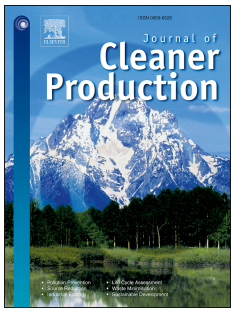

Organizing a sustainable smart urban ecosystem: Perspectives and insights from a bibliometric analysis and literature review

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Organizing a smart and sustainable urban ecosystem:

Perspectives and insights from a bibliometric analysis and literature review

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Organizing a sustainable smart urban ecosystem:

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Abstract

Cities struggle to enhance their sustainability by fostering their smartness, i.e. their ability to use advanced technologies and resources in an intelligent and integrated way to achieve a socially and environmentally viable economic growth. The transition towards urban ecosystems has been proposed as a practical solution to merge smartness and sustainability in the smart city discourse. However, little is known about the recipe for implementing and organizing a sustainable smart urban ecosystem. The bibliometric analysis and interpretive narrative review presented in this article found some contrasting perspectives on the approaches that should be embraced to run a viable smart urban ecosystem, shedding light into the manifold attributes of sustainable urban smartness. The research findings suggest that the viability of smart urban ecosystems relies on the ability of focal actors to implement a techno-bureaucratic governance model which relies on an integrated policy framework that accounts for the tripartite social, economic, and environmental challenges faced by cities. Citizen-centredness and greenness are the core values that embed urban smartness. Such values are useless if not backed by community engagement. Further developments should be targeted to unravel the role of datification and computerization in underpinning the collective intelligence of smart cities for the purpose of urban sustainability.

Keywords: Smart city; Smartness; Sustainability; Urban ecosystem; Viability

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Abstract

Cities struggle to enhance their sustainability by fostering their smartness, *i.e.* their ability to use advanced technologies and resources in an intelligent and integrated way to achieve a socially and environmentally viable economic growth. The transition towards urban ecosystems has been proposed as a practical solution to merge smartness and sustainability in the smart city discourse. However, little is known about the recipe for implementing and organizing a sustainable smart urban ecosystem. The bibliometric analysis and interpretive narrative review presented in this article found some contrasting perspectives on the approaches that should be embraced to run a viable smart urban ecosystem, shedding light into the manifold attributes of sustainable urban smartness. The research findings suggest that the viability of smart urban ecosystems relies on the ability of focal actors to implement a techno-bureaucratic governance model which relies on an integrated policy framework that accounts for the tripartite social, economic, and environmental challenges faced by cities. Citizen-centredness and greenness are the core values that embed urban smartness. Such values are useless if not backed by community engagement. Further developments should be targeted to unravel the role of datification and computerization in underpinning the collective intelligence of smart cities for the purpose of urban sustainability.

Keywords: Smart city; Smartness; Sustainability; Urban ecosystem; Viability

Introduction

Cities are not exempt from the quest for sustainability (Botequilha-Leitão and Díaz-Varela, 2020). Scholars and practitioners do not agree in defining the conceptual and practical attributes of urban sustainability (Zeemering, 2009). Lack of consensus is primarily related to the multifacetedness of the urban sustainability concept, which comprehensively involves the cities' ability to achieve a long-term viability from an environmental, economic, and social perspective (Mori and Christodoulou, 2012). A city is considered to be sustainable when it is effective in improving human wellbeing via durable social development, balancing the economic cycle of growth with the preservation of the surrounding physical and natural environment (Huang *et al*., 2015).

Alongside its basic tripartite (economic, social, and environmental) architecture, urban sustainability includes a technological shade (Bugliarello, 2011). The achievement of sustainability requires smart technological innovations that enable green and socially viable urban management practices (Chiappetta Jabbour and de Sousa Jabbour, 2016; Pizzi *et al.*, 2020). Nevertheless, due to the fragmentation and lack of cohesiveness that characterize the extant scientific debate, the conceptualization of urban smartness is as challenging as the definition of sustainability (Mora *et al.*, 2017). Urban smartness occurs in "*...those parcels of land in which intense communication processes take place*" (Salomon, 1996: p. 78). More specifically, smartness takes its roots in two phenomena triggering vivid communication exchanges among urban

actors: 1) the intensive use of technologies to integrate and coordinate individual behaviors to achieve a collective urban action (Bifulco *et al*., 2016); and 2) the recontextualization of urban dynamics and experiences in new realities that go beyond the physical space and achieve a cyber-physical locus (Cassandras, 2016). From this point of view, urban smartness relies on two pillars: 1) a tangible one, including the physical infrastructures and channels that intertwine the entities who participate in the functioning of the city; and 2) an intangible one, consisting of the tacit and immaterial factors that underpin the city's identity and subjectivity (Marsal-Llacuna, 2016).

In light of the above considerations, a smart and sustainable city can be conceived of as an urban entity which is able to integrate available social and digital technologies and to coordinate extant knowledge with the purpose of tackling the environmental, social, and economic issues that affect its long-term viability (Hara *et al*., 2016). Among others, Gil-Garcia *et al*. (2015) identified some essential components that underpin the smartness of a city. They can be grouped in four layers, three of which are vertical, whilst the other is horizontal. The first building block can be retrieved in the physical environment (Balaban and de Oliveira, 2017): the more cities are able to merge the natural environment with their built-in environment in a perspective of long-term viability, the smarter they are (Bayulken and Huisingh, 2015). Secondly, smart cities need a sound government structure that should provide people with reliable institutional arrangements, effective administration, and timely public services (Wirtz *et al*., 2020).

However, a sustainable natural environment and an effective government structure would be useless, if a vivid and engaged society is missing (de Oliveira *et al*., 2013). Urban smartness necessitates sharing the human and social capital across the constituents of the city (Macke *et al*., 2019). Lastly, smart cities require a horizontal layer consisting of distributed technologies that create connection between the three vertical layers to boost urban creativity (Wolff *et al*., 2020).

These arguments lead to understand smart and sustainable cities as living urban ecosystems. Generally speaking, an ecosystem is an environment composed of an "*…evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations…*" that connect actors, activities, and artifacts (Granstrand and Holgersson, 2020: p. 1). An urban ecosystem is composed of both natural and artificial components, which are strictly intertwined in the design and implementation of initiatives intended to foster the achievement of sustainability (Tan *et al*., 2020). Single actors have distinguishing roles and functions, but they are integrated in the larger social organism. The continuous interactions between the knots of the ecosystem nurture the effectiveness of individual actors and sustain the viability of the population of actors as a whole. Hence, an organizational effort is required to enhance the integration between the components of the urban ecosystem and to set the condition for its sustainable development (Appio *et al*., 2019).

The ecosystem lens has been largely put on to investigate the role that the different components – *e.g*., physical environment, government, society, and technologies – may have in the development of a smart city (e.g., Vinod Kumar, 2020). However, further developments are needed to shed light on what is needed to organize and steer a viable smart urban ecosystem. Previous studies have targeted specific topics related to the urban sustainability, including governance issues and societal challenges (Fu and Zhang, 2017). Notwithstanding, there is no agreement about the mechanisms and approaches that should be designed to set the conditions for a sustainable smart urban ecosystem (e.g. Russo *et al*., 2014). Lack of agreement spurs from the challenges that arise when structuring and running a smart urban ecosystem, such as the coordination and amalgamation of the formal (planned) and the informal (unplanned) sources of urban creativity (Mengi *et al*., 2020) and the active engagement of citizens to feed the social and civic capital on which the smartness of the urban ecosystem is established (Foth *et al*., 2016).

This study intends to stimulate the debate about the creation and the organization of a sustainable smart urban ecosystem. To advance what we currently know about this topic, it complementarily proposes a bibliometric analysis and an interpretive literature review. In particular, it articulates an interpretative framework using the ecosystem perspective to delve into the sustainable attributes of smart cities and to discuss the

macro, meso, and micro level challenges that affect the design of viable smart urban ecosystems. In sum, the article attempts to answer the following research question:

R.Q.: What is the state of the art of the literature on organizing smart urban ecosystems and what are the key drivers of smart urban ecosystems' viability?

An outline of the paper follows. Next section includes an overview of the research design and methods. Then, the study findings are reported, alongside a brief description of the selected most influential papers, thematically clustered according to the output of bibliometric analysis. Lastly, the study results are critically discussed and an interpretative conceptual framework is presented, shaping the theoretical and practical implications of this research.

Methods

Study design

A mixed methodology consisting of a bibliometric analysis followed by an interpretive literature review has been designed to meet the study aims. This approach was intended to blend the extensive systematic inquiry of a bibliometric examination with the in-depth insights provided by an interpretive literature review. The mixed approach ideally diminishes the deficiencies of each methodology, exploiting their respective strengths. Drawing on previous studies adopting a similar research design

(e.g., Dabić *et al*., 2020), an *ad hoc* study protocol was developed. It included three steps: 1) data collection: a thorough citation database search for capturing the highest volume of scientific contributions consistent with the study aims; 2) data cleaning: the arrangement of specific inclusion and selection criteria to pick out the most influential and relevant pieces of literature; and 3) core analysis: an in-depth examination of retrieved items. The final stage was articulated in two sub-steps: 3_a) a clusterization derived from bibliometrics; and 3_b) an interpretive literature review.

As compared to conventional methodological approaches focusing on past citations and literature impact to identify trend topics within a discipline (Kessler, 1963a), the bibliographic analysis primarily intends to highlight the ongoing knowledge areas, to detect the roles and impacts of documents in subsequent literature, and to capture the early stages of a scientific pursuit evolution (Boyack and Klavans, 2010; Hervas-Oliver *et al*., 2015). The spectrum of documents that can be analysed in bibliometric studies ranges from a set of few articles (*e.g.*, 40 papers on Kessler's first attempt in 1963b) to an exceedingly large batch of documents (Dabić *et al*., 2020). In line with the purpose of this research, the bibliometric analysis provided two perspectives to analyze retrieved items: 1) a retrospective view: an investigation of seminal contributions and the reconstruction of the intellectual process for detecting the current trends in the field of smart city research; and 2) a prospective view: a comprehensive assessment of emerging topics in the realm of smart cities and urban ecosystems' research.

Whilst the bibliometric analysis allowed us to systematize retrieved contributions in light of their citational proximity, the interpretive literature review enabled an in-depth account of the identified research streams. The guidelines for accomplishing a systematic review of the literature were followed (Tranfield *et al.*, 2003). More specifically, i) the item selection was performed sticking to a clear and replicable protocol; ii) the theoretical framework used to analyse the selected papers was not *a priori* determined, but rather organised according to the clusters resulted from VOS algorithms (Van Eck and Waltman, 2010); and iii) the instructions for a literature-informed approach based on mixed methods were followed (Dabić *et al*., 2020). A low level of formality was used, since excessive standardization might constrain the capacity to discover insights and to develop ideas starting from retrieved contributions. Consistently, a narrative, non-standardized reporting structure was used to increase the explanatory power of this study (Tranfield *et al.*, 2003). Figure 1 includes a flow diagram which graphically summarizes the research design. A detailed report of the three research steps follows.

[Please, put Figure 1 about here]

Data collection

Items' search kicked off in early August 2019. As a first step, a set of keywords that were coherent with the study purposes was developed. This step was crucial, since the

inclusion or exclusion of a single keyword may result either in a constraining set of data or in an unnecessarily broad dataset. After several iterations, the authors identified the most significant terms to showcase the highest range of studies to meet the study aims. The main focus was put on the "smart" idea, in order to disentangle the determinants of smartness within urban ecosystems. Searching for smart and smartness allowed us to collect insights into the triggers and the dynamics that constitute the urban ecosystems' ability to coordinate available knowledge and to integrate technologies in order to achieve an increased value creation capability. In line with the intention to illuminate the determinants of smart urban ecosystems' viability, issues related to "sustainability" were also included in the research strategy. The inclusion of "sustainability" into our search string permitted us to tailor the analysis on issues related to urban smartness sticking to a tripartite – environmental, social, and economic – contextualization of urban ecosystems' activities. Finally, yet importantly, since the achievement of sustainability requires an organizational effort to create cohesiveness amongst the components of smart urban ecosystems, topics related with "organization" were contemplated in the query. Accounting for organization-related issues was consistent with the study aim of obtaining evidence about the structural and procedural challenges that may influence the viability of a smart urban ecosystem. Alongside these three primary keywords, a list of secondary keywords was designed to keep the focus on the urban context. The resulting search string follows:

TITLE-ABS-KEY (("smart" AND "sust*" AND "organ*") AND ("urb*" OR "Cit*" OR "Civi*" OR "metropol*" OR "town" OR "local" OR "municip*")) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "re")) AND (LIMIT-TO (LANGUAGE,"English"))*

The asterisk (*) was adapted for inclusion of all possible variations for each term and allowed collecting the highest possible number of contributions. Several online resources are available to scholars interested in performing literature reviews, including *Google Scholar*, Clarivate Analytics' *Web of Science*™, and Elsevier's *Scopus*®. Due to their larger coverage, Web of Science and Scopus are largely considered the two dominant options for bibliometrics and literature reviews (Dabić *et al*., 2020). They index sources from leading publishers across the world and from main scientific associations involved in theoretical and empirical research about smart cities, such as the Association for Computing Machinery (ACM) and the Institute of Electrical and Electronics Engineers (IEEE).

After a cross validation aimed at ensuring the inclusion of all relevant data, Scopus was found to yield a more comprehensive and reliable range of contributions. Web of Science was affected by several discrepancies, with many relevant studies being not indexed. This situation probably occurred in reason of the newness of the topic and its recent developments, that did not reach most mainstream journals, yet. Therefore, Scopus was selected as the main data source. The identified keywords were run in a

Boolean search query performed on titles, abstracts, and keywords. The search was limited to "articles" and "reviews", as these document types are high-quality peer-reviewed manuscripts and, thus, they can be considered certified knowledge (Dabić *et al*., 2020). Conversely, conference proceedings and books were not contemplated in this literature review, since it was not possible to check their consistency with the peer review method. To enhance the replicability of the study design, only items published in English were taken into consideration. No other limitations were assigned. The last query was run on April, 3rd 2020 and returned 239 documents.

Data cleaning

Given the wide spectrum of items collected, a three-steps procedure was accomplished to refine our dataset. At the beginning, all retrieved documents were stored in an electronic worksheet shared among the authors. All contributions were independently read, focusing on their titles, abstracts, and keywords. The screening was performed according to three exclusion criteria: 1) lack of a clear relationship with the aims and scope of this study (*i.e.*, limited focus on organizational and managerial issues related to the smartness and sustainability of urban ecosystems); 2) marginal contribution to the advancement of scientific knowledge (*i.e.*, descriptive reports of smart cities' projects); 3) paucity of managerial and practical implications (*i.e.*, review articles unable to provide insights into the triggers of urban ecosystems' smartness and

sustainability). This screening phase resulted in a quite convergent results of the independent lists of papers to be excluded (138 discarded items). However, there was a disagreement on 23 records. After a research meeting involving all authors, 14 papers of this doubtful set were confirmed to be 'outliers', or not strictly consistent with the study aims. The finalized dataset included 87 relevant and impactful papers.

Core analysis

The last research step primarily consisted of a bibliometric analysis based on the Visualization of Similarities (VOS) technique. VOS elicited homogeneous clusters of scientific contributions based on direct citation relations. The core part of the analysis was run in VOS viewer, *vers. 1.6.10* (Van Eck and Waltman, 2010). Bibliographic coupling was used as the aggregation method. No limitations were assigned for the VOS viewer's parameters. Bibliographic coupling occurs when two papers have one or more shared references: the higher the reference overlap between two items, the more they are assumed to belong to the same cluster (Boyack and Klavans, 2010). Through this routine, VOS viewer generates a co-occurrence matrix depicting a two-dimensional map for all the items, which are located in accordance to their similarity measures. The closer the items reported in the matrix, the stronger their connections. This returns a cluster analysis, where groups can be interpreted as coherent themes. Clusters were systematized using an interpretive approach. Drawing upon such interpretations, a

keyword analysis based on authors' keywords was implemented to explore the most important topics discussed in the extant scientific literature. In light of this additional analysis, the findings were integrated with the identification of avenues for future development.

Findings

Overview of the items included in the analysis

The majority of items included in this literature review were research articles (92%), with the remaining part consisting of reviews (8%). None of the latter presented either bibliometric analyses or systematic reviews that focused on the topics addressed in this study. The publication years ranged from 2003 to 2020. More than a fifth of the items was published in 2015 or before (21.8%). About 1 in 2 contributions was published in the three years preceding this study (49.4%). This confirms the timeliness of the research subject.

A variety of sources hosted the contributions examined in this literature review. The principal subject areas were: business, management and accounting, urban informatics, urban science, public administration, environmental science, computer science, and engineering. More than 60 journals were taken into consideration in this research. Nevertheless, three journals (the International Journal of Information Management, the Journal of Cleaner Production, and Sustainability) accounted for 1 in 6 articles (16.1%).

On average, records included in this review were cited 21.7 times (σ = 36.7), ranging from a minimum of 0 citations to a maximum of 204 citations.

Cluster analysis

Figure 2 graphically depicts the cluster analysis' output. In sum, 11 clusters were retrieved, some of which were mutually intertwined. The closeness between the clusters suggests that the topics addressed in this literature review partially overlap, even though they provide with different conceptual and empirical lenses to advance what we currently know about the organization of smart and sustainable urban ecosystems. No elaborations intended to reduce the number of clusters was performed. This distinguishes our study from other reviews which adopt a more comprehensive, but less detailed clusterization approach. The decision to maintain the original number of clusters was consistent with our purpose of discovering the broadest spectrum of homogenous pieces to discuss a relatively innovative phenomenon. This allowed us to obtain a fine grained, albeit synthetic overview of the research in the field of smart urban ecosystem.

[Please, put Figure 2 about here]

On average, the clusters contained 8 items (σ = 2.1), ranging from a minimum of 5 articles to a maximum of 12 articles. The average number of citations for each cluster was 138.4 (σ = 87.), ranging from a minimum of 36 citations to a maximum of 264

citations. The topics included in these 11 clusters can be classified in two overarching areas: 1) the components that are needed for establishing and running a sustainable smart urban ecosystem; and 2) the approaches and tools that should be used – at the macro, meso, and micro level – to design and structure a sustainable smart urban ecosystem.

Literature review

Cluster 1: the policy and politics of sustainable smart urban ecosystems

Smartness is a new paragraph of the urban policy discourse aimed at reinventing the process of urban growth and development (Neuvonen and Ache, 2017). Smart cities are specific as compared with previous urban policy ideas (*e.g.*, sustainable cities, green cities, or eco cities) in that they rely on a "*…tripartite eco–economic–social relationship…to create a more prosperous future, with high-tech industries and efficient social services for future generations*" (Fu and Zhang, 2017: p. 114). The achievement of smart urbanism entails unprecedented policy challenges that cannot be addressed using functional approaches, but require an integrative perspective (Karppi and Vakkur, 2020). The need for reconciling environmental, economic, and social issues heralds ambiguities and contradictions, which may bring to institutional clashes (Paydar and Rahimi, 2018). To minimize such conflicts, scholars argue that the debate on smart cities should be repoliticized, emphasizing its multifacetedness and putting the

individual and collective wellbeing at the centre of urban policies (March and Ribera-Fumaz, 2016). For this purpose, the conjoint use of stakeholders' engagement and incrementalism in the development of smart urban ecosystems have been advanced as effective strategies: they allow to address the complexity of the smart city idea and to effectively account for the diverging environmental, social, and economic perspectives at its basis (Neuvonen and Ache, 2017).

Alongside stakeholders' engagement, tailored innovations should be introduced to democratise the decision making process and to take into account the viewpoints of the different actors who participate in framing the smart city policy discourse (Milan *et al*., 2015). Smartness relies on active collaboration and exchanges among actors in the urban context (Nielsen, 2014). Such actors should be deeply engaged – from both a strategic and organizational point of view – in the establishment of sustainable smart ecosystems (Deslatte and Swann, 2017). Attention should be paid to the risk that social elites enter the smart city policy discourse with a predominant role which enables them to constrain policies and decisions and to gain selfish advantages (Dierwechter, 2013). This is especially true when a coercive philosophy underlies the establishment of a smart urban ecosystem, which does not adequately assess the importance of local resources for the development and strengthening of urban smartness (Hawkins, 2011). A twofold fine-tuning of the policy discourse on smart cities should be accomplished to curb this risk. On the one hand, local interest groups should be solicited and encouraged

to actively participate in the design of the smart city idea, activating their social resources to support the viability of the urban ecosystem (Ramirez de la Cruz, 2009). On the other hand, initiatives should be taken to avoid exclusion and/or marginalization of underprivileged social groups who are not effectively represented in existing local interest groups. This may pave the way for a fully-fledged involvement of citizens in the smart city discourse (Pearsall and Anguelovski, 2016).

Cluster 2: the co-production imperative to nurture urban sustainability

The ecosystem nature of smart cities stresses the importance of citizens' active participation in the decision making process, which is argued to spur the improvement of urban smartness (Hajduk, 2018). Actually, citizens' engagement has been identified as one of the distinguishing traits of smart cities (Kankaala *et al*., 2018). It creates a greater commitment to civic life, which is essential to establish lively urban ecosystems. Besides, it enables to benefit from the wisdom of the crowd, which is enacted via service co-production and value co-creation (Kuru and Ansell, 2020).

Citizens' engagement in the co-creation of a smart urban ecosystem is ripe with challenges. In fact, improper citizens' involvement may produce side-effects on the inclusiveness of the smart urban ecosystem, triggering value co-destruction due to unfairness in the participation of the community to the policy making process. Wataya and Shaw (2019) proposed a framework to address the specificities of a smart urban

ecosystem and to assess its value co-creation potential in a perspective of citizens' involvement. It assumes that the smartness of an urban ecosystem depends on its ability to tackle "…*societal and economical issues with, for, and by citizens*" (Dupont *et al*., 2015: p. 245). Citizen engagement requires an empowerment process, which may be either direct – *i.e.*, the active participation of citizens in shaping and implementing urban strategies (Carli *et al*., 2018) – or indirect – *i.e.*, accommodating individual behaviors to urban smartness' promotion (Akbari and Hopkins, 2019). Innovative technologies, such as the internet of things and the blockchain, may foster the engagement of citizens in the co-value creation process, recontextualizing relationships among value co-creators in the cyber-physical environment (Knieps, 2017). However, they can also increase the divide between advantaged and disadvantaged groups of the community, which is detrimental to citizens' engagement (Shen and Pena-Mora, 2018).

Cluster 3: advancing towards self-fulfilling communities

Even though service co-production and value co-creation are two requisites to setting up a smart urban ecosystem, they are not enough. Co-production and co-creation primarily focus on the contribution of individual citizens to urban smartness. Therefore, they do not acknowledge that smart urban ecosystems involve the transition towards cohesive and co-generating urban communities, which are established on a collective effort to boost the sustainability of smart cities (Østergaard and Maestosi, 2019).

Sustainable smartness takes its roots in the willingness of a community "*…to accept and actively promote a self-sustainable economic policy, that can be harnessed through constant participation of local associations, crowdfunding projects and other initiatives aimed at enhancing the human capital*" (Cappellaro *et al*., 2019: p. 161).

The process that leads to the construction of a self-fulfilling and co-generating community occurs through six steps: 1) the introduction of an enabling and non-binding formal regulation, which formalize expected behaviors of community members and avoid the rise of a discretionary bureaucratic power (Sanseverino *et al*., 2015); 2) the promotion of a strong territorial identity and the visioning of a consistent urban strategy intended to engage the community in territorial development (Ceglia *et al*., 2020); 3) the community empowerment and the encouragement of the collective social innovation spirit (Angelidou and Psaltoglou, 2017); 4) the improvement of available technologies and the construction of common platforms to ensure a fair participation of the community to the establishment of a sustainable smart urban ecosystem (Pramanik *et al*., 2017); 5) the reliable and timely forecasting of individual and collective behaviors to enhance collaboration and integration (Tascikaraoglu, 2018); and 6) the integrated assessment of community engagement in a perspective of urban smartness' continuous improvement (Koirala *et al*., 2016).

Cluster 4: the importance of interconnecting platforms

A self-fulfilling community needs interconnecting platforms, which have a twofold purpose: they serve as catalysts of interactions, boosting the interdependencies amongst the members of the community, and they enact frequent and thick exchanges that are essential for the success of a smart urban ecosystem (Bifulco *et al*., 2016). Therefore, it is not surprising that smart cities have been largely conceived of as platforms, which are aimed at the achievement of self-organized urban smartness through citizens' empowerment (Anttiroiko, 2016).

Interconnecting platforms fulfil four key functions, which are critical to enhance the smartness of an urban ecosystem. They primarily act as a repository of shared information, increasing the collective access to timely and reliable data that inspire individual and collective decision making processes (Encalada *et al*., 2017). Besides, they foster collaboration at different institutional levels, nurturing the social capital upon which a smart urban ecosystem is able to build its competitiveness (Bamwesigye and Hlavackova, 2017). Boosting social learning processes that are fostered by horizontal collaboration and beyond-the-box thinking, platforms feed the smart urban ecosystem's innovativeness and adaptability (Carayannis *et al*., 2017). Lastly, they allow the awarding of behaviors and decisions that are consistent with the purpose of smartening the urban community, creating involvement and commitment (Stone Jr., 2003). It is worth noting that platforms should be pervasive and should involve all the

spheres of an urban ecosystem to fully express their positive contribution to the city's smartization process (Turgel *et al*., 2019).

Cluster 5: smart cities as data-driven ecosystems

The conceptualization of smart cities as co-generating knowledge platforms implies the acknowledgement of the empowering role of technologies, which reshape the urban environment's structures and dynamics. The conjoint use of big data analytics and context-aware computing paves the way for the creation of a constellation of platforms, which integrate and build collective intelligence around the "*…physical, infrastructural, spatial, spatiotemporal, operational, functional, and socio-economic forms*" of a smart urban ecosystem (Bibri and Krogstie, 2017: p. 46). Datification and computerization define a common language to handle the interaction between those who are involved in the smart urban ecosystem's functioning, nourishing the collective urban intelligence through mutual and consistent information exchanges (Bibri, 2019a).

Literature identified several issues that should be overcome to foster the transformation of urban contexts into data-driven smart ecosystems. Uneven access to the urban computing technologies and resources should be addressed, allowing all the members of the community to benefit from the integrating role of Information and Communication Technologies (Ansari and Mehrotra, 2019). Moreover, lack of consolidated approaches and tools to initiate data-driven urban governance initiatives

should be filled in through bricolage and experimentation (Nayak and Joshi, 2019). Existing information and communication gaps among different spheres of urban governance and management need to be bridged, promoting interoperability and integration of innovative technologies applied to urban computing (Duvier *et al*., 2018). Lastly, yet importantly, the social acceptability of data-driven smart urbanism should be supported, emphasizing the way technologies bring "*…new visions on how cities as a microcosm of societies will evolve*" (Bibri, 2019b: p. 22).

Cluster 6: sustainable smart cities as knowledge-based urban ecosystems

A sustainable smart urban ecosystem has been understood as a place with a strong knowledge orientation, that derives from the conceptualization of the city as a living organism (Lu *et al*., 2015). Being a complex knowledge-based ecosystem in which a multitude of actors is concomitantly involved in complex processes of value co-creation, the success of a smart city relies on the intertwinement of network management practices and knowledge management practices (Dameri and Ricciardi, 2015). From this standpoint, multi-level governance approaches – which sustain the involvement of all relevant stakeholders in decision making processes and encourage knowledge sharing – have been argued to be especially effective to underpin the smartness of an urban ecosystem (Dameri and Benevolo, 2016).

These considerations trigger some critical reflections about the governance model of a smart urban ecosystem. Far from being understood as large-scale urban agglomerations, smart cities should be managed as vividly connected communities, where actors "*…share information and perform joint decision-making to create sustainable and equitable work and living environments*" (Damiani *et al*., 2017). Governing a smart urban ecosystem entails steering a collaborative community, whose ability and willingness to integrate available resources and to exchange current assets foster the collective smartness (Snow *et al*., 2016). Hard and soft ingredients are needed in the recipe for creating collaborative communities. On the one hand, an integrated and adaptive governance model should be designed and implemented to ensure the widest community participation to the dynamics of the smart urban ecosystem (Hudec, 2017). On the other hand, value sharing and motivation to concerted actions should be stimulated to mobilize individual resources for the progress of collective knowledge (Garau *et al*., 2017).

Cluster 7: myth or reality? Embedding greenness in sustainable cities

Sustainability and greenness are two cornerstones of a smart urban ecosystem. A smart city is usually understood as a hub of green solutions. However, embedding environment-related issues into the strategic visioning and management of a smart urban ecosystem is not an easy endeavour (Israilidis *et al*., 2019). Lu *et al.* (2018)

discussed the barriers that inhibit the ability of a smart city to include environmental and ecological concerns in their strategic and operative plan, such as the ambitiousness and ambiguity of concurring goals, the scarcity of available resources, and the weak integration and collaboration between different categories of stakeholders.

Part of the literature contends that the greening of a smart urban ecosystem is a myth, rather than a reality. The predominant individualistic approach that is embraced in promoting environmentally sustainable policies and practices is thought to generate drawbacks on the effectiveness of green solutions, since it does not contemplate the overlapping of such solutions with the broader social and economic dynamics of smart cities (Barr and Prillwitz, 2014). Besides, the focus on environmental, social, and economic performances as relatively independent phenomena prevent the design of consistent interventions intended to cope with the complex eco–social–economic relationships underlying the proper functioning of a smart urban ecosystem (Ahmad and Mehmood, 2015). Finally, the absence of a meta-organization which connects the different stakeholders, aggregates information, nourishes individual and collective knowledge, and creates commitment to accomplish sustainable goals may weaken the desirability and feasibility of greening policies and practices (Rajabion *et al*., 2019).

Cluster 8: smart cities as citizen-centred and socially sustainable entities

The merge of economic growth and environmental protection is necessary, but it is not sufficient to boost the smartness of an urban ecosystem. Smart cities rely on a third pillar, that is social sustainability, or the ability to safeguard "*…human rights together with the promotion of community social capital and citizens' empowerment*", enacting a smart citizenship (Marsal-Llacuna, 2016: p. 1198). In line with these considerations, it should be noted that the achievement of a smart citizenship does not occur "*…by expanding the possibilities of democratically engaged citizens, but rather by delimiting the practices constitutive of citizenship*" (Gabrys, 2014: p. 45).

The construction of a smart urban citizenship and the implementation of a citizen-centred and socially sustainable urban ecosystem progress through three steps. At the beginning, a social standardization of citizens' duties and rights is required to minimize risks of unequal participation of citizens to the functioning of the smart urban ecosystem (Marsal-Llacuna, 2017). Next, the strengthening of collective urban identities through material and immaterial artifacts is needed to encourage citizens' sense of belonging and participation to the promotion of urban smartness (Sepe, 2014). Thirdly, and lastly, the awakening of citizens' dormant assets and their activation to enhance the viability of the urban ecosystem reinforce the smart urban citizenship and activate a self-nourishing cycle, which fosters urban smartness (Marciano, 2013).

Cluster 9: governing the sustainability of smart urban ecosystem

Embracing an organizational point of view, smart urban ecosystems can be conceived of as place-specific organizational fields, whose structures are designed according to a configurational approach. Such an approach is articulated in two stages: a high-level phase, which permits to outline the boundaries of the urban ecosystem, and a bottom-level stage, which focuses on the roles of individual actors involved in the functioning of the city (Pierce *et al*., 2017).

The high-level stage consists of the activities that are intended to elicit and assess the tangible and the intangible elements that intervene in the process of urban smartization (Wu and Chen, 2019). The identification of the smart urban ecosystems' boundaries within which such elements can be retrieved should be realized acknowledging that smart cities have an "*…open, nonlinear, fluctuating, and non-equilibrium nature*" and that their development is affected by "*…synergetic, competitive, chaotic, orderly, and self-similar mechanisms*", resembling self-organizing systems (Yan *et al*., 2020: p. 2). Rather than delimiting the contours of a smart urban ecosystem, the high-level analysis should be intended to point out the relevant actors and the distinguishing attributes of smart cities, informing the subsequent phase (Raspotnik *et al*., 2020).

The bottom level stage starts with the design of a co-governance model that is consistent with the nature of smart cities as complex socio-technical systems (Ben Yahia *et al*., 2019). The co-governance model is not static. Rather, it co-evolves with

the smart urban ecosystem. During the initiation phase, attention is primarily paid to the arrangement of cooperation strategies and to the strengthening of trust and loyalty among urban actors through a transformational leadership approach. During the growth stage, the focus is put on goal setting and motivation, sticking to a transactional style of leadership to create commitment and cohesion (Ooms *et al*., 2020). The co-governance model is then articulated in a strategic plan, whose purpose is to determine the requisites and the conditions for integration among the actors who are involved in the functioning of a sustainable smart urban ecosystem (Marzouk and Othman, 2020). In the strategic plan, the co-governing body defines its own role of regulator, enabler, and provider of smart solutions intended to foster infrastructures and resources' sharing among the members of the urban ecosystem (Zvolska *et al*., 2019). In addition, the modes of citizens' involvement in value co-creation and service co-production are formalized, emphasizing their contribution to the success of the smart city (Berquier and Gibassier, 2019). Lastly, a tailored performance measurement system is arranged to create agreement and commitment to the strategic aims that steer individual and collective actions (Brorström *et al*., 2018).

Cluster 10: managing the smart urban ecosystem

The effective management of smart cities is established on nine horizontal layers, that involve (Russo *et al*., 2014): 1) context-specific and non-constraining policies; 2)

integrated planning; 3) citizen centredness; 4) knowledge sharing; 5) openness of data and information; 6) communication protocols; 7) consistent business models; 8) tailored funding schemes; and 9) integrated measurement management systems.

As previously anticipated, conventional bureaucratic approaches in arranging smart policies and regulations trigger institutional compartmentalism, poor convergence, and lack of integration, which do not fit with the need for flexibility and adaptability of smart urban ecosystems. Post-bureaucratic thinking is required to craft context-specific urban policies that are consistent with the specificities of a smart city (Praharaj *et al*., 2018). Integrated planning allows to account for the heterogeneous and partially diverging expectations of stakeholders interested to the social, environmental, and economic features of a smart urban ecosystem, making conflicting perspectives explicit and avoiding subtle struggles (Li and Ren, 2019). Citizens-centredness is essential for this purpose, addressing the propositions and the behaviors of stakeholders towards the empowerment of the community and the enhancement of individual and collective well-being (Caputo *et al*., 2019).

Knowledge – and, more in general, resource – sharing represents the distinguishing attribute of a smart urban ecosystem. Organizing and managing a smart city basically imply dealing with complex and evolving systems of exchanges among the actors who constitute the urban ecosystem and sustain its intellectual and social capital (Heddebaut and Di Ciommo, 2018). Knowledge sharing is enabled by a pervasive and distributed

big-data architecture, which ensure the full availability of relevant information to the members of the smart urban ecosystem (Villegas-Ch *et al*., 2019). Besides, communication protocols and standards are required to facilitate mutual connections and exchanges (Boukhechba *et al*., 2017).

The business model that is designed to address the exchanges between people and organizations should be tailored to the dynamic capabilities that underpin the competitiveness of a smart urban ecosystem. The business model should create alignment among the urban actors and should enhance their change capability via increased awareness of available opportunities and greater willingness to exploit them (Chong *et al*., 2018). Since large amount of resources are needed to support the continuous growth of the smart urban ecosystem, appropriate financial tools should be used to sustain the implementation of the business model. Alongside external financial sources, a smart city should activate autonomous revenue streams to reduce its dependency from outside stakeholders (Vadgama *et al*., 2015). Lastly, sound performance management systems based on integrated key performance indicators that emphasize both individual and collective contributions to the success of the smart urban ecosystem are quintessential for the long-term viability of a smart city, promoting the commitment of urban actors to the urban smartization process (Salvia *et al*., 2016).

Cluster 11: sustaining the smartness of smart urban ecosystem

Preserving and cultivating smartness is the biggest challenge for a smart urban ecosystem. Literature argues that the ability of a smart urban ecosystem to sharpen its smartness depends on its effectiveness to combine top-down and bottom-up initiatives, exploiting their synergistic effect on the urban innovation capacity (Capdevila and Zarlenga, 2015). Top-down interventions involve the design and the adoption of an integrated, multidisciplinary approach to cope with the macro-level issues that affect the behaviors of the actors who participate in the functioning of a smart urban ecosystem (Rahul *et al*., 2018). Such an integrated approach enacts the arrangement of a shared roadmap, which elicits the interdependencies among actors and exploits them for the purpose of information sharing and knowledge creation (Lee *et al*., 2013). Alongside supporting decision making processes and integrating economic, social, and environmental evaluations (Rybnytska *et al*., 2013), this stimulates the responsiveness of a smart urban ecosystem, improving the ability to acknowledge the multifacetedness of urban phenomena (Song *et al*., 2017). Bottom-up interventions are aimed at shedding light on the evolving needs of citizens, contextualizing them to the cyber-physical setting of a smart urban ecosystem (Carrasco-Sáez *et al*., 2017). They are also intended to stress the contribution that individual actors can bring to enhancing the smartness of a city, supporting individual commitment to urban growth and development (Crovini *et al*., 2019). The smartness of an urban ecosystem is rooted into the collective

consciousness of individual actors, that permits to shift towards a distributed and fully-democratic governance of smart cities (Woodhead, 2018).

Discussion

Conceptual and practical implications

The research findings are summarized in Table 1, which synthesizes the main theoretical and practical implications of this study. From a conceptual point of view, the results shed light on the building blocks that underpin a smart urban ecosystem which is oriented towards sustainability. As graphically depicted in Figure 3, the smartness of an urban ecosystem relies on a tripartite policy framework which accounts for the social, economic, and environmental challenges faced by smart cities to achieve a fair and viable growth (Fu and Zhang, 2017). Urban services' co-production and value co-creation explicate such an integrated policy framework (Cappellaro *et al*., 2019). Co-creating relationships among the actors and stakeholders who are either directly or indirectly involved in the functioning of a smart urban ecosystem trigger a greater collective ability to handle the trade-offs between the social, environmental, and economic dimensions of the smart city, enhancing its long-term sustainability (Appio *et al*., 2019).

[Please, put Table 1 about here]

[Please, put Figure 3 about here]

Community empowerment and citizens' engagement are essential to foster the transition towards a sustainable socio-economic growth of smart urban ecosystems, paving the way for a self-fulling approach to urban planning and management (Yu *et al*., 2019). Nevertheless, literature has warned of the challenges that are evoked by citizens' involvement. The prevailing paternalistic and pragmatic discourse around smart urbanism neglects the acknowledgement of social rights to citizens. This may determine a failure in bestowing a smart political citizenship to people, undermining the active participation of the community in service co-production and value co-creation (Cardullo and Kitchin, 2019). In spite of the efforts that are accomplished to empower citizens and to involve them in the functioning of a smart urban ecosystem, (Teli *et al*., 2020), the degree of people engagement is curtailed by behind the scene selfish interest of dominant stakeholders, who may be willing to constrain the breadth of the smart city policy discourse (Mattern, 2020). This leads to the need for envisioning a brand new idea of smart urbanism, which stresses decentralization and life-cycle planning to merge ecological, economic, and social sustainability in daily decision making processes of a smart urban ecosystem (Fu and Zhang, 2017).

A threefold meso-level architecture should be designed to sustain the macro-level components that enact the smartization of the urban ecosystem. Firstly, interconnecting platforms create a thick web of communication exchanges linking all the actors of the smart urban ecosystem. They enable data and information sharing and nourish the social

capital available within the community of actors (Lee *et al*., 2013). Besides, they enact a multisensory urban engagement (Barns, 2020), reshaping the everyday socio-spatial experience of smart cities to facilitate citizens' participation (Barns, 2019) and allowing "*...a range of socio-technical engagements (…) being negotiated daily by a range of actors both within and outside city administrations*" (Barns, 2018: p. 11).

Interconnecting platforms are fed by advanced data-driven technologies that, via datification and computerization, set a common language and facilitate the transformation of social capital into collective intelligence (Bibri, 2019a). The transition towards computerization and datification should be handled carefully. Even though it has been argued that citizens have a right to a digital city which takes advantage of ICTs to enhance the individual ability to participate in the smartization of urban ecosystems (Foth *et al*., 2015), becoming too digital may constrain – rather than empower – citizens (Sadowski, 2020). The reliance on algorithms and big data is thought to entail a dehumanization of cities, triggering a surveillance – rather than an enabling – approach to urban governance (Zuboff, 2019). This may pave the way for increased oppression and inequality, which are not consistent with the transition towards a sustainable urban smartness (O'Neil, 2016 and Noble, 2018). To deal with this issue, a digital enough principle should be adopted, maximizing the enabling role of ICTs and minimizing the side effects of datification and computerization on urban ecosystems' dehumanization (Green, 2019).

Lastly, common knowledge repositories act as the central brain of the smart urban ecosystem, collecting the intellectual capital and coordinating the exchange of data and information that stimulate collective intelligence (Qian *et al*., 2019). These repositories enact an instrumental rationality, which increases the ability of a smart urban ecosystem to timely and effectively address the challenges that may put its sustainability under stress (Palumbo, 2014). The realist epistemology that is attached to instrumental rationality should be accompanied by an ethical framing of urban issues, recognizing their contingent and relational nature (Kitchin, 2016).

Two micro-level values inspire the integration of the macro-level policies and the meso-level architecture that compose a sustainable smart urban ecosystem. Greenness should be understood as the *leitmotiv* guiding the governance and the management of a smart city (Vinod Kumar, 2020). It should replace the technocentricity that has characterized most of urban smartization processes, intertwining social development, economic growth, and environmental viability (Yigitcanlar *et al*., 2019_a). Moreover, citizen-centredness is needed to make a smart city the best places to live for people, targeting a continuous improvement of individual and collective wellbeing (Certomà *et al*., 2017). A post-anthropocentric perspective should be embraced to establish a bridge between greenness and citizen-centredness (Yigitcanlar *et al*., 2019_b). Whilst greenness takes into account the need for balancing economic affairs with environmental issues, citizen-centredness accounts for the social viability of the smart urban ecosystem

(Kankaala *et al*., 2018). The juxtaposition of smartness, greenness, and citizen centredness boosts the self-nourishing ability of smart urban ecosystems to achieve a socially and environmentally sustainable economic growth (Macke *et al*., 2019). This calls for a more than human approach in the design and organization of a smart urban ecosystem that addresses the social needs of people, even though it rejects human privilege in undertaking strategy and management decisions (Forlano, 2016).

From a practical perspective, the study alleges that a smart urban ecosystem is dependent on the contribution of two focal actors: local public authorities and technological partners. Local public authorities have a regulating and orchestration role: they formalize the interactions between the members of the ecosystem, coordinate exchanges among them, and steer the high-level and the bottom level governance stages of a smart urban ecosystem (Vilajosana *et al*., 2013). Local public authorities should endorse a post-human model of urban ecosystems' design (Forlano, 2017), acknowledging that a focus on technology-based smartization is likely to nurture a disconnection between aspirational and actual levels of urban viability (Loh *et al*., 2020). Technological partners have an enabling role in the development of a smart urban ecosystem. They provide with the data-driven and ICT-based solutions to accommodate the nonlinear and fluctuating nature of a smart city. Promoting information sharing and knowledge creation, technological partners support the self-organization capability of a smart urban ecosystem (Duvier *et al*., 2018). Lastly,

bridging the gap between local authorities and citizens, they set the conditions for the active involvement of the community in value co-creation (Bibri, 2019b).

The focal actors are expected to express diverging propositions and approaches, condition that may negatively affect the governance of a smart urban ecosystem (Macke *et al*., 2019). Local authorities are generally inclined to a bureaucratic model of urban governance, which intends to create vertical and horizontal alignment among relevant stakeholders and to seize the opportunities for the urban ecosystem's expansion (Dameri and Benevolo, 2016). Technological partners are intrinsically oriented towards a technocratic approach to urban governance, that is driven by advances in the technological realm and is targeted to a full contextualization of the interactions among the members of the ecosystem in the cyber-physical environment (Bibri and Krogstie, 2017). The viability of the smart urban ecosystem is affected by the ability of finding a compromise between these two models in an attempt to address the dynamics and the evolution of a smart urban ecosystem. It is possible to exploit and combine both the consistency of the bureaucratic model and the flexibility of the technocratic approach, avoiding the side effects of their clash on citizen centredness (Joss *et al*., 2017). The implementation of a techno-bureaucratic governance model is expected to enhance the citizens' participation in the decision-making processes of smart cities, increasing the transparency of bureaucratic actions, minimizing the risks of exploitation of

disadvantaged classes by social elites, and paving the way for greater opportunities of citizens' involvement (Ruhlandt, 2018).

For this to happen, people need to obtain a data sovereignty, being able to control and manage data and information that are related to the functioning of the smart urban ecosystem (Kukutai and Taylor, 2016). The right of underprivileged people to data sovereignty should be especially ensured, promoting their comprehensive and fair involvement in the governance of a smart city (Walter and Suina, 2019). Data sovereignty is the first step towards technological sovereignty, which is thought to reduce people anxieties of control when confronted with the technocratic side of smart urbanism (Leszczynski, 2015). Moreover, it stimulates the citizens' willingness to have an active role in the design of a smart urban ecosystem (Leszczynski, 2020). Going beyond personal control and enacting collective empowerment, technological sovereignty allows "*...to invert asymmetrical power relationships (...) between corporations, governments and data subjects, while providing avenues for greater citizen and citizenry autonomy*" (Mann *et al*., 2020: p. 7).

Community inclusion and engagement in the functioning of an urban ecosystem is a distinctive attribute for sustainable smartness. However, tailored modes and forms of community involvement should be crafted. Since citizens may not be aware of their potential contribution to the success of a smart urban ecosystem, an empowerment process is required. Empowerment is intended to awaken the 'dormant' assets of

citizens, activating them for the purpose of value co-creation. An involvement process follows, that aims at establishing physical and digital contexts for citizens' participation in urban service co-production. An engagement phase concludes the process of community involvement, acknowledging the importance of citizen centredness for urban smartness' development (Palumbo, 2016).

Agenda for future research

Further developments are needed to advance what is currently known about the establishment and the organization of a sustainable smart urban ecosystem. To illuminate avenues for future research, a keyword analysis of the scientific contributions included in this literature review was performed. Figure 4 visualizes the 100 most representative keywords obtained from the analysis. On the right side of Figure 4, themes related to the transition toward a techno-bureaucratic approach to smart urban ecosystems' governance emerge. In this domain, issues concerning data-driven smart growth and technology-enabled sustainability are especially relevant. Future studies should pay attention to the manifold implications of innovative technologies that foster the datification and computerization of smart urban ecosystems (*i.e.*, blockchain, internet of things, big data, and context-aware computing). They trigger increased opportunities for information sharing and collective intelligence creation. Also, they enact a cognitive and operative alignment among the actors of the smart urban

ecosystem, which significantly contributes to the long term viability of smart cities. However, datification and computerization generate ethical challenges, which should be carefully investigated and addressed. The technocentricity that characterized most of advancements in the field of smart urban ecosystems led to a sort of dehumanization of urban governance. A contextualization of data sovereignty to citizen-centredness is needed for illuminating the dark side of technocentricity in the smart policy discourse and for balancing datification and computerization with a citizen-centric view of smart urban ecosystems.

[Please, put Figure 4 about here]

The left side of Figure 4 puts emphasis on topics related to community engagement and citizens' active involvement in the functioning of a smart urban ecosystem. The conceptualization of smart cities as open organizational fields and collaborative spaces will assist to better understand the specificity of citizens' participation in urban services' co-production and value co-creation. Platformization and cyber-physical architectures are critical tools to boost citizens' engagement in the strategic and management decisions of a smart urban ecosystem. This aspect seems to have gained increasingly attention of scholars and practitioners and this trend may continue in the near future. However, further attention should be paid to the capability of smart urban ecosystems to ensure the engagement of underprivileged groups of the population in the digital architectures that are implemented to promote citizens' involvement in value co-

creation. In fact, the smartness of an urban ecosystem may be prevented by the inability to account for the special needs of categories of agents which have not been conventionally involved in framing the urban policy discourse because of their weak political and social representation.

Whilst studies dealing with citizen-centredness prevailed in the past years, datification and computerization represent the main focus of current literature. A merge between these two research streams is required to provide new insights about citizens' empowerment and engagement enacted by technological innovations. It should be acknowledged that a transition towards a post-human model of urban governance is needed for achieving the conjoint purposes of economic, ecologic, and social sustainability that underpin the viability of a smart urban ecosystem. This raises new research questions that should be thoroughly addressed in forthcoming research, as briefly reported in Table 2. Both conceptual and empirical studies may provide answers to such questions, pushing forward what we know about the structuring and the functioning of a sustainable smart urban ecosystem.

[Please, put Table 2 about here]

Conclusions

This study attempted to overcome the fragmentation that characterizes the extant scientific debate about sustainable smart urban ecosystems. Such an endeavour was

accomplished from both a theoretical and a practical point of view. Adopting a conceptual slant, the study findings pointed out the need for recontextualizing the building blocks that underpin the smartness of an urban ecosystem according to a socio-material perspective. A sustainable smart city relies on an integrated and tripartite policy framework, which is intended to accommodate economic growth with an enhanced ability to preserve social and environmental sustainability. Acknowledging smart cities as complex and continuously evolving socio-technical ecosystems, this literature review encourages to pay attention to the reconciliation between the hard and the soft ingredients that are required in the recipe for urban smartness. The platformization and the datification of a city is an unavoidable step in the transition towards smart urban ecosystem. However, they should be integrated with entitlement of a smart urban citizenship to people, here included disadvantaged groups of the population. This calls for a process of citizens' empowerment, involvement, and engagement, which is crucial to accomplish a fully-fledged participation of people in urban services' co-production and value co-creation.

From a practical perspective, the study recommends that the success of a sustainable smart urban ecosystem primarily depends on the joint contribution of two focal actors: local authorities and technological partners. Whilst the former focus on the arrangement of a smart governance which is targeted to the empowerment of citizens and to the achievement of a socially and environmentally sustainable economic growth, the latter

set the conditions for information and resources' sharing, which is quintessential to foster the smartization of urban ecosystems. The better the alignment between these actors and the more effective their conjoint efforts to realize citizen centredness in a post-human perspective, the greater the ability of a smart urban ecosystem to develop a rich and self-nourishing collective intelligence, that is at the basis of a long-term urban viability.

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Table 1. An overview of the research findings

Cluster no.	Color	Main theme	Key contents	Key references
Cluster no. 1	Red	The policy and politics of sustainable smart urban ecosystems	A tripartite – economic, social, and environmental – perspective is required to enact the smart city policy discourse. The multifacetedness of this discourse may pave the way for ambiguities and contradictions. Stakeholders' engagement and incrementalism are concomitantly required to overcome this situation. Since social elites are able to enter the smart city policy discourse with a predominant role, attention should be paid to the risks of exclusion and marginalization of disadvantaged groups of the population	de la Cruz, 2009; Fu and Zhang, 2017; March and Ribera-Fumaz, 2016
Cluster no. 2	Yellow	The co-production imperative to nurture urban sustainability	Citizens' participation in policy making and decision making processes are key features of smart urban ecosystems. Involvement is a requisite for urban services' co-production and value co-creation, which underpin the smartness of urban ecosystems. A tailored value co-creation framework should be designed to boost citizens' engagement and minimize the risks of co-value destruction entailed by improper citizens' involvement	Carli *et al*., 2018; Dupont *et al*., 2015; Shen and Pena-Mora, 2018
Cluster no. 3	Purple	Advancing towards self-fulfilling communities	Smart urban ecosystems involve the transition towards cohesive and co-generating urban communities. Non-binding regulation, territorial identity, community empowerment, availability of interconnecting technologies, forecasting of individual and collective behaviors, and continuous nourishment of community engagement are key to establish a cohesive and co-generating smart urban ecosystem	Angelidou and Psaltoglou, 2017; Koirala *et al*., 2016; Pramanik *et al*., 2017
Cluster no. 4	Orange	The importance of interconnecting platforms	Smart cities should be understood as platforms, which aim at the achievement of self-organized urban smartness through citizens' entrustment and empowerment. Platforms should be pervasive and they should act as: 1) repository of shared information; 2) a collaboration mechanism; 3) a social learning space; and 4) a catalyst of commitment and involvement	Anttiroiko, 2016; Bifulco *et al*., 2016; Encalada *et al*., 2017
Cluster no. 5	Fuchsia	Smart cities as data-driven ecosystems	Technologies provide new visions on how cities will evolve acting as a microcosm of societies. Datification and computerization set a common language to foster interactions between agents who are involved in the functioning of the smart urban ecosystem. Data-driven smart urbanism permits us to timely address the unprecedented governance and management challenges faced by smart urban ecosystems	Bibri, 2019; Bibri and Krogstie, 2017_a; Duvier *et al*., 2018
Cluster no. 6	Brown	Sustainable smart cities as knowledge-based urban ecosystems	Smart urban ecosystems can be metaphorically conceived of as living organisms with a strong knowledge orientation. From this standpoint, a combination of network management and knowledge management practices is needed for ensuring the viability of smart urban ecosystems. Among others, multi-level governance approaches are especially effective to steer the growth of smart urban ecosystems	Dameri and Ricciardi, 2015; Lu *et al*., 2015; Snow *et al*., 2016
Cluster no. 7	Cyan	Myth or reality? Embedding greenness in sustainable cities	Although greenness is a cornerstone of smart urban ecosystems, embedding environment-related issues into the strategic visioning of smart cities is not an easy endeavour. Ambiguity of concurring goals related to the tripartite, ecological, economic, and social interpretation of smart cities, the scarcity of available resources, and the weak integration among different stakeholders are relevant barriers to embedding greenness in sustainable cities	Capdevila and Zarlenda, 2015; Carrasco-Sáez *et al*., 2017; Lee *et al*., 2013
Cluster no. 8	Pink	Smart cities as citizen-centred and socially sustainable entities	Social sustainability is quintessential to the smartization of urban ecosystems. It entails a smart urban citizenship which recognizes the need for safeguarding human rights together with the promotion of community social capital and citizens' empowerment. Citizens' empowerment, strengthening of collective urban identities, and a social standardization of citizens' duties and rights are required for this purpose	Bibri and Krogstie, 2017_b; Gabrys, 2014; Marsal-Llacuna, 2016
Cluster	Dark	Governing the	Smart urban ecosystems are place-specific organizational fields, whose structuring involves a high-	Brorström *et al*., 2018;

no. 9	green	sustainability of smart urban ecosystem	level stage (*i.e.*, the outlining of the ecosystem's boundary) and a bottom-level stage (*i.e.*, the definition of individual roles and tasks). The co-governance model which results from these two steps permits to define the approaches of citizens' active involvement in the process of value co-creation and identifies a tailored performance measurement system to assess the growth of the smart urban ecosystem	Pierce *et al*., 2017; Wu and Chen, 2019
Cluster no. 10	Blue	Managing the smart urban ecosystem	Since smart urban ecosystems show a need for flexibility and adaptability, conventional bureaucratic approaches to arrange smart policies and regulations should be avoided in order to minimize compartmentalism, poor convergence, and disintegration. Effective smart urban ecosystem governance model relies on citizen-centredness and resource sharing, facilitating integration via increased connections and exchanges	Chong *et al*., 2018; Russo *et al*., 2014; Vadgama *et al*., 2015
Cluster no. 11	Light green	Sustaining the smartness of smart urban ecosystem	The urban ecosystems' ability to sharpen smartness depends on the combination of top-down and bottom-up initiatives, exploiting their positive, synergistic effect on the urban innovation capacity. Whilst top-down interventions tackle the macro-level challenges that affect the success of smart urban ecosystems, bottom-up actions are aimed at contextualizing the evolving need of citizens into the cyber-physical setting of smart cities	Ahmad and Mehmood, 2015; Barr and Prillwitz, 2014; Lu *et al*., 2018

Table 2. Avenues for further developments and future research questions

Future Research Questions	Main Focus	Related clusters	Most fitting research design(s)
F.R.Q. 1	What are the side effects of computerization and datification on the smartization process of urban ecosystems?	Clusters nos. 1, 4, 5, 6, 10, and 11	Quantitative longitudinal and cross-sectional empirical research Systematic Literature Reviews Bibliometric Analysis
F.R.Q. 2	How can citizen-centredness be contextualized to the platformization that is typical of smart urban ecosystem?	Clusters nos. 2, 3, 5, and 8	Qualitative, in-depth empirical research Conceptual advancements
F.R.Q. 3	What are the implications of the increased use of cyber-physical architectures on citizens' empowerment and involvement in smartening urban ecosystems?	Clusters nos. 2, 3, 8, 10, and 11	Quantitative longitudinal empirical research Experimental research
F.R.Q. 4	What are the requisites to the implementation of a post-human model that combines the tripartite, ecologic, economic, and social policy priorities of smart cities?	Clusters nos. 1, 6, 7, 8, and 9	Grounded theory development Critical research methods
F.R.Q. 5	How is it possible to address the drawbacks of smart cities' technocentricity on urban policies and governance's dehumanization?	Clusters nos. 3, 4, 5, 8, 10, and 11	Qualitative, in-depth empirical research Quantitative longitudinal and cross-sectional empirical research

Figure 1. The three-steps study protocol

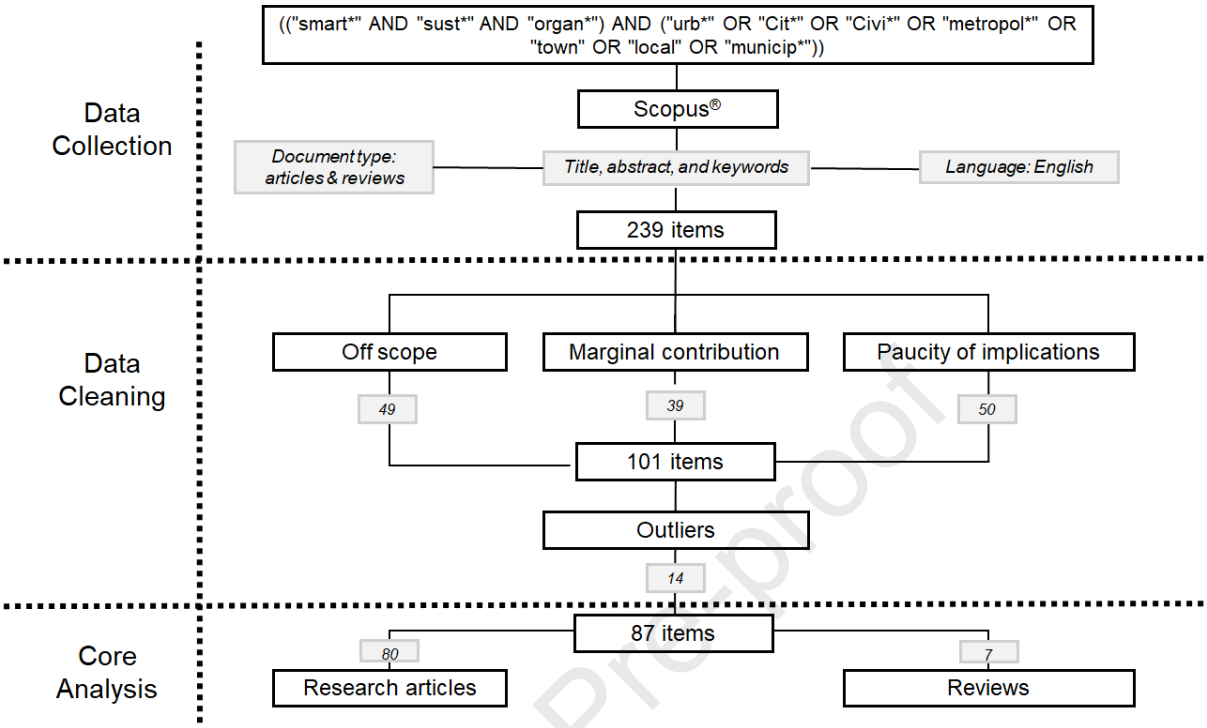


Figure 2. The cluster analysis' output

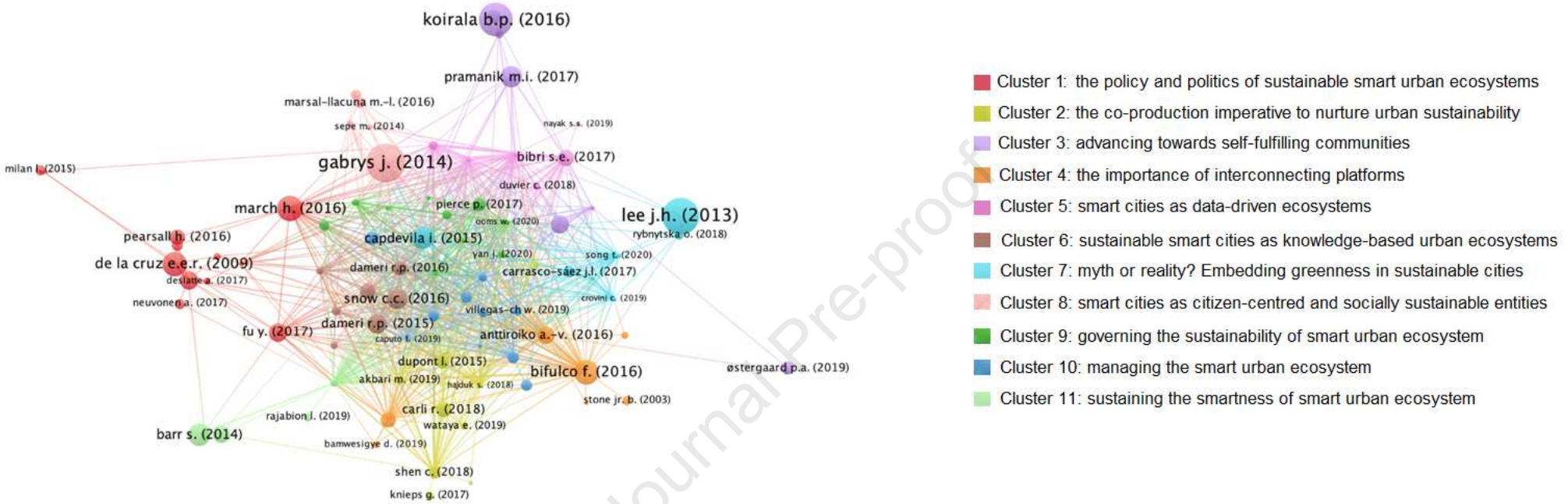


Figure 3. The “building blocks” of smart urban ecosystems

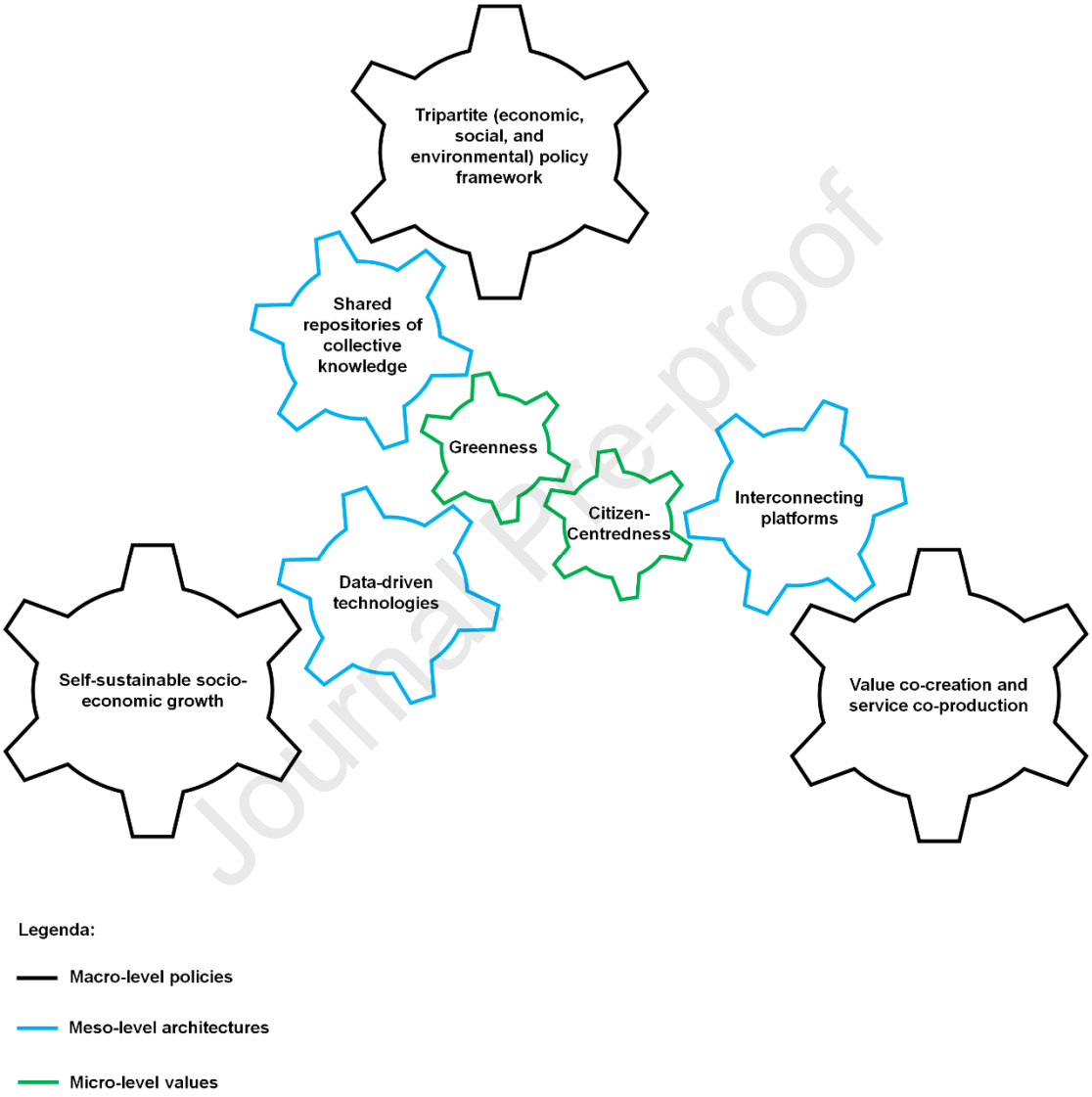
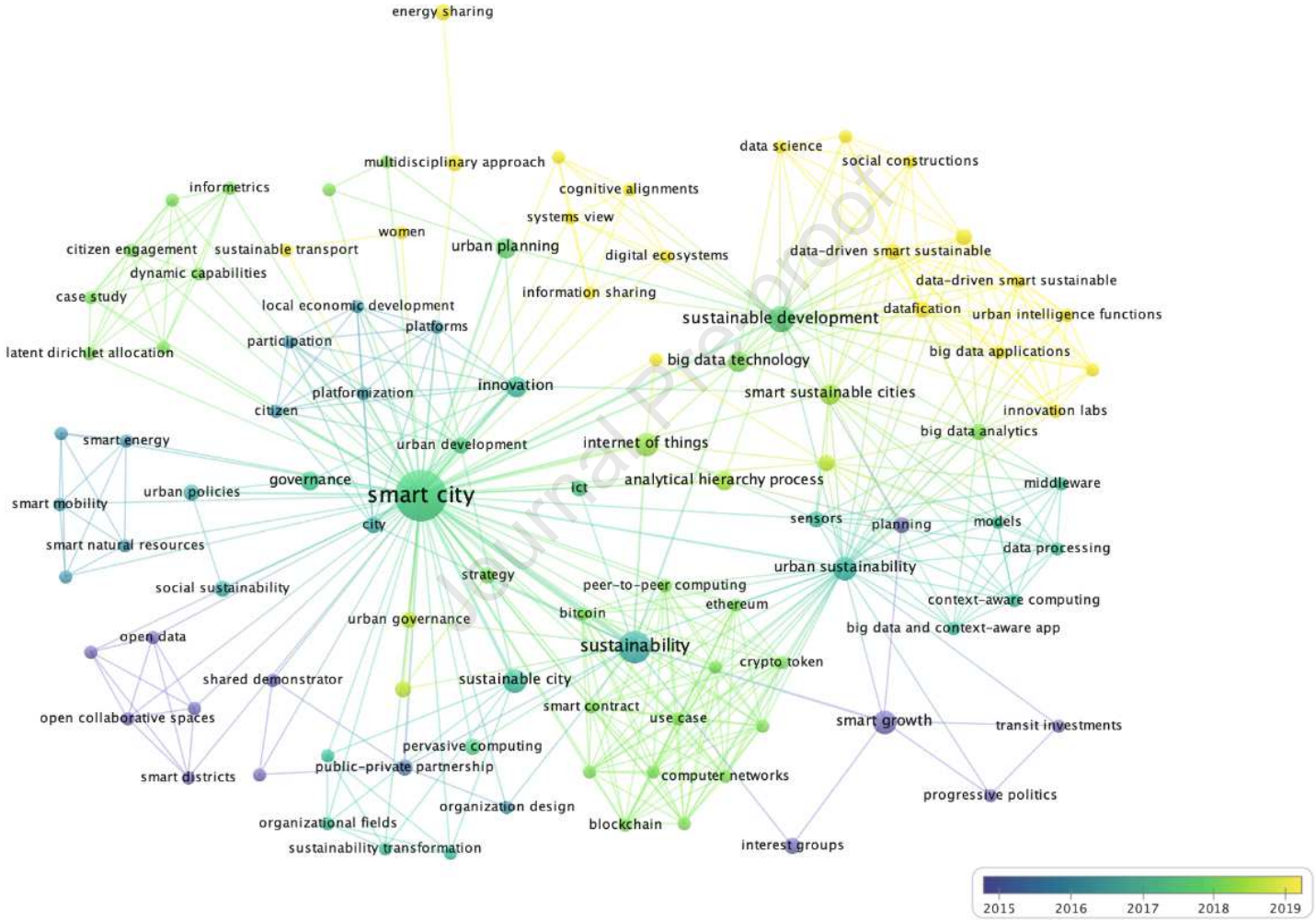


Figure 4. Avenues for further research triggered by keywords' analysis



Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: