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DEBATES AND INTERVENTIONS

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Why does urban Artificial Intelligence (AI) matter for urban studies? Developing research directions in urban AI research

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ABSTRACT

New digital technologies and systems are being extensively applied in urban contexts. These technologies and systems include algorithms, robotics, drones, Autonomous Vehicles (AVs) and autonomous systems that can collectively be labelled as Artificial Intelligence (AI). Critical debates have recognized that these various forms of AI do not merely layer onto existing urban infrastructures, forms of management and practices of everyday life. Instead, they have social and material power: they perform work, anticipate and assess risks and opportunities, are aberrant or glitchy, cause accidents, and make new demands on humans as well as the design of cities. And yet, urban scholars have only recently started to engage with research on urban AI and to begin articulating research directions for urban development beyond the current focus on smart cities. To enhance this engagement, this intervention explores three sets of questions: what is distinctive about this novel way of thinking about and doing cities; what are the emerging mutual interdependencies and interrelations between AI and their urban contexts; and what are the consequent challenges and opportunities for urban governance. In closing, we outline research directions shaped around new research questions raised by the emergence of urban AI.

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Introduction: AI goes urban

In this paper, we extend current debates around urban Artificial Intelligence (hereafter "urban AI") by outlining new modes of framing or conceptualizing urban AI, understanding its trajectory, and proposing avenues for steering its development. We do this in three ways: first, by defining how thinking about cities through an urban AI

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lens is distinctive. Second, by grounding the interrelations and genealogies between AI and the urban context. Third, the paper outlines key governance challenges, including potentials and pitfalls, integration, and limits to urban AI governance, as well as opportunities for thinking about progressive urban AI. The paper builds on recent work (Cugurullo et al., 2023a) by a collective of urban geographers and urban scholars engaged in researching the ever-growing links between AI, automation, robotics, smart and platform urbanism and the city.

AI is no longer confined to industrial applications but is also rapidly emerging in urban environments (Del Casino, 2016). The rise of urban AI involves a range of technologies and processes including AI systems themselves, robotics (Sumartojo et al., 2021), machine and deep learning applications (Ullah et al., 2020). Today these technologies have both an obvious and opaque presence in cities. The most prevalent applications of urban AI today include urban software agents, city brains (Zhang et al., 2019), urban robots, and Autonomous Vehicles (AVs) (Cugurullo, 2021).

More broadly, urban AI encapsulates both the material manifestation of these systems and approaches in cities and their infrastructures as well as their less immediately obvious (if no less substantive) effects on urban design, planning and governance. Urban AI is featured in experiments, demonstrations, products and knowledge networks associated with these technologies, from the integration of AI into newly planned cities in projects such as Saudi Arabia's NEOM (Hassan, 2020), to the use of urban AI in COVID-19 biosecurity governance in China and elsewhere (Chen et al., 2020; McGuirk et al., 2021), to the use of myriad AI-based technologies and systems in urban governance, consumption and other aspects of city life (Caprotti & Liu, 2022). In short, urban AI serves as a new, potentially radical transformation of smart cities and the digitalization of the built environment, fueled by AI's capacity for autonomous and anticipatory action, and for its decision-making and calculative logics that extend beyond (and even outside) the human repertoire. Unlike the vision of the smart city as a steerable, ultimately integrated and efficient machine, the AI city is more unpredictable, adaptive and subject to emergent logics.

Although many of the spaces where urban AI can be found are already constituted by entanglements of socio-technical relations, given its capability for autonomy urban AI holds considerable potential to reconstruct or reshape these relations (While et al., 2021). Additionally, it poses complex and novel challenges to urban governance. In the case of the construction of AI-based urban digital twins, for example, Deng et al. (2021, p. 132) have shown how the digital twin aims to be a "self-perceiving, self-determining, self-organizing, self-executing, and adaptive platform for urban operation and maintenance." And yet, as Frank et al. (2018) have shown, the impacts of automation and AI on cities are likely to be diverse, multifaceted, and refracted through scale, location and other factors.

In this debate paper, we interpret urban AI as composed of three sets of interrelated more-than-human capacities. First is the sensemaking capacities that involve "artifacts operating in cities, which are capable of acquiring and making sense of information on the surrounding urban environment" (Chen et al., 2020, p. 3), and to use this acquired information to act in a rational manner, along the lines of pre-defined aims, in highly dynamic urban settings where information may be missing, incomplete, or a state of flux. Second is how the robotization of urban services has the capacity to replace and

augment existing activities by enabling tasks that are too dangerous, repetitive or monotonous for humans, or require strength, precision, replicability and reliability beyond human capacity (Macrorie et al., 2021). Third is the capability of urban AI to replace, reduce, supplement, enhance, extend and/or simplify human calculation and/or control in the management of systems that underpin urban functionality (Macrorie et al., 2021).

Framing urban AI

The past two decades have seen rapidly developing connections between smart technologies, digital governance and associated processes. This has included the emergence of Big Data analytics, the Internet of Things (IoT), sensor systems and 5G mobile networks, among others (Golubchikov & Thornbush, 2020). It is tempting to frame urban AI as the inevitable successor to smart cities in the technological evolution of cities. Yet in contrast to multiple existing visions of data-optimised smart cities (see the typology in Caprotti et al., 2022), there is no coherent vision for urban AI. This is not just because AI is in its infancy and its broader implications are still unfolding, but crucially because the change processes that are implicated in urban AI are markedly different from those of smart cities. This is shown by recent research (Cugurullo et al., 2023b) that has charted how smart urbanism is defined by a near-real-time temporal horizon, while AI urbanism is generally concerned with the future. Furthermore, where smart city visions envisage creating a seamless, digitally connected whole out of the fragmented analogue city (Caprotti et al., 2022; Karvonen et al., 2019), AI is about creating autonomous flows and circulations that are in constant flux and recalibration, but that are not abstract, being deeply materially embedded in the urban (Cugurullo et al., 2023b).

Building on this, we extend the argument that the emergent and undefined character of urban AI differentiates it from the smart city. In particular, the end state of urban AI is always in the making: urban AI aligns with change processes in the actually existing city that involve incremental and iterative adjustments, piecemeal change and feedback loops. Machinic metaphors associated with the smart city (emphasizing predictability, optimization, control) give way to organic metaphors of the AI city that champion uncertainty, unpredictability, constant change and recalibration. We argue that this involves a shift from control to autonomy, and from optimization to emergence.

Urban AI narratives also differ from those of smart cities because they often lack distinct, observable spatialities. Smart cities frequently focus on digitalizing existing infrastructure networks, as is the case with smart city projects focusing on specific urban places, sites and buildings (Caprotti, 2019; Caprotti & Cowley, 2019; Cugurullo, 2018; Valdez et al., 2018) Meanwhile, more-than-human intelligences tend to be virtual and exist "in the cloud". Thus, there is a need to ground and embed AI in spatial human and material contexts (Kinsley, 2014), as in instances where automation has clear spatial, urban effects, such as with automated mortgage approvals (Perry & Martin, 2022). An emphasis on the place-specific characteristics and impacts of urban AI can help to draw out its multifaceted political, social and cultural implications. Seen this

way, cities provide ways to ground and spatialize AI both materially and cognitively in broader processes of socio-technical development.

AI and the city/the city and AI

Both smart urbanism and urban AI share aspects of techno-utopian thinking focused on the notion of (smart or AI) technologies' potential to deliver efficiencies through frictionless and glitch-free integration with/of multiple aspects of urban life. Indeed, every facet of contemporary urban life is mediated through technicities (infrastructures, protocols, standards, apps, platforms), which shape how entities (both human and non-human) are perceived and become available as objects that can be controlled and exploited (Ash, 2012). In this vein, proponents of urban AI assert that self-governing systems can eradicate error-prone, fallible humans from decision-making processes and the control of infrastructures, ambient environments, vehicles and even entire ecosystems (Li et al., 2022). This narrative of safe, infallible autonomous systems (embodied in drones, robots, AVs, home automation, automated ecologies, and the like) promises liberation from the grind of routine tasks, human error, congestion, human exposure to unsafe environments, and taxing optimization of infrastructure networks as well as providing capacity to repair damaged ecosystems (Lockhart & Marvin, 2020).

Without a reflexive understanding of conceptual-historical contexts, however, perspectives on urban AI risk reproducing narratives that celebrate techno-utopian "novelty" and present urban AI as "flat", purely technical and in some cases exhibiting agency far removed from human intention (Kinsley, 2015). It is key to remain sensitive to the fact that "AI has a genealogy" (Cugurullo, 2020, np). Conceptually, the promise of AI to provide real-time and predictive urban governance, consumption and efficiency, and its security, injustice- and inequality-related risks are evolutions of the Janus-faced character of urban development in modernity (Kaika & Swyngedouw, 2000). Therefore, analysis of urban AI needs to be conceptually rooted in the broad sweep of development of the link between the city and technology, and in the defining elements of what Ellul (1967) called the emerging society of technique, namely rationality, artificiality, automatism, self-augmentation, monism, universalism and autonomy. In this vein, for example, AI research increasingly focuses on understanding human-machine interactions as socio-technical practices that need to be interrogated and delineated to reveal the constitution of AI systems in particular assemblages (Shults, 2022). Cities, in particular, are increasingly seen as sites where multiple forms of (human, artificial, non-human) intelligence(s) are shaping the urban.

We identify three interfaces linking AI and city, and argue that it is crucial to frame them within the trajectory of modernity: this will help urban scholars understand *where the AI city is going*. The first interface we outline focuses on the ***distinctiveness of AI systems*****:** we build here on research (Marvin et al., 2022) highlighting the ways in which AI is integrated into an already highly technicised urban context involving technical systems that predate AI. While smart cities research has attended carefully to how smart technologies are developed and operationalized in place (Dowling et al., 2021), a key question for research into AI urbanism is to what extent and how the city itself (as a highly complex pre-existing sociotechnical system) changes and co-constitutes AI. While urban AI applications build on the data structures and computational

systems of digital and smart technologies, they also extend these in novel ways through new enhanced functional capacities (Barns, 2021). Central to this is the ability to generate new ways of knowing the urban and to provide the capacity for enabling machine-mediated action in urban life. Two dimensions of this newly enhanced capacity require further engagement; first, the ways in which urban AI enables modes of automated decision-making that exceed the cognitive capacity of humans and, second, how urban AI enables material and physical action(s) through AVs, drones, delivery robots, and the repair of infrastructure.

The second interface addresses the need to understand the highly ***contingent and specific genealogies of AI*** before they are transmuted into urban contexts. Research has shown how promulgators of the smart and platform city primarily refer to corporate visions to illustrate how digital systems can integrate the multifaceted aspects of city life (Caprotti et al., 2022; Söderström et al., 2014). In contrast, AI has more diverse origins beyond the computational sector, including advanced manufacturing, automated logistics, automation of aviation, military and defence robotics, and the like (Crawford, 2021). A key task for urbanists is to unpack the ways in which operational logics, rationalities and modes of organization in existing AI applications might inform urban development. These AI histories are critically important to reveal the controversies, glitches and tensions associated with the use of AI systems prior to their integration into the urban domain.

The third interface focuses on how ***AI works through the urban context***. While smart city research has chiefly engaged with smart technologies layered onto the city as solutions to perceived urban inefficiencies, research into AI urbanism needs to engage with how the materiality of the city is groomed to integrate AI systems. Developers of autonomous systems search for techniques to "simplify" and "smooth out" the urban social and material milieu to align with the presumptions and operational requirements of autonomous systems (Gaio & Cugurullo, 2022). For example, the unpredictable behaviour of pedestrians and the ambiguity of "edges" in the roadway are seen as barriers to be corrected to optimize AI system performance. The challenge here is to unpack the social and material implications of re-ordering existing environments and designing new cities to facilitate autonomy.

Governing urban AI

The three interfaces of urban AI described above all point to challenges for urban governance that extend far beyond those of smart city governance. In the following paragraphs, we draw out four key governance challenges to urban AI.

First, what are the potentials and pitfalls of AIs' capacities to be active (non-human) agents that govern urban processes? Specific attention is warranted to the important governance implications raised by the ability of urban AI to "think" and the (freighted) promise of autonomy that suggests the capacity to restructure the logics, rhythms and materialities of the urban (Marvin et al., 2022). Initially, AI technologies used to support and extend urban decision-making capacities have raised questions about technology ownership and related opportunities for increased influence by the private sector in urban governance processes. More fundamental, though, are issues raised by AIs' potential to introduce more-than-human decision-making processes that insert a

wholly new agent into urban governance with unknown consequences. Despite the weight of these questions, AI has emerged in what Hajer (2003) calls an "institutional void", surrounded by uncertainties not just about the effects of technology (Collingridge, 1980) but also the object of governance itself (Stilgoe, 2018).

Second, how can the iterative integration of AI with urban social and material landscapes be governed? Urban AI is characterized by ***permanent iteration***, including beta-testing, change and development *in situ*, in the context of shifting yet situated socio-technical entanglements. While hardware represents a finished product that can be regulated and governed, urban AI and its underlying software are constantly changing, resulting in continually evolving human-tech interactions in real time (Stilgoe, 2018). A central question, then, is what does governance look like in this continuously shifting landscape? In 2018, Batty insisted that now is the time to "tame" AI by introducing regulatory structures to channel and govern its emergent character (Batty, 2018). This assumes that conventional mechanisms and processes of governance are up to the task of harnessing AI. Indeed, "[w]e have yet to dream up new ways of creating policies that link humans and non-humans within a city that could become 'smart' in a much more literal sense than is often imagined" (Picon, 2018, p. 274). How do we compose and enact governance capacity when the ground is unsettled and will not settle, and where AI can generate rules and protocols based on unknown (to most) and non-apprehendable logics? Does this point towards modes of continuous governance experimentation (Karvonen, 2018), and if so, how might the associated risks be identified and mitigated?

Third, what are the ***limits to governing urban AI as a collection of discrete entities***? Although many urban socio-technical entanglements in which AIs are embedded are labelled autonomous, AIs' connections to wider systems and networks mean they are parts of these systems and are dependent upon them. This is exemplified in AVs (Stilgoe & Cohen, 2021) as well as robotic and autonomous systems (Macrorie et al., 2021). However, it is key to remain sensitive to the fact that "AI has a genealogy" (Cugurullo, 2020, np). Thus, the challenge is not only to govern AI objects and agents, but also about related scaled-up infrastructural systems that cohere within and beyond the city and that transform them, even as individuals may choose not to engage with specific AI modalities. Thus, while we need to engage with the specificities of governing distinct incarnations of urban AI, we must also: look beyond these to think of governing the "AI city", where AI is understood as a "distributed function of the material world" (Bratton, 2021, p. 1308). We also need to consider the embeddedness of AI systems in wider sets of political-economic relations and structures where urban AI produces a built environment that is fundamentally different from the contemporary city.

Fourth, if urban AIs are being crafted in a capitalist context of private ownership, commodification and profit-orientation, are there opportunities to develop other ***progressive urban intelligences*** (Mattern, 2021) and if so, how might this be advanced through urban governance? This might emerge from the urban as a site of political authority or as a concentrated socio-material node of urban AI applications that co-constitute AI's emergent properties. If the urban is the material context in which AI operations cohere in various sectors including housing, transport, and policing, how can urban governance capacities (in all their forms) go beyond simple regulating of urban AI's outcomes to steer its transformative capacities towards socially positive

ends and to enhance the public good? This will require the opening up of AI and associated entanglements to collaborative intervention, to shape the socio-technical pathways introduced by urban AI, and to enhance city life and nurture the qualities we may seek there.

All four critical questions point to the politics of AI and, specifically, to the capacity to socialize and direct AI to enhance the public good. This demands more attention to insights from human–computer interaction and collaborative design, as well as the rejection of naive presumptions that integrating AI merely involves replacing a person with a computer (Stilgoe, 2018). At the very least, it will involve a careful examination of how AI reconstructs interfaces of human-machine relations (Hookway, 2014) and thus how subjectivities and power geometries which are recreated through relations of exteriority and interiority are formed through these. The emergence of new subjectivities and power geometries will inevitably lead to the reconstruction of spaces (and existing notions of, for example, home), and perhaps more generally, urban experiences. Seen in this way, urban AI is simultaneously a form of politics and regulation in and of itself as well as a focal point for policy and design interventions.

Practically speaking, to open up the design of urban AI to a broader actor constituency, it must be rendered visible. Currently, AIs are situated in urban socio-technical entanglements but given their systemic nature, they are often difficult to pin down. The *outcomes* of urban AI tend to be far easier to locate, but the object of design, the socio-technical interfaces comprising actors and relations, is far less so. At the very least a conceptual framework and language is needed to materialize and situate urban AI and to provide a basis for discussion and design interventions to govern it.

Developing research directions in urban AI research

In addition to subjecting autonomous AI systems to wider societal debate, critical research is needed to understand the emerging urban implications of AI (Graham & Marvin, 2022). Novel AI systems are layered on the sediments of traditional smart cities, but the emergence of urban AI is not linear or predictable because of the unpredictability of what are often opaque non-human intelligences. This will take urban researchers into new domains that extend far beyond those already traversed by smart city researchers. In this epistemological context, the conceptual apparatus developed for researching smart cities needs to be leveraged but also augmented with new capacities as outlined in the following paragraphs.

As discussed in the previous sections, the introduction of AI into urban environments leaves behind logics of predictability, optimization and control to embrace unpredictability, change and recalibrations with an undefined and emergent character. Consequently, one central task for urban AI researchers will *be to investigate the extent to which urban AI produces emergent properties*, and to characterize how the new and unanticipated forms of urban life and social organization. This calls for a double inquiry into the potential urban futures that AI is shaping, and the underpinning visions that inform its implementation. We noted the connections between urban AI and centuries-old visions of modernity, but the spectrum of narratives at play goes well beyond urban planning and the rational rollout of large technical systems. AI developers and entrepreneurs such as Elon Musk often quote science fiction writers such as Isaac Asimov and William

Gibson to justify the rationale for a particular AI vision. Meanwhile, current AI technologies are producing new imaginaries, expectations and politics that are eclipsing longstanding narratives of progress and development (Bareis & Katzenbach, 2022).

Storytelling can be understood as a site of political struggle where urban futures can be impactfully articulated (Joss et al., 2017; Söderström et al., 2014). Urban AI researchers, therefore, need to disentangle this maelstrom of ideals, where the boundaries between fiction and non-fiction blur in unpredictable ways. The mutually constitutive relation of cities and artificial intelligences, as well as the emergent properties that arise from the resulting constellations, can be usefully studied in terms of the three interfaces discussed earlier in this article and revisited in this section – namely, the interfaces between AI and already highly technicised urban contexts; the interfaces between AI and its multiple genealogies, and the interfaces among AI, urban space, form and materiality.

As researchers investigate the interface between AI and pre-existing, highly technicised and increasingly "smart" contexts, the introduction of non-human agencies will be one key differentiator between the smart city and the AI city. Consequently, one pressing task associated with the study of this interface will be the *close scrutiny of artificial and hybrid forms of agency that govern urban AI*. It is necessary to investigate how urban AI (re)configures boundaries between human and machine decision-making and how this (re)shapes urban fabrics and urban governance regimes (Macrorie et al., 2021) while giving rise to new hybrid and cybernetic forms of sociality and civic engagement (Rose, 2020). Urban AI must avoid triggering damaging socio-environmental disruptions and instead be steered towards socially beneficial ends. Such interventions are unlikely to be realized if urban AI is framed as infallible, rational and apolitical, or if machine learning processes are allowed to establish their own logic and course of action without human oversight and control. Therefore, researching urban AI implies unpacking hitherto obscure algorithmic logics in an attempt to expose their flaws and then rectify them through collective political initiatives. Researchers must approach urban AI as inherently *political* and reveal the politics and social biases that are inadvertently or deliberately embedded into these sociotechnical devices.

The inherently political nature of urban AI draws attention to the second interface of mediating between AI and the urban, including its practices as well as its forms and materialities. A pressing task for urban AI researchers is to *geographically locate the spaces of AI and to map out its sphere of influence and the shifting power geometries that non-human agencies introduce across urban domains and areas*. Given the multidimensional character of urban AI as a technology that operates at the intersection of material and virtual spaces (see McCarroll & Cugurullo, 2022), the conceptual and methodological tools of digital geography will be vital to this task. However, they are insufficient by themselves as the diverse urban artefacts in which AI is embodied blur the boundaries between the digital and the material. Many of these occupy volumetric space and can be followed and analyzed. Others are distributed, invisible, capable of sensing and acting from a distance and thus appearing to be everywhere and yet nowhere (Cugurullo, 2020; Lynch & Del Casino, 2020). Their multifaceted presence (embodied, distributed, invisible or otherwise) may extend and automate existing human agencies while simultaneously introducing opaque non-human agencies into urban constellations. AI has the potential to permeate and reconfigure urban spaces in ways that replicate and amplify existing

socio-spatial inequalities, segregations and exclusions, but it can also create opportunities for more inclusive, socially-just and sustainable cities (Macrorie et al., 2021). Critical urban scholars are ideally positioned to shed light on the new socio-spatial relations of production and consumption enabled by AI, and on the emerging human-machine relations fostered by urban AI (Bissell & Del Casino, 2017).

Finally, as researchers investigate the interface between AI and its multiple genealogies, a pressing task is to *develop a common vocabulary to cogently discuss the presence of AI in and its impact upon cities*. Despite important recent contributions, the meaning of terms such as *autonomous*, *sentient*, *intelligent* and *emergent* remains undertheorized and thus ambiguous (Cugurullo, 2020; Lynch & Del Casino, 2020). Concepts and terminologies about urban AI would benefit from more rigorous grounding in the field of AI and cognate disciplines interested in broader questions of intelligence, including philosophy, theology, neuroscience, psychology and linguistics. Importantly, conceptual tools developed to study human intelligence need to be expanded to investigate more-than-human forms of intelligence, consciousness and cognition. This includes, for example, hive-minds and multiple AIs inhabiting urban spaces and interfacing them with human minds in augmented realities where *artificial* and *human* intelligences collide in new and confounding ways.

Conclusions

Artificial intelligence is increasingly impacting urban development processes through systems such as autonomous vehicles, city brains, urban software agents and robots. The emergent nature of urban AI raises multiple questions about autonomy, intelligence and the development of new, upcoming urban dynamics (Luusua et al., 2022). We have outlined how urban AI represents a distinct break from the smart cities agenda and identified a set of tasks for urban researchers to interrogate (and hopefully influence) the trajectory of urban AI in the coming years.

Critical inquiries into urban AI need to recognize that the increasing influence of the digital on cities does not necessarily lend itself to inevitable outcomes, but is also an opportunity to produce a range of urban futures. Ultimately, debates about urban AI need to recognize the inherently political implications of integrating the digital with urban built environments, economies and everyday lives. It is key to unpack, interrogate, and steer the novel, emergent properties of urban AI. The coming decades will be a critical period of rollout for urban AI and all stakeholders need to be involved to ensure that these technologies support emancipatory, just and equitable futures for all.

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