed and disseminated by major global IT companies, proposing a model of a perfect city through the interconnection facilitated by the Internet of Things (IoT). According to a notable definition, a smart city is one that "makes optimal use of all the interconnected information available today to better understand and control its operations and optimize the use of limited resources" (IBM, n.d.). Despite generalist insights (Woetzel et al., 2018), urban planning theorization has been slow to mature in these years, proposing an effective definition of urban intelligence (Fistola, 2013). The exploration of the city as a complex system also finds a new dimension in the contributions of Michael Batty (Batty, 2009), who introduces reflections on big data, observing a significant shift in the nature of information available regarding events, locations, and timing within cities (Batty, 2013). Similar reflections are formulated in other interesting studies (McGreevy, 2017) and in the definition of the senseable city (Ratti, 2011), which, only a few years later, allows the development of studies on the digital twin as an environment for city management and planning (Ferré-Bigorra et al., 2022) and, more recently, on the city of AI. The relationship between smart cities and AI has been investigated in some interesting studies examining how AI could contribute in various fields of urban activities (Rjab & Mellouli, 2019). Recent studies on the Artificial Intelligent City (AIC) focus on the nature of this new urban structure, starting from the definition that considers the AIC: "a urban community that functions as a solid system of systems, and whose economic, social, environmental, and governmental activities are based on sustainable practices guided by AI technologies, helping us achieve social good and other desired outcomes and futures for all human and non-human beings" (Yigitcanlar et al., 2020). In extreme summary, carrying out a general examination of the literature it is highlighted that the topic has been of interest since 2010 with an explosion of contributions which from 2020 to date exceed 300 articles (Koumetio Tekouabou et al., 2023). What seems relevant to investigate further, and this paper attempts to do so, is the definition of a methodological background that starts from the systemic interpretation of the city. Even in the cited paper, a reference for many subsequent reflections, it is evident how the systemic interpretation is closely linked to the new technological structures of the city. In other terms, what remains to be completed, and this contribution moves in that direction, is an in-depth analysis of the role that AI can concretely play, if properly adopted, in urban planning processes, both in its interpretative role in the systemic approach and in the operational definition and construction of regulatory frameworks for city governance and management.

3. City as a complex system

As briefly mentioned previously, the development of the systemic approach to the study of urban phenomena began in the 1960s. The General System Theory by Ludwig Von Bertalanffy (1968) remains the reference text through which the theory of the urban system was developed. Given that cities are dynamically complex systems, they necessitate a theoretical model to comprehend their temporal evolution, model their complexity, and ascertain their components (Papa et al., 2021). In this way, the study by Sundstrom and Allen (2019) highlighted that complex systems can be dissected into structural and procedural elements across spatial and temporal scales. They proposed an adaptive cycle, based on Holling's (1986) phases: growth, conservation,

release, and reorganization. During the growth phase, resources are utilized, while conservation leads to increased rigidity, potentially resulting in a loss of resilience.
The release phase involves the dissipation of accumulated energy, prompting the need for reorganization.
In the reorganization phase, the system may either maintain its original structure (predictable trajectory) or adopt a wholly different configuration (unpredictable trajectory).
In summary, it is possible to affirm that the systemic approach, also deepened in the study of urban complexity formalized through fractal functions (Batty, 2009), remains, to date, the most capable of explaining the transformation of the urban system and other systems in physical reality (Sanders et al., 1997), for which interactions among parts represent the key to understanding their behaviour (Parisi, 2021). This approach considers the territory as a complex system that evolves autonomously in space and time, and for which technology represents a dynamically powerful catalyst.
The "liquidity" of society (Bauman, 2011) finds in fluid and widespread technology its ideal context, its breeding ground, the most fertile territory for development.

4. City and technology: a new digital revolution

A notable statement by Schumpeter in 1942 reads: "In a free and capitalist society, innovation can impact certain sectors so intensely as to compel the societies within them to evolve, under penalty of extinction" (Schumpeter, 2001). The innovation of technique and technology has always been a determinant in the evolution of humanity. Among the determinants of urban change that characterize many dimensions of the contemporary city, technological change plays a fundamental role in understanding and envisioning future scenarios. The widespread adoption of new technologies in all fields of human activities is substantially influencing the behaviours and usage patterns of the city or its inhabitants. The phenomena of virtualization of activities settled in the territory are gradually altering the functional layout of cities, redefining models of location and distribution of functional weights. Technology has exerted its transformative power on human settlements by acting on production systems and social interactions.
Throughout history, humans have always interacted by exchanging symbolic forms or initiating communicative processes within a shared physical space. Digital technologies have progressively challenged this model, and the spread of multimedia systems has generated new forms of social interaction, gradually transforming the community's use of urban space, as a part of urban planning research foresaw about two decades ago (Fistola, 2003). New communication is slowly, invisibly but probably irreversibly, transforming the primary place of information processing and circulation: the city (Meier, 1962). Attempting an extreme synthesis of the relationship between technology and human activity, one can propose the paradigm of the three S's: Sustain, Support, and Substitution (Fig.1).
Technological advancement has undoubtedly played a decisive role in the progress of human activities. In the first phase, technological innovation sustained humans by opening new dimensions of activity. Subsequently, technological innovation has offered concrete and growing support in many human activities. Currently, also thanks to the advent of AI, human activities are almost entirely carried out by digital agents that tend to replace human action.
The advent of AI, currently declared for use in various human activities, has opened unimaginable scenarios until just a few years ago and is producing a significant acceleration between the S's of the paradigm. In other words, considering the most advanced research, AI facilitates the transition between the last two S's of the paradigm. In a short time, there will be a shift from supporting human activities to almost complete substitution. The comparison between AI and human intelligence, already proposed in interesting and detailed studies, will not be delved into here (Slaughter, 2024).

Fig.1 The three S's paradigm shows the relationship between technological innovation and human activity

AI is currently used in many fields of human activity. Its applications range from identifying new drugs and antibiotics capable of saving human lives (the case of Halicina is emblematic in this sense) to decoding the text of ancient scrolls in Pompeii and identifying dinosaur footprints by palaeontologists with 90% reliability, as happened at Lark Quarry. In the consideration of AI usage, we are currently in the support phase; in other words, humans use the artificial reasoner's rapid similarity consideration and analysis capacity for countless interactions. In general considerations, it is undoubtedly clear that AI's development promises rapid advancements for humanity in many fields, and medical-scientific research is undoubtedly the most interesting. Sequencing the human genome took ten years of research and a total expenditure of five billion dollars. Today, with AI support, it is possible to process a personalized anti-tumor vaccine for a patient in just two months. As in all previous cases of scientific-technological discoveries, the dilemma posed by Oppenheimer arises, stating that technology with enormous potential can be used for good or to support processes of destruction. In this sense, it should be considered that AI has quickly led to the discovery of antibiotics, such as Halicina, capable of resolving severe human conditions.

Through Google Deep Mind's Graph Network for Material Exploration (GNoME), 2.2 million new materials (inorganic crystals) were discovered, among which 380,000 are particularly stable and essential for advanced applications in energy, electronics, and mechanics (Merchant et al., 2023). Finally, thanks to Google Deep Mind and the use of imitative AI, students and professors at Stanford University have developed a robot known as Mobile Aloha, capable of assisting humans in all domestic activities (Zhao et al., 2023). Another interesting aspect of AI lies in its potential as a transformative agent of key systems of human organization (social, economic, etc.), as emphasized by relevant studies on the topic of Transformative Artificial Intelligence (Gruetzemacher & Whittlestone, 2021). On the other hand, it is known that AI has already been employed for military purposes and operations targeting the elimination of human agents and the destruction of infrastructure. It should also be considered that the extreme speed in the generative processes of AI could lead to a dimension of consciousness/sentience, as demonstrated by Google Synthesia's AI (built through LaMDA) and experienced by Lemoine, who subsequently resigned. In this sense, the experience of the AI software AlphaZero is significant. This software, designed to play chess, won in 2018 against the most advanced existing software, executing moves that were not previously recorded in its memory during the learning phase but were autonomously generated to achieve the goal of winning the game (Silver et al., 2018). A new form of partnership between humans and machines is emerging: humans first define a problem or goal for the machine, and then the machine, operating in a domain beyond human reach, identifies the optimal process.

5. AI and Urban System: a new interpretative paradigm

As underlined before, the advent of AI has transformed our perception and interaction with urban spaces, giving rise to the widely recognized concept of AI cities (AIC). These advanced urban settings harness AI technologies to enhance different facets of city living, such as transportation, energy consumption, public safety, and more. In this document, we will delve into a holistic view of AI cities, examining the diverse influence of AI on urban infrastructure, governance, and the overall urban environment. Through a thorough analysis of the intricacies and interconnections within AI city systems, our goal is to achieve a comprehensive understanding of how AI is redesigning the contemporary urban landscape. To understand the role that AI can play in defining a new urban and territorial planning, it is necessary to reconsider the specifics of the systemic approach, briefly outlined in the previous paragraph. The city is a complex system articulated into interacting subsystems. As already explored in other studies (Fistola, 1992), it is possible to schematize this interpretation by considering the elements that constitute the urban system and the active relationships among them (Fig.2).

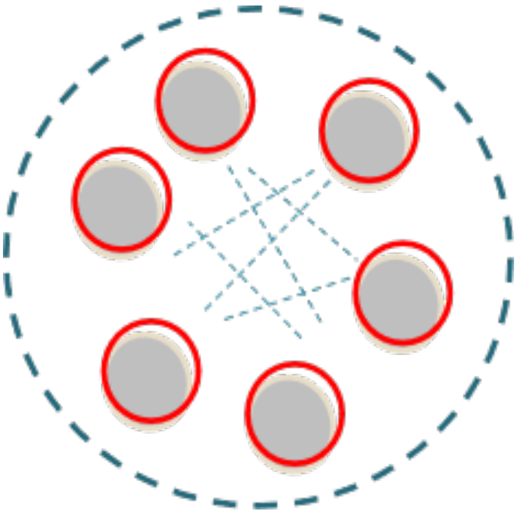

Fig.2 The system in its conceptual representation composed of elements in relation (interaction) with each other

Considering the properties of complex systems, it can be affirmed that the elements themselves constitute subsystems. To construct an effective model of the city, certain subsystems are considered useful for understanding and modelling the behaviour and functioning of the entire system (Fig.3).

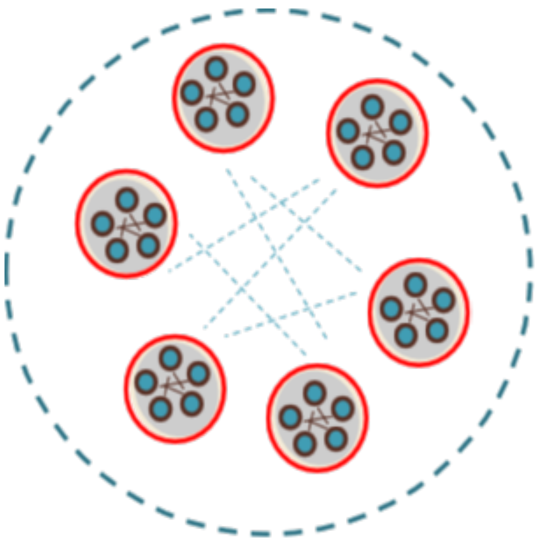

Fig.3 The system in its conceptual representation in which the parts represent subsystems in relation to each other. Each subsystem contains, in turn, other subsystems

In other words, thanks to the systemic approach, it is possible to identify a significant number of component subsystems: the geo-morphological subsystem (constituted by the physical substrate of the territory), the socio-anthropological subsystem (represented by the human component that adapts space and settles activities), the physical subsystem (directly represented by the urban artefact and the material component of the city), and the functional subsystem (consisting of functions performed within anthropic spaces). There is also another subsystem to consider among others, namely the psycho-perceptive subsystem, which considers the mental image that each citizen constructs within themselves through the perception of the space around them (Lynch, 1964). Moving from this approach, it is possible to affirm that the urban subsystem most impacted by IT is currently attributable to the social component of urban settlements. A further insight, which would further complete the reflection, could be formulated by distinguishing the material part of the city from the abstract component or the natural from the artificial. In this regard, interesting contributions have been made with arguments that, based on systemic complexity, come to ontologically distinguish the human artifact within the pre-existing natural environment (Cameli, 2020). The new technologies: widespread, pervasive, invisible, portable, wearable, and soon even "implantable," guide actions, dictate behaviours, direct movements, and characterize relationships. As highlighted by studies conducted by Giorgio Parisi, Nobel Prize winner in Physics 2021, in complex systems, what is crucial to study, formalize, and understand is the structure of relationships (Parisi, 2021). Relationships determine the autonomous and somewhat endogenous evolution of the system that proceeds in space and time. In the case of the urban system, they are fundamental to understanding its evolution and transition (Gargiulo & Papa, 2021).

Urban planning is a discipline of foresight (Carpentieri et al., 2023); it envisions the arrangement of human settlements in the future, seeking to understand how subsystems will evolve due to the relationships that activate among them. In this sense, AI can play a crucial role if it is possible to build an innovative theoretical-disciplinary layout that adopts and guides procedures and actions.

Through further exploration of urban complexity, one can envision an evolution of the proposed conceptual framework for the interpretation of modern metropolitan settlements. It is indeed possible to imagine that the systemic articulation does not lie on a single plane, but the multiplicity of urban subsystems suggests a multi-dimensional organization. In other words, in a preliminary hypothesis, one can think of a representation containing not a single systemic plane but a star of planes in space (Fig.4).

Each of the planes contains a system with its subsystems connected through the axis of the star. In this topological space, interactions between different systems take place.

Following this conceptual development and iterating the systemic planes n times, it is also possible to arrive at a deeper understanding.

This reflection is based on the following fundamental considerations:

- the star of "n" planes defines a three-dimensional topological space;
- this space with indefinite boundaries is of a fuzzy type, given that the city and the territory are open systems;
- the structure of interactions is articulated among all parts of the systems.

Remaining within a conceptual prefiguration, it is possible to imagine the existence of a "relational fluid" in which the different systemic elements are immersed (Fig.5) and that extends indefinitely.

This conceptualization allows us to recognize, as stated, the importance of inter-systemic relationships declared in the holistic-systemic approach with the formula: "The whole is not equal to the sum of the parts".

The limitation that has always characterized the systemic approach in all its fields of application (from neurology to particle physics to the study of the universe and beyond) is attributable to the difficulty of considering and classifying the relationships activated among the parts of the system.

Today, thanks to AI it's possible to understand the composition of the relational fluid by analyzing all the relationships inside it.

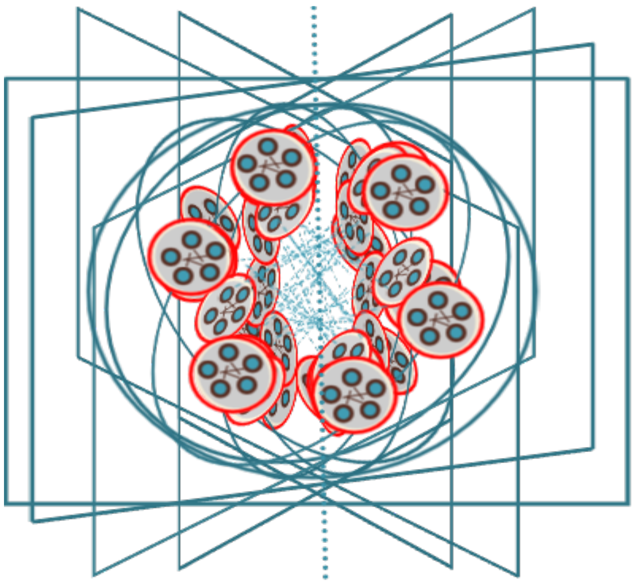

Fig.4 The star of systemic planes with the axis of connection for relationships

This is what has happened in all the cases mentioned earlier (the discovery of new antibiotics or protein structures, etc.) to analyze and classify, with very high speed, all relationships and their potential effects on systemic and sub-systemic components.

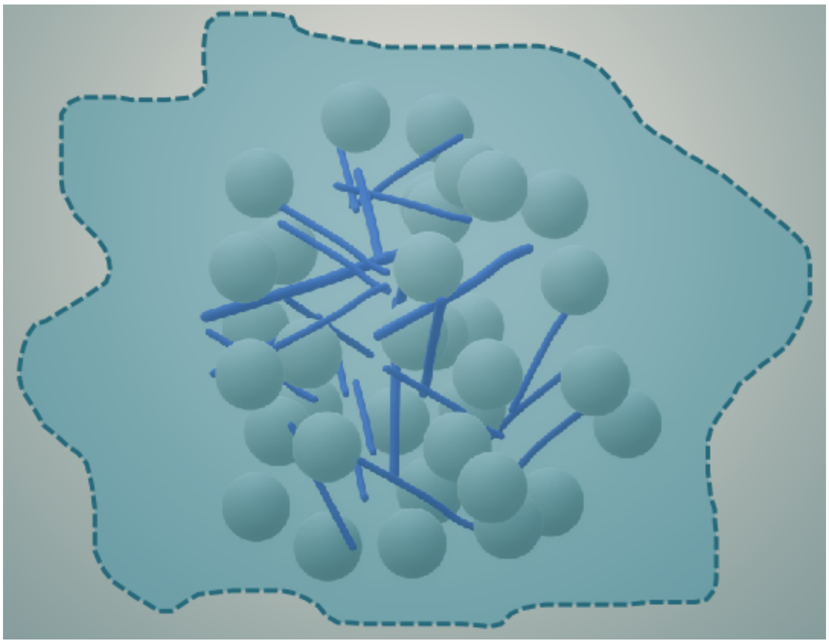

Fig.5 Conceptual image of the system and sub-systems immersed in the communicational fluid

This capability would allow for the rapid assessment of the best actions to activate in the urban system to properly govern its transformation. In an era of resource scarcity and necessary ecological transition, the preservation of natural resources and the appropriate consideration of ecosystem services (Fistola, 2023) become extremely relevant in the urban planning process, which must be innovated by consciously adopting technological innovation. In this sense, the overcoming of the smart city is configured, and a new urban smartness is envisioned characterized by effective collaboration between humans and machines.

6. Discussion and future developments

The proposal to consider the city as a dynamically complex system interpretable through the systemic approach (Fistola & La Rocca, 2013), which may seem outdated in its original formulation, can still hold scientific relevance given the potential offered by technological innovation, with AI being its most advanced expression today. This methodological proposal implies a redefinition of theories and approaches that have characterized urban and territorial transformation governance since the post-war period. It is no longer possible to ignore or simply add technology to the city, as seen in some cases of constructing smart cities. In particular, with smart cities, largely attributed to the desire of major IT companies to commercialize devices and systems capable of interacting in the IoT, urban theorists had to subsequently construct a disciplinary path that took into account the technology already widespread in the territory and society. In other words, scholars of urban phenomena have always had to chase technological advancements and try to construct, ex-post, a theoretical-disciplinary framework that encompasses their transformations. Focusing solely on the technological dimension, urban areas already have "urban control rooms" processing real-time data from sensors within the city and various IoT devices, constituting a sort of digital twin. Within such systems, AI algorithms can be implemented to manage and resolve anomalous or crises (Kissinger et al., 2023). An example of great interest in this regard is the Snap4City platform (www.snap4city.org) currently in use in many urban areas. These systems could represent elements of the transition from the smart city to the Artificial Intelligent City and need to be considered in defining new theoretical paths for governing urban and territorial transformations. Moving beyond the purely technological perspective, there is now a need to build a theoretical-disciplinary background that, considering the generative potential of AI, appropriately adopts its capabilities to envision sustainable future configurations of the urban system compatible with available resources (Sanjo, 2023). For smaller urban systems, a conceptual prefiguration could involve AI automatically proposing territorial zoning and regulatory frameworks based on information, data, and examples of cyber tools for territorial governance with similarities to the specific urban settlement. While such automatic propositions have the limits of imitative construction, they might offer a possible urban planning for the interest of local administrators who need territorial governance tools within their administrative period. This type of AI usage could lead to dangerous trends in urban and territorial transformations. However, this consideration deserves specific exploration, which is beyond the scope of this paper but certainly subject to future developments.

7. Conclusions

The debate on the role of AI in urban planning has already produced interesting insights (Sanchez et al., 2023). However, this paper emphasizes the need to change the perspective regarding the significant change that AI is producing in every aspect of human activity. In studying urban phenomena for developing actions in territorial transformation governance, it is necessary to adopt AI in interpreting the transformations of the city system. This is possible today thanks to the potential of AI to formalize the structure of systemic relationships and enable the prefiguration of future states of the urban system. We are currently witnessing a transformation in which entire sectors are incorporated into AI-assisted processes, making it sometimes difficult to distinguish between purely human decisions, purely artificial decisions, or the result of collaboration between humans and AI. Today, the digital revolution cannot be considered solely a "technical" revolution; it must be placed among the "ethical" revolutions capable of modifying the actions and interactions of individuals within anthropized contexts. This reflection has long been shared among scholars who believe that technological innovation represents an evolutionary determinant capable of "guiding" anthropic systems and their components (social, functional, economic, etc.) toward new evolutionary configurations. The transformation is no longer just the adoption of advanced technical tools for service production, but it is in the producers themselves modifying their behaviours due to the introduction of new technological dimensions capable of reconfiguring citizens' relational systems and, as mentioned, their way of acting and interacting in the city. As recently noted, the revolution is not only "digital" but probably "mental". AI, fueled by new algorithms and increasingly powerful and inexpensive computing power, is spreading almost everywhere. The advent of AI will change humanity's conception of reality and, therefore, of itself. We are moving towards great enterprises, but these enterprises should lead us to a more general philosophical reflection. This paper attempts to propose a different way of looking at technological innovation in the field of urban planning and to issue a warning to scholars and practitioners. With AI, we will not see what happened in the past when various technological devices were used to support planning actions, but we will be able to act to prefigure a new background panorama, the contours of which need to be outlined today. “What we need now [...] is a real push for demonstrating how AI can be used in urban analysis and city science, in urban planning and design. In this quest, we need a concerted effort to explore the limits of AI in our understanding of cities, in how we can invent new ways of automating functions within cities, and within the wider context of their urban planning” (Batty, 2018).

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Image Sources

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