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From the "smart city" to the "smart metropolis"? Building resilience in the urban periphery

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Abstract

The "smart city" has risen to global prominence over the past two decades as an urban planning and development strategy. As a broad but contested toolkit of technological services and policy interventions aimed at improving the efficacy and efficiency of urban systems, the "smart city" is subject to several pressing critiques. This paper acknowledges these concerns, but recognizes the potential of "urban intelligence" to enhance the resiliency of metropolitan areas. As such, we focus on an under-researched dimension of smart city urbanism: its application in peripheral urban areas. The paper introduces a threefold typology of: (a) geographic (spatial); (b) hard (material); and (c) soft (social) urban peripherality. Second, it reviews the concept of urban resilience and considers how its central characteristics can inform the objectives and implementation of "smart city" infrastructures and planning. Six European smart city plans are assessed via a qualitative content analysis, to identify the target of smart city actions; the characteristics of urban resilience mobilized; and the spatial focus of planned interventions. The comparative analysis reveals a variegated set of smart-city approaches. Notably, "smart" actions aimed at enhancing social innovation are the most common type of intervention, while overall there remains a strong tendency for smart urbanism to focus on the urban core. We conclude by calling for a research agenda addressing smartness in, of, and for, peripheral urban spaces and communities.

Keywords

Comparative urbanism, peripheral urbanization, smart urbanism, urban infrastructure, urban and spatial planning

Introduction

Over the past two decades, "smart-" and "intelligent cities" have risen to prominence as a technological and policy fix for the current (and future) challenges of urban sustainability (Komninos, 2015). Forged at

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the intersection of urban development, economic growth, and urban technology, "smart" urbanism has travelled the globe as a "fast policy" planning paradigm (Angelidou, 2015; Calzada, 2017; Peck and Theodore, 2015). Cities looking to catalyze urban (re)development and enhance their economic competitiveness have readily embraced "smart" urban technologies and techniques of data-driven governance. Across Europe, for example, over 240 cities with populations of over 100,000 are now pursuing smart policy initiatives (Euractiv, 2017).

Despite this pervasiveness, the notion of the "smart city" encompasses a broad and loosely defined toolkit of technological "solutions" and policy interventions aimed at: (a) implementing urban technologies to monitor urban systems and improve their efficacy through real-time monitoring and "big data" analytics; and (b) urban development and capacity-building through the generation of technology-enabled human capital. This definitional ambiguity means that the "smart city" not only presents a "seductive and normative vision of the future" (Luque-Ayala and Marvin, 2015: 2105), but remains subject to on-going debate regarding the composition of "actually existing" urban intelligence (Albino et al., 2015; Shelton et al., 2015). A substantive body of scholarship further critiques the problematic relationship between technology-driven urbanism and democratic accountability, social inclusion, and environmental sustainability, particularly given the role of global technology companies (IBM, Cisco, etc.) in producing a market for pre-packaged smart-city services (e.g. Trivellato, 2017; Viitanen and Kingston, 2014; Wiig, 2015). Recent critical discussions of smart urbanism point to the need for more detailed theoretical and empirical research on the socio-technical and political implications, and transformative potential, of the smart city's proliferation (see Marvin et al., 2016).

In this paper, we acknowledge and seek to build upon this critical literature by focusing on what we see as an under-researched dimension of smart-city practice: the capacity of smart urbanism to enhance the resilience of metropolitan peripheries; the dynamic and often chaotically unfolding landscapes beyond points of urban centrality. The rapid and ongoing urbanization of the planet presents important challenges and significant opportunities for urban policy and planning; not only regarding what policy and technical interventions are most appropriate to address the demands of our "urban century," but where in (post-)metropolitan space they can be most effectively implemented. We are well aware of the mantra that more people than ever are living in towns and cities (United Nations, 2014). Yet most of these new urban inhabitants will not reside in "the city" as traditionally understood; they will occupy the peripheries of urban society—from the expanding urban agglomerations of Europe and North America, to the megacities of the Global South—inhabiting and remaking them in spatial and social terms (Keil, 2017). As suburban landscapes (broadly conceived) evolve with varying intensities and features, they will be pivotal sites of urban tension, adaptation, and resiliency in the 21st century (Addie, 2016; Filion and Keil, 2017). Smart-city scholarship and application, we contend, needs not only to promote locally-adapted implementation strategies (Kitchin, 2015; Paskaleva, 2011), but concertedly address the sustainability challenges and uneven geographical development shaping extended urbanization.

"Smartness," as a development strategy, has been upscaled in several instances: in France, metropolitan governance regimes in Bordeaux and Lyon are taking their first steps to develop as *smart metropolises*, while geographically-small countries like Singapore and Malta have formulated *smart nation* policies. To date, though, it is the urban core that remains the predominant area of focus for smart urbanism, with urban competitiveness serving as a primary driver of most advanced smart-city initiatives. Smart-city planning in and for peripheral urban areas has yet to garner concerted academic or policy attention. There is a clear need to rebalance the myopic focus of smart-city ideas in the privileged spaces of the urban core. First, while upgrading obsolete or over-pressured urban systems in the central city will require significant investment, the majority of urban infrastructure built in the 21st century will facilitate the continued extension of metropolitan areas, either through the construction of infrastructure services to massive new developments, or to support informal settlements surrounding (and penetrating) the planned city. Second, although the urban core offers critical densities associated with sustainable urbanism, these cannot be readily transferred to suburban landscapes that tend to be attached to, and reproduce, unsustainable ways of life.

Our argument is that we need to examine how and where urban "smartness" and "intelligence" is, and can be, leveraged to integrate peripheral sites into the material and social fabric of urban society. To this end, the primary contribution of our analysis is the development of an approach to identify how smart-city initiatives can enhance the resiliency of peripheral urban areas and promote integrated metropolitan governance by targeting actions towards specific spatial, material, and social interventions. The paper is structured as follows: in the next section, we present an overview of issues of urban peripherality (understood geographically and in terms of material (hard) and social (soft) infrastructure provision) and urban resiliency. After outlining our conceptual framework, we interrogate the relationship between smart-city infrastructure, resiliency, and urban peripherality via a comparative assessment of six European smart-city plans. We conclude by highlighting the policy relevance of the study and point to directions for future research.

Smart resiliency on the edge: A conceptual framework

Unpacking urban peripherality

Prior to the mid-20th century, as Lang and Knox (2009) summarize, urban and metropolitan forms "could safely be conceptualized in terms of the outcomes of processes of competition for land and ecological processes of congregation and segregation, all pivoting around a dominant central business district and transportation hub" (2009: 791). Writing in relation to the American context, they argue that the rise of automobility and massive public subsidies for homeownership and highway construction engendered "the evolution of dispersed, polycentric spatial structure and the emergence of [new] urban realms," which defied the core-periphery logics theorized by the Chicago School (Lang and Knox, 2009: 791). The most distinctive category of this "New Metropolis" is the pattern of suburban and exurban development now commonplace in both North America and Europe: the amorphous "exopolis" (Soja, 2000), the "diffused," "edgeless" city (Lang, 2003), or "zwischenstadt" (Sieverts, 2003), which challenges the spatial logics of the older central city and its radiating hinterlands.

The urban periphery defies easy categorization in the face of these broad urbanization patterns (Taylor and Lang, 2004). Globally, metropolitan hinterlands now exhibit a tremendous degree of diversity in terms of urban morphology, governance arrangements, and socio-economic structure (Keil, 2017), and have been subject to codification and categorization through a myriad of typologies and signifiers (Harris and Vorms, 2017). The condition of urban peripherality itself is expressed in endless physical forms and social relations. As with Lang and Knox's "New Metropolis," European suburbs are highly heterogeneous (Hesse and Siedentop, 2018; Phelps, 2017). There tends to be, however, a strong discursive connection between suburban environments and disadvantaged areas characterized by dependence, disconnection, poverty, and outmigration (Kühn and Bernt, 2013). In this view, peripheral urban areas are deemed to lack the resources to sustain their own growth over time and, as a result, their potential for development is largely dependent upon urbanization processes driven by, and centered within, the traditional city core (Portnov and Pearlmutter, 1999). Such thinking belies the socio-spatial and political relations, which leads to the marginalization of suburban landscapes and communities like the French *banlieues* or the Italian suburbs of Scampia in Naples and Rozzano in Milan.

In contrast, the urban periphery in Anglo-American contexts has tended to be read through normative suburban and exurban imageries tied to sprawling low-density residential developments at the edge of a city (Beauregard, 2006; Knox, 2008).[1] The quintessential imagined North American suburban landscape is not associated with disadvantage: the "American Dream" may be most clearly embodied in a desire for a detached single-family suburban home and the aspirational middle-class life this can facilitate (Anderson, 2010). Rather, it is the inner-city that is traditionally linked to problems of peripherality: disinvestment, blight, and concentrated (racialized) poverty. Over the past four decades, however, flows of capital back into the city have engendered a partial reversal of such trends. As the center gentrifies, we are witnessing the increased suburbanization of race, poverty, and precarity (Lo et al., 2015; Schafran, 2013).

Urban peripheries in the Global South disclose more wrinkles. In an insightful post-colonial analysis, Caldeira (2017) forwards the concept of "peripheral urbanization" to capture the ways in which home-, neighborhood-, and city-building operate on the margins of official planning logics to generate new urban forms, citizens, and ways of life. Importantly for our argument, her theorization is not tied to the extension of urban centers into their hinterlands: peripheral urbanization "does not simply refer to a spatial location in the city – its margins – but rather to a way of producing space that can be anywhere" (Caldeira, 2017: 4).

Across these instances, the urban periphery is fundamentally constructed—usually in pejorative terms—relative to the social and spatial centrality of the urban core. Urbanism pivots around clustered agglomeration and sites of political authority forged through social and material connectivity, and operationalized through public space and multifunctional mobility. In contrast, suburbanism reflects dispersed and dependent urban forms, characterized by segregation and imposed order and premised upon automobility and domesticity (Walks, 2013: 1479). It is not that suburbs lack urbanity or present an alternative mode of urbanism, but instead the urbanity of the periphery is somehow underdeveloped or partially realized (Walks, 2013: 1476).

Significantly, though, as scholars including Bourne (2010) and Caldeira (2017) note, urban peripherality should not be simply read as a locational characteristic understood in opposition to a singular territorialized point of centrality. A growing literature now recognizes divergent processes and experiences in the formation of urban peripheries, from the dramatic centrifugal expansion of urban agglomerations at a global scale (Angel et al., 2012) to the rise of peripherality in inner-city areas suffering from deindustrialization, disinvestment, or outmigration (Bernt and Rink, 2010; Lang, 2012). Life on the edge of the city (socially and spatially) can present conditions of precariousness, marginalization, disconnectivity, and vulnerability. Yet far from a mere site of decay and alienation, the urban periphery is also a locus for novel, adaptable urban development (Kinder, 2016; Lo et al., 2015). Economic opportunities and social innovation rise in peripheral areas, not just in the central city (Fitjar and Rodríguez-Pose, 2011). We therefore conceptualize *urban peripherality* as denoting a distancing and differentiation between the urban core and its metropolitan hinterland in social, economic, political, and spatial (not purely geographic) terms, while recognizing its latent potentiality. In Table 1, we develop a typology that categorizes dimensions of urban peripherality in terms of their geographic (spatial) situation (GUP), and hard (material) (HUP) and soft (social) (SUP) infrastructural foundations, which forms the basis of the following analysis. These categories are neither mutually exclusive nor rigidly-bound; they constantly interact in ways that stress the interconnectedness of the spatial, material, and social dimensions of networked urban infrastructure (Graham and Marvin, 2001; Kitchin, 2011).

Smart-city urban development frameworks offer the potential to integrate peripheral spaces and communities into the wider urban fabric (albeit in not necessarily progressive ways). Peripheral (sub)urban environments can serve as vital testbeds for smart policy and technical interventions that not only dramatically transform the connectivity and resiliency of place, but may also generate approaches that are more impactful and transferable than those presently pioneered in the core. Such transitions, though, depend upon effectively addressing entrenched cultural norms and social practices, in addition to restructuring the morphologies and fixed capital embedded in the built environment (Filion and Keil, 2017). Two issues are fundamental here: (a) recognizing the shifting socio-spatial organization of urban spaces, and the emergence of polycentric urban regions that invoke distinct forms of integration and exclusion along political, technological, and territorial lines (Graham and Marvin, 2001); and (b) unpacking the diverse forms of resiliency that smart-city interventions can promote in peripheral urban areas.

Table 1. Dimensions of urban peripherality.

Characteristic	Dimensions
Geographic (spatial) urban peripherality (GUP)	• GUP 1: Absolute distance from the urban core (i.e. a suburban location on the fringes of the metropolitan area). • GUP 2: Relative spatial distancing as metropolitan areas are "bypassed" by the physical and social urban infrastructure. • GUP 3: Discursive marginalization of urban space and communities: for example, the pejorative dismissal of sprawling suburban landscapes or the demonization of blighted inner cities and suburban tower blocks.
Hard (material) urban peripherality (HUP)	• HUP 1: Poor quality or limited access to formal urban infrastructure services (transport, water, waste, energy, and communications). • HUP 2: Poor quality or deteriorating built environments, including housing, buildings, roads, bridges, pipelines, etc. • HUP 3: Lack of proximity to quality educational and cultural institutions, public spaces, knowledge infrastructure, hospitals, and other civic facilities.
Soft (social) urban peripherality (SUP)	• SUP 1: Limited or absent diffusion of knowledge, culture, competencies, civic participation, social equity, and social innovation. • SUP 2: Concentration or growth of subjects excluded from economic activity (e.g. long-term unemployment, youth unemployment, people engaged in precarious/illegal labor markets). • SUP 3: Concentration or growth of socially vulnerable populations (e.g. low-income families, the elderly, disconnected immigrant communities) alongside significant indicators of urban marginality, (e.g. high crime rates, low rates of school graduation, etc.)

A genealogy of (urban) resilience

The complexity of contemporary urbanization, and its interactions with a range of social and ecological structures, foregrounds the relevance of "systemic" urban analysis (Batty, 2013). The different pressures impacting urban systems continue, however, to be treated separately in academic and applied terms (Kanter and Litow, 2009). The result is the perpetuation of fragmented, and subsequently ineffective, urban policy. In response, a growing number of researchers and international organizations have embraced the concept of "resilience" as a means to increase the capacity of social and territorial systems to adapt in the face of instant risks and longer-term challenges (Bahadur et al., 2010; Folke, 2006). In normative terms, resilience is understood as the buffer capacity of an element (a material or an ecosystem) to absorb perturbations before a radical change is catalyzed in its structure. In scientific discourse, however, the concept lacks a singular accepted definition, and its utility and application has evolved through several definitional and analytical approaches.

Resilience has deep roots in several scientific disciplines. Born in physics to describe the resistance of materials in the presence of external disturbances, the concept gained popularity in ecology in the late 1960s and the early 1970s. Holling (1996)—one of the first to use the term resilience to describe the behavior of natural systems in the presence of external disturbances (see Holling, 1973)—provided a useful distinction between "engineering resilience" and "green resilience." The former, strictly connected to the concept of stability, was based on characteristics including efficiency, a return to an earlier condition, and, above all, the uniqueness of the equilibrium state. The latter was defined as the magnitude of the disturbance that can be absorbed before the system changes its structure. Ecological interpretations of resilience have been strengthened by its adoption in the study of socio-ecological systems, which emphasize the interrelationship between anthropogenic and natural components and their capabilities to learn by experience when confronted by facing environments (Bankoff et al., 2004; Walker et al., 2004).

Table 2. Synthesis of scientific literature on resilience.

Field	Representative author	Characteristics of resilient systems
Complex adaptive systems	Folke et al. (2002)	Diversity; redundancy; adaptability; self-organization; innovation; storage; experience; knowledge; learning ability; convertibility
Systems thinking	Fiksel (2003); Bahadur et al. (2010)	Adaptability; cohesion; diversity; effectiveness and reliability of institutions; efficiency; control mechanisms; participation; knowledge; preparation; equity; networks; learning ability; multi-scale perspective
Urban systems	Desouza and Flanery (2013)	Diversity; redundancy; resistance; adaptability/flexibility; collaboration; interdependence; autonomy; efficiency
Communities	Davis (2005); Norris et al. (2008)	Redundancy; strength; availability of resources (resourcefulness); rapidity/capacity for mobilization
Socio-ecological systems	Walker et al. (2004); Folke et al. (2010)	Resistance; latitude; precariousness; panarchy; persistence; adaptability; convertibility
Ecosystems	Adger et al. (2005)	Diversity; redundancy; space organizations
Economic systems	Van der Veen and Logtmeijer (2005); Briguglio et al. (2008)	Redundancy; sustainability; transferability; efficiency; rapidity; flexibility
Urban communities	Chuvarajan et al. (2006)	Diversity; redundancy; self-organization; storage; networks; innovation; individual capacity; spatial interactions; temporal interactions; self-confidence; feedback
Social systems	Maguire and Hagan (2007)	Resistance; resilience; creativity
Social-ecological and economic system	UNESCAP (2008)	Redundancy; strength; availability of resources
Infrastructural systems	McDaniels et al. (2008)	Strength; rapidity
Organizational theory	Gibson and Tarrant (2010)	Resistance; reliability; flexibility; redundancy

The transposition of resilience to complex adaptive systems is closely linked to Gunderson and Holling's (2001) concept of "panarchy." Here, the term describes the evolution of systems according to: (a) their *potential* (i.e. the availability of accumulated natural and social capital); (b) their *connection* (a system's ability to control its own destiny); and (c) their *resilience* (which decreases when the system stabilizes and increases in phases of reorganization). Recent developments in resilience studies linked to panarchy have further redefined these evolutionary dynamics to reflect a system's *persistence* (the ability to resist impact), *adaptability* (the capacity for internal regulation in the face of external pressure), and *transformability* (the ability to modify internal structures to enter a different stability domain) (Folke et al., 2010). Such thinking is significant as it negates the idea of resiliency as the capacity of a system to recover to a previous state of equilibrium (Davoudi, 2012). This has implications for the study of cities as complex systems, as their contradictory internal logics and interactions with exogenous factors mean that their dominant condition is one of flux.

Over the past two decades, resilience has been appropriated in a variety of ways across the social sciences, including psychology, organizational studies, and network studies (Vanolo, 2015). The resultant conceptual extensions risks stripping the term of its intellectual utility, and critics have identified problems regarding both translation and application (Rose, 2007). In response, in Table 2 we draw from Galdersi (2016) to categorize the discourses and terminology used to describe resilient systems across a variety of academic and professional disciplines. The results indicate that the main features of a resilient system identified by Folke et al. (2010)—persistence, adaptability, and transformability—appear as recurrent motifs across the literature examining social, economic, ecological, and infrastructural systems, alongside notions of adaptability, diversity, resistance, and strength.[2]

The smart city and its infrastructure

Smart-city strategies may be constituted by a diverse array of technological and policy interventions aimed at enhancing the effectiveness, efficiency, and resilience of hard (material) and soft (social) urban infrastructures. Hard infrastructure-oriented smart-city initiatives utilize urban technology to monitor and improve the functions of urban systems: public services, housing, transport, and so on. Urban intelligence is realized through the implementation of technological systems that, in many instances, are provided in the form of replicable and readily-accessible products offered by technology vendors. Cities select from a portfolio of services in different areas of urban living, and, with a little calibration, quickly obtain operational (if not directly applicable or locally-adapted) smart solutions. Rio de Janeiro is a flagship case of such information technology-driven urbanism, with the city collaborating with IBM to implement smart-city applications for environmental monitoring and traffic management (Angelidou, 2017). While hard infrastructure-oriented smart-city programs can utilize advanced technological systems to monitor and improve diverse components of complex city networks, this approach has been criticized as being exposed to performance failure through the systemic transfer of errors across proprietary systems. Moreover, issues about data ownership, citizen lock-in, inclusivity, and accessibility to smart services persist (Glasmeier and Nebiolo, 2016; Kitchin, 2015; Komninos, 2015; Van Zoonen, 2016), raising spatial and social justice questions resulting from "splintering urbanism" (Graham and Marvin, 2001) and "urban digital divides" (Crang et al., 2006).

In contrast, soft infrastructure-oriented smart-city initiatives emphasize citizen empowerment and the development of human capital. Urban technologies are used to support bottom-up initiatives aimed at capacity-building through establishing an environment of openness and civic participation. The short and medium-term effects of these types of smart-city approaches include data collection via citizen science programs, the activation of collective intelligence mechanisms, the development of needs-driven and relevant solutions, and the inclusive representation of ideas and minor stakeholder groups (Hollands, 2015; Kitchin, 2015; Paskaleva, 2011). Long-term effects include social and digital inclusion, a culture of citizen agency, and advanced social innovation dynamics (Angelidou and Psaltoglou, 2017). Key examples of soft smart-city approaches include the cities of Amsterdam, Barcelona, and Vienna, which, as we will discuss, have sought to develop open smart-city platforms that invite urban stakeholders to co-create smart-city applications. Nevertheless, we need to keep in mind that cyberspace is, by definition, neither completely public, nor accessible to everyone, while the collection of large amounts of data does not automatically guarantee progressive smart-city futures (Leszczynski, 2016; Neves, 2009).

Although smart cities are built upon the usage of advanced technologies, the way that these will be utilized determines spatial relationships related to accessibility, social exclusion, and gentrification (Hollands, 2008, 2015), as well as panoptic control and surveillance (Elmaghraby and Losavio, 2014; Kitchin, 2015; Van Zoonen, 2016). How smart-city interventions can target the issues of hard and soft urban peripherality, as the (admittedly Euro-centric) strength, weakness, opportunity, threat (SWOT) analysis presented in Table 3 indicates, remains an open question.

Considering *where* smart-city interventions are targeted, in addition to *what* infrastructures are selected, is a vital step in addressing the challenges of urban peripherality. Suburban infrastructure is more than simply located in a peripheral/suburban place: infrastructure may be *in* suburbs (insofar as they are physically embedded in suburban landscapes); *of* suburbs (insofar as they are produced and performed in suburban social space); or *for* suburbs (insofar as they support processes of suburbanization and suburban ways of life) (Addie, 2016). In other words, the use of smart-city interventions, whether technological (chiefly addressing HUP) or

Table 3. Strength, weakness, opportunity, threat (SWOT) analysis of the possible effects of smart-city actions on peripheral urban areas (adapted from Angelidou, 2017).

Strengths	Weaknesses
• Social mix. • Well-developed neighborhoods (useful for social street projects). • Ability to access funding for urban regeneration premised upon smart-city applications/approaches. • Urban leaks to be recovered for smart projects. • Ability to galvanize community support for, and adherence to, urban recovery initiatives	• Lack of skills needed to participate in smart-city calls. • Decay and vandalism can shorten the life of smart projects (both with regard to maintenance of hard infrastructure and the enhancement of soft infrastructures). • Priority of urban renewal interventions with respect to smart actions (e.g. securing the periphery of buildings) that infringe upon smart projects.
Opportunities	**Threats**
• Improvement of peripheral urban economic activity: manufacturing, commerce, businesses and finance, education, research, health, and tourism. • Improvement of peripheral urban infrastructure and utilities. • Quality of life improvements. • Promotion of social inclusion, social care, safety, and security. • Improvement of suburban governance, city services, civic participation, and benchmarking. • Promotion of environmentally sustainable lifestyles, knowledge-based development, and democratic urbanism through awareness/education/digital inclusion initiatives.	• Polarization and concentration of smart-city activities in urban center activities (tourist, economic, professional, etc.) • Different time dynamics between smart-city applications for hard and soft infrastructures (in peripheral and suburban areas this gradient determines amplified effects compared to the urban center).
• *Modularity* presents both opportunities and threats. For suburban areas, districts that are initially subject to smart interventions may become regional exemplars stimulating smart upgrading processes in other peripheral neighborhoods. At the same time, smart investments in peripheral areas may be adversely impacted by negatively externalities arising from geographically proximate deprived areas.	

social (chiefly addressing SUP), can have a distinct and uneven impact of experiences of spatial peripherality (GUP). Building privileged infrastructure systems may be heralded as a state spatial strategy to enhance the competitiveness and resilience of metropolitan regions (Brenner, 2004; Calzada, 2017); but because urban infrastructures are contested, power-laden elements of the urban fabric, they establish and exacerbate uneven access and uneven geographic development, with risks and failures experienced unequally across urban populations (Graham and Marvin, 2001). In the remainder of this paper, we assess the extent to which smart-city planning currently acknowledges, incorporates, and addresses this essential idea in practice.

Smart-city resilience in the urban periphery: An analysis of six European cities

Methodology

Extending smart-city approaches into peripheral urban areas has the potential to enhance local resilience and promote integrated metropolitan governance, but are urban peripheries a concerted focus of contemporary smart-city planning? To assess the extent to which "actually existing" smart-city plans (Shelton et al., 2015) target aspects of urban peripherality, we draw on evidence from six European cities: Amsterdam, Barcelona, Helsinki, Naples, Stockholm, and Vienna. The cases were selected based on earlier analyses of smart-city characteristics in European cities (Angelidou, 2016, 2017) and provide an exploratory comparison to examine our preceding critique. Each city is pursuing smart urbanism, but they display diversity in terms of the plans developed and the context of their application. Amsterdam and Barcelona have emerged as leading success stories of European smart-city planning (and consequently departure points for smart policy transfer, see Wiig, 2015). In contrast, cities like Naples represent metropolitan areas that are now looking to embrace smartness as an urban policy paradigm. The cases also capture sufficient variation in terms of urban morphology, governance structure, and planning culture to explore the position of urban peripheries in divergent metropolitan and national contexts within the European Union (EU). EU-level discourse on the smart city is significant because EU institutions carry a certain authority to operationalize concrete actions. The key issue, then, is what happens to the framing of smart urban sustainability as it is mobilized in specific contexts.

"Smart" plans and planning, of course, do not simply equate to "smart" implementation or "smart" results—yet they are telling of the objectives and intentions of cities, key urban actors, and citizens in striving to be "smart," "networked," and "connected." In line with similar studies by Anthopoulos (2017), Calzada, (2017), and (Cowley et al., 2018) the units of analysis for our comparative approach are the range of discourses and proposed actions detailed in smart-city policy frameworks, not the cities themselves. The presented smart-city strategies are on the one hand complex institutional constructs, which tackle a large number of urban and regional planning and development issues. On the other hand, they tend to employ open innovation methodologies and are completely open to the community. This means that any citizen, entrepreneur, and their formal/informal coalitions can "post" projects on the smart-city platforms of Amsterdam, Barcelona, and the other cases we analyze in this paper. Each smart-city platform is framed by strategic documents and objectives that codify urban "smartness," but often comprise hundreds of individual projects. It is important to stress that these smart-city ecosystems are neither mono-functional nor highly-centralized, even as they provide comparable data availability to facilitate strong comparative analysis (Kantor and Savitch, 2005). The following analysis therefore captures the overall characteristics and approach of each city's smart planning, and highlights the aims and objectives of flagship and representative projects. Data for the following analysis have been analyzed from each municipality's smart-city websites and associated planning documents (see Table 4), alongside reporting in the popular media (newspapers, technology and municipal blogs) and academic research on the case cities.

Findings

Amsterdam, the Netherlands

Amsterdam Smart City is a broad, open partnership among businesses, authorities, research institutions, and the people of Amsterdam to improve the environmental and social sustainability record of the city. Current smart-city actions focus on: (a) infrastructure and technology; (b) energy, water, and waste; (c) circular city; (d) governance and education; (e) citizens and living; and (f) a Smart City Academy (Amsterdam Smart City, 2017). The "open" and "social" nature of the initiatives included aim to enhance digitally driven social innovation throughout the city, both in urban and suburban areas, for example through events including Smart Dialogue with Citizens, Connect with Amsterdam's Smart City Innovators, and the Smart Charging Challenge. The primarily environmental orientation of the program targets energy efficiency with regards to public services and the city's building and infrastructure stock. There is a concentration of smart-city initiatives in the core area of the city, although limited attention is paid directly to SUP issues in the urban periphery.

While Amsterdam Smart City brings together more than 250 projects, three in particular are worth noting with regard to HUP issues in the core and periphery. First, Climate Street is a pilot project launched in 2009 with the aim of utilizing a busy city street to showcase smart products and services. Chiefly funded by the city government, the project has functioned as a "living lab" for technology and

Table 4. Application of smart urban actions in the core and periphery of six European cities.

City	Key documents reviewed	Urban core impact						Core score	Urban periphery impact						Periphery score	Central resiliency characteristics addressed
		HUP			SUP				HUP			SUP				
		1	2	3	1	2	3		1	2	3	1	2	3		
Amsterdam	Primary: Amsterdam Smart City (2017) Secondary: Angelidou (2014, 2016, 2017); Angelidou et al. (2017); Mora and Bolici (2017); Van Winden and Van den Buuse (2017)	▲	▲		▲			0	▲			▲			−2	Adaptability; autonomy; cohesion; collaboration; control mechanisms; convertibility; diversity; efficiency; innovation; interdependence; multi-scale perspective; spatial organization; sustainability.
Barcelona	Primary: Barcelona Digital City (2017) Secondary: Angelidou (2014, 2016, 2017); Angelidou et al. (2017); Bakici et al. (2013); Buscher and Doody (2013); Calzada (2017); Leon (2008); March and Ribera-Fumaz (2016)	▲	▲	▲	▲			+2							−6	Autonomy; cohesion; collaboration; control mechanisms; convertibility; diversity; effectiveness of institutions; efficiency; equity; experience; innovation; interdependence; resilience; spatial organization; sustainability.
Helsinki	Primary: Helsinki City Council (2017) Secondary: Anttiroiko (2016); Culminatum (2005); Forum Virium Helsinki (2017); Hielkema and Hongisto (2012); Shahrokni et al. (2015); TEM (2014)	▲	▲	▲	▲	▲	▲	+6	▲	▲	▲	▲	▲	▲	+6	Adaptability; autonomy; cohesion; collaboration; convertibility; diversity; effectiveness of institutions; efficiency; equity; experience; innovation; interdependence; multi-scale perspective; spatial organization; sustainability.
Naples	Primary: Italian Ministry for Universities and Research (2017)			▲	▲		▲	0				▲			−4	Adaptability; cohesion; collaboration; diversity; innovation; interdependence; persistence; self-confidence; spatial-organization; speed.
Stockholm	Primary: Stockholm Smart City (2017) Secondary: Angelidou (2016, 2017); Buscher and Doody (2013); Shahrokni et al. (2015)	▲		▲	▲		▲	+2	▲		▲	▲		▲	+2	Cohesion; collaboration; control mechanisms; convertibility; diversity; effectiveness of institutions; efficiency; equity; innovation; interdependence; multi-scale perspective; resilience; spatial organization; sustainability.
Vienna	Primary: Smart City Wien (2017) Secondary: Anthopoulos (2017); Madreiter and Haunold (2012)	▲	▲	▲	▲		▲	+4	▲	▲	▲	▲		▲	+4	Adaptability; autonomy; cohesion; collaboration; control mechanisms; diversity; effectiveness of institutions; efficiency; equity; innovation; interdependence; spatial organization; speed; sustainability.

utilities companies to test new innovations that have, along with the Climate Street model itself, been exported to more peripheral sites around Amsterdam (see Van Winden and Van den Buuse, 2017). Consequently, the project has facilitated knowledge diffusion associated with addressing SUP 1. Second, Energy Atlas is an innovation-based platform collecting and upscaling access to energy data. Energy Atlas helps to identify the geographic locations in the city with the highest potential for adopting new energy solutions (HUP 1). The project includes expansion and replication in the upscaling process, and demonstrates that: (a) the vision and ambitions of public authorities can be an important enabling factor in scaling processes; and (b) knowledge transfer and learning mechanisms are crucial for wider dissemination of smart-city solutions both in core and peripheral areas (SUP 1). Third, Cargohopper is a private logistics company using electric vehicles as part of a sustainable city agenda. Amsterdam's city government allowed Cargohopper to operate within the environmental zone in the city center for the delivery of goods, and partially subsidized the development of the first electric vehicle. The model has now been replicated in several outlying neighborhoods.

Barcelona, Spain

Barcelona has an established reputation as a pioneering European Smart City. The city's current smart-city framework, Barcelona Digital City (2017), is a series of initiatives driven by the municipal government to promote open data, civic innovation, and high-speed connectivity at the intersection of "international promotion," "international collaboration," and "local projects." Specific actions, which include over 100 projects, are targeted on three main sectors: (a) digital transformation; (b) digital innovation; and (c) digital empowerment. The city's initiatives are focused on inclusive, citizen-centered urban technological innovation, geared to improve public space quality, urban renewal, and cultural heritage protection and promotion. The notion of "smart governance" is a prominent discourse and has prompted the development of innovative mapping platforms and open data sharing. The main objective here, however, has been on improving access to government information rather than strengthening the social prospects of marginalized and vulnerable urban populations.

The backbone of Barcelona Digital City involves special public property infrastructure plans, including wi-fi and optical fiber, a new mobility plan, new heating and cooling systems, new energy networks, and underground galleries (see Bakici et al., 2013). Such investments can take the form of minor road renewal to the transformation of whole urban districts. There is, however, a clear concentration of smart-city initiatives in the more urbanized areas of the city to the detriment of the urban periphery. In certain central districts, Barcelona has pushed the limits toward an effective and sustainable city by transforming itself from an industrial area into a home for new innovative companies. The 22@ Barcelona development is emblematic of this social and geographic focus (Leon, 2008). As a knowledge city model, 22@Barcelona covers smart-city standards with regards to economics, green infrastructure, inclusiveness, science and technology, housing, mobility, quality of life, and identity—yet these diverse functions all remain clustered in the urban core.

Helsinki, Finland

Helsinki Smart City (Helsinki City Council, 2017) aims to advance economic competitiveness, service innovation, and "quadruple helix" innovation in a climate of openness, experimentation, democracy, and inclusivity. The vision for Helsinki is the city's transformation into a functional, world-class, business and innovation hub. A multilevel collaboration has been established with other major cities and metropolitan authorities to enhance interoperability and develop economies of scale. Open, user-driven innovation and living lab approaches are key to this strategy (Hielkema and Hongisto, 2013). In this sense, all aspects of soft infrastructure are leveraged and promoted towards the goal of economic prosperity, and both hard and soft infrastructure seek to support high-quality urban innovation. The city maintains a co-creation platform called Helsinki Loves Developers, which co-organizes hackathon programming marathons and open data apps competitions across the metropolitan area. In doing so, Helsinki's smart-city actions provide extensive opportunities for residents to experiment with "actually existing" smart services. Citizen-led smart initiatives have resulted in local improvements to the urban environment (including the creation of playgrounds and landscaped construction sites); smart adaptions to refuse services (via the implementation of remotely-monitored street waste containers); and community initiatives supporting elderly care (the Senior House property and community, where smart services assist the elderly in their everyday lives).

Peripheral urban areas are also specifically targeted in Helsinki's smart spatial strategies. For instance, the former commercial harbor area of Kalasatama has been identified as a "smart city district" and the site for an experimental innovation platform to co-create smart infrastructures and services. Over 200 stakeholders have been engaged in the Smart Kalasatama initiative (including 30 city departments, citizen groups, SMEs, start-ups, universities, and local residents), which aims to realize time and cost efficiencies related to residents' everyday chores through agile piloting, local smart services, and resource efficacy. The smart district approach being piloted in the neighborhood (which is largely premised on ICT and big data analytics) is intended to serve as a model for smart and clean services that can be scaled up to other sites across Helsinki and further afield.

Naples, Italy

The smart-city plan for the city of Naples was launched in 2015 following a national National Operational Program (PON) call on "Smart City, Communities and Social Innovation." It specifically aims to develop Naples as a "smart" tourist destination, promoting the city's historical and cultural elements through data analytics and smart-city applications. For example, open-source technologies have fostered the development of co-created geocoded digital platforms that enable tourists to explore Naples using personalized and contextual information regarding the city's history and culture. This project diffuses knowledge across the metropolitan area (addressing SUP 1), though cultural heritage sites are largely located in the old city core. Other digital smart actions have targeted young people across Naples: Talking Shop Window provides a platform to share information and reviews about stores across the city. While concerted attention has initially been paid to economic development around tourist and commercial industries, the long-term goals of Naples's smart-city plan involve nurturing a "local information society" and the promotion of sustainable development and mobility across the region (University and Research Italian Minister, 2017). Core to this strategy is strengthening social inclusion and creating virtual and material public knowledge spaces (addressing HUP 3).

Stockholm, Sweden

Stockholm's smart-city aspirations were solidified in 2014, following the EU's first Smart Cities and Communities (SCC) call, under Horizon 2020 (SCC-01-2014). The call for lighthouse projects included two or three cities working to develop smart urban solutions that integrated energy, transport, and ICT infrastructures. The GrowSmarter project (which included Stockholm, Cologne, and Barcelona) was one of three initiatives to receive European funding. Alongside this project, Stockholm has pioneered approaches to urban digitization. On 3 April 2017 the Stockholm City Council adopted a strategy to coordinate this on-going work with its "smart and connected" city agenda. In the resultant plan, Stockholm Smart City (2017), innovation, openness, and connectivity are vital mechanisms to make the city economically, ecologically, democratically, and socially more sustainable. The program spans a broad and inclusive variety of projects that test environmental and information technologies throughout the city's infrastructure (Shahrokni et al., 2015). There is a clear focus here on addressing issues surrounding access to smart-city services for residents in urban and rural areas. Questions of smart connectivity are engaged through three main areas: operations, technologies (including applications and services, digital platforms, IT infrastructure, and tools for information security and privacy), and principles of cost distribution. Public and private stakeholders (including the Royal Institute of Technology, Telefonaktiebolaget LM Ericsson, Vattenfall, Asea Brown Boveri (ABB), Skanska, and Scania) are collaborating with the city of Stockholm in the Digital Demo Stockholm innovation arena to develop digital solutions to improve Stockholmers' quality of life. Elsewhere, government–university–industry partnerships are being curated at the Urban ICT arena in suburban Kisa Science City.

Vienna, Austria

Vienna adopted the Smart City Wien Framework Strategy in 2014 with the goal of ensuring the best quality of life for the city's residents, along with the greatest possible conservation of resources. Smart City Wien (2017) is part of a cross-functional and balanced vision, aiming to create a greener, more sustainable, cooperative, and inclusive city. Increasing economic prosperity for the region is to be achieved through sustainable and effective citizen services' provision and infrastructure management. Civic, collaborative, and technological innovation are deployed as a means to promote urban intelligence. Over 100 projects are currently being pursued around categories including built form, digitization, education, energy, environment, health, innovation, mobility, social affairs, and urban development. The aims and objectives of these initiatives span a very broad spectrum of social, economic, and environmental sustainability goals, and include a strong degree of decentralization across the metropolitan area (see Anthopoulos, 2017).

A key example here is the pan-metropolis Optihubs project. Building on the results of Vienna's Smart Hubs 2.0 project, Optihubs was launched in August 2014 with financing from the Austrian Research Promotion Agency (FFG) and institutional coordination by the Technical University (TU) Vienna and the University of Applied Sciences BFI (Berufsförderungsinstitut) Vienna. The project aims to optimize an integrated logistics, operations, and administration system for the Port of Vienna. Using innovative simulation algorithms, Optihubs has identified systematized processes for increasing freight traffic on the Danube river while increasing resource use efficiencies. Another flagship development project, aspern Urban Lakeside Vienna, has utilized smart technologies to include citizens in an urban master planning process. Moreover, as the 240-hectare development is located in the auto-centric outskirts of Vienna, strong attention has been paid to (future) residents' mobility patterns towards more sustainable and active forms of transportation (the development is expected to house 22,000 people by 2028). A companion smart action, aspern.mobil, serves as a living lab in which social and technological urban mobility innovations can be developed, assessed, and monitored in real time.

Comparative analysis

Reading these six smart-city plans via an iterative qualitative content analysis (identifying key tropes, objectives, types, and locations for proposed actions) reveals the centrality of resilience discourses to smart urban interventions. Key resilience characteristics appeared across all of the smart-city plans, with the following common to each: cohesion, collaboration/participation, diversity, experience/learning ability, innovation/creativity, and spatial organization and interactions.

In terms of identifying geographic approaches to addressing hard and soft forms of urban peripherality, we see socio-technically interconnected smart-city actions in both the core and periphery placing concerted attention on HUP 1 (improving the quality of networked infrastructures) and HUP 3 (improving access to cultural and knowledge services). Actions targeting HUP 2 (improving the quality of the built environment) are a prominent concern in the urban core, but virtually absent in peripheral urban spaces. The most prevalent target of smart-city planning, though, is SUP 1; building urban resiliency through social innovation and human capital in the center city is common across all six plans—with all bar Barcelona also addressing this issue in the absolute geographic periphery of the metropolis (GUP 1). Perhaps unsurprisingly, given the diffuse nature of the infrastructures involved, this rhetoric defies ready geographical specifications. SUP 3 (supporting vulnerable populations) is also an important target of smart urban interventions in the urban core (four cities) and periphery (three cities). Actions targeting SUP 2 (economically marginalized citizens)

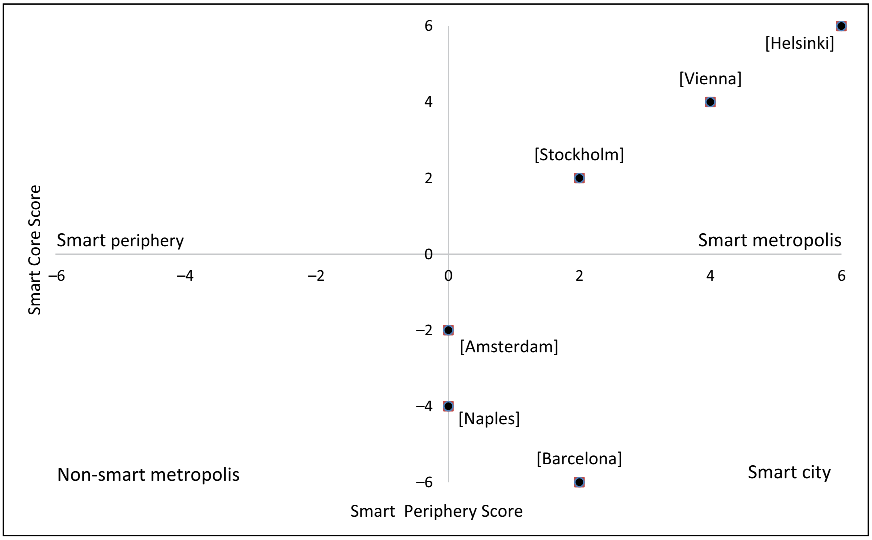

Figure 1. Comparison of urban core/periphery resilience actions.

in the core and periphery are notably neglected, with only Helsinki Smart City engaging this form of peripherality.

Building on the above analysis, the cities' smart-city plans were assigned a score of +1 for each aspect of hard and soft urban peripherality directly addressed, and a score of −1 for each neglected aspect. Given the plethora and diversity of smart actions included in these smart-city plans, we did not focus on quantifying the impact of individual actions, but sought to identify the presence of at least one specific project that addressed dimensions of urban peripherality identified in Table 1. This method was performed for actions targeted: (a) in the urban core; and (b) in the urban periphery, with the results presented in Table 4.

The degree to which smart urban actions promote urban resilience across metropolitan space can be represented on a core-periphery abacus constituted by four quadrants (see Figure 1):

1. Quadrant ++ indicates "smart metropolises": smart actions have positive effects on both the urban core and peripheral areas;
2. Quadrant − − indicates "non-smart metropolises": smart actions do not have positive effects on either the urban core or periphery;
3. Quadrant + − indicates "smart urban core": smart actions are designed for city center needs to the exclusion of peripheral areas;
4. Quadrant − + indicates "smart peripheries": smart projects are targeted towards features of peripheral areas rather than those of the urban core.

This matrix constitutes a conceptual tool that can be used to compare the penetration and latitude of spin-off effects of smart-city initiatives towards their broader metropolitan area. In this instance, Helsinki and Vienna have clearly adopted smart-city approaches that look to resonate across their cities' urban areas and engender positive impact upon the resilience of both urban core and periphery. Stockholm follows the steps of Helsinki and Vienna, although less dynamically. At the other end of the spectrum, Amsterdam, Naples, and Barcelona pursue smart-city programs that are highly concentrated in the urban core. Cities positioned in the "smart urban core" quadrant may realize positive effects on their peripheral areas because of technological, infrastructural, or social innovation diffusion from the urban core. The application of urban core-designed and implemented strategies, however, is likely to struggle when simply transplanted into the periphery, given variations in social, morphological, political, and scalar structures. Similar issues of portability are likely to arise with looking to apply "smart periphery" actions in the urban core.

Discussion and conclusions

The above exploratory analysis points to the continued prioritization of the urban core in the development and application of smart-city plans. Consequently, highly selected areas of the central city remain the privileged beneficiaries of the enhanced urban resiliency engendered by both hard and soft smart interventions. Yet in the cases of Helsinki and Vienna, we are beginning to witness the embrace of urban intelligence as an urban development strategy at the metropolitan scale. The incorporation of suburban and marginal districts into strategic planning for smart-city agendas is an encouraging trend: to address the social and spatial marginality of peripheral urban areas and enhance their resilience, it is necessary to overcome entrenched conceptual and material forms of core–periphery opposition. Initially, this tends to occur with peripheral areas being identified as "integrated smart regeneration areas"—that is, areas targeted for systematic transformation via the convergence of building redevelopment interventions, cultural heritage and landscape designation, economic revitalization, infrastructure investment, and the strengthening of citizenship services through innovative technologies. It is vital to note that peripheral urban areas are not necessarily "infrastructural deserts" and indeed may be home to an overabundance of urban infrastructures, smart or otherwise (Filion and Keil, 2017). An urban periphery may be crisscrossed with expressways, rail lines, or fiber optic cables, or house major airports or water treatment plants. The ability to utilize such facilities is not guaranteed given the fragmented nature of such systems, however, and marginalized residents are often burdened with solely-negative externalities (Graham and Marvin, 2001).

The key task moving forward is to examine how socio-technically integrated smart actions promote access to urban space and society in meaningful and sustainable ways. In other words, there is a need to concertedly address how smart urbanism can spur resiliency to address the conditions of HUP and SUP across the smart *metropolis* through the creation of new centralities and the reconnection of marginalized urban space into new material and social urban constellations. Through this paper, we have argued that urban peripherality is not a simple locational attribute, emerging due to a place's situation relative to the urban core. Nor is it an isolated space or aggregate category. It is a socio-spatial condition whose production and experience is shaped by public policy, regional and urban planning regulations, and the application (or not) of local investment. Rather than marginalized places and sources of conflict, contemporary urban peripheries are vital components of the current metamorphosis of urban regions. They are dynamic and unpredictable places. As such, they have significant potential to serve as real-life laboratories to foster urban resilience, and to support the flexible management of contemporary urban sustainability and inclusion issues. More than the implementation of locally-adapted technological and policy interventions, this suggests the need for many interpretive, localizing, and managerial approaches attuned to the specific resiliency requirements of historically, spatially, and culturally distinct, evolving conditions of urban peripherality in concrete terms. Emphasizing the spatial, material, and social dimensions of urban peripherality (as we do through the GUP–HUP–SUP framework) avoids the traps of technological and environmental determinism in accounting for urban transformation. As such, it is vitally important for both institutions developing and implementing smart-city metrics (including ISO standards; International Organization for Standardization, 2017), and cities looking to mobilize smart technical and policy toolboxes, to take the often-overlooked and highly-differentiated challenges (and opportunities) of peripheral urban areas seriously.

This article has contributed to on-going critical debates on smart urbanism by foregrounding the concept of, and challenges presented by, urban peripheries for the development, application, and governance of the smart city. Starting by establishing the conceptual terrains of urban peripherality and resilience, we have proposed a framework to assess the intersection of each around the development of smart-city interventions. To investigate how current smart-city approaches can be extended to peripheral urbanized areas in a way that enhances local resilience and promotes integrated metropolitan governance, we then analyzed six European smart-city projects, developing a matrix to comparatively represent the relative paucity of planning for smart peripheries. As such, the paper challenges the myopic city-centrism of contemporary applied urbanism and academic debate, and points to the need for smart urban planning agendas to target enhanced resiliency goals for the most marginalized and unsustainable parts of the urban region. In concluding, we therefore call for a new research agenda analyzing and adapting the potential of progressive smart interventions in, of, and for, the peripheral spaces of the 21st-century metropolis.

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Notes

1. Over the past decade reloaded “suburban studies” have contested the conceptual dominance of the “white picket fence” North American suburban ideal to uncover the dynamism and diversity of suburban forms, histories, and livelihoods (Nijman and Clery, 2015).
2. Several overlapping terms are present across the literature, reflecting disciplinary preferences and categorizations. Terms such as “robustness” and “strength” are often preferred to “persistence” to capture the capacity of a system to experience an event without undergoing alterations. Notions of “flexibility” are largely synonymous with “adaptability,” “innovation” with “creativity,” etc. (see De Jong et al., 2015).

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