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An Alternative Discourse on the Shrinking City
: Through the Lens of the Smart City*

Jang, Seok-Gil Denver** · Bayarsaikhan, Tsolmon*** · Gim, Tae-Hyoung Tommy****

Abstract

The attention on shrinking cities has recently shifted from analyzing the causes of urban shrinkage to its context and dynamics. Hence, demand is currently increasing for strategic alternatives to the transition towards a sustainable urban system in shrinking cities. Using optimized measures based on information and communication technologies, smart city approaches are being considered as a solution for overcoming the limitations of current policy responses to shrinking cities, and for transforming their urban systems in a sustainable way. However, studies on a comprehensive analysis of varied contexts and types of smart city approaches to urban shrinkage are few, as previous studies have focused on identifying smart city strategies in only specific cases of shrinking cities. Thus, this study analyzes the main topics and structural features of smart city discourses as an alternative to a shrinking city, through a network analysis of 264 literature samples (119 journal articles, 111 conference papers, and 34 books) that discuss smart city approaches in terms of urban shrinkage. The main topics fall into five clusters: (1) urban system, (2) innovation, (3) infrastructure, (4) environment, and (5) big data, with the systematic elements (urban system, innovation, and big data) having a higher number of nodes and link strength than the physical ones (infrastructure and environment).

Keywords Shrinking City, Smart City, Sustainability, Big Data, Network Analysis
주제어 축소도시, 스마트도시, 지속가능성, 빅데이터, 네트워크 분석

Ⅰ. Introduction

In recent policy responses to urban shrinkage, efforts have been made toward adaptive responses (e.g. smart shrinkage and right-sizing), rather than the existing tendency toward pro-growth policies. However, applying such responses in shrinking cities is often treated within transitional strategies in pursuit of urban regrowth, i.e. a return to the previous state (Coppola, 2019). Such framing lacks the capability for a new, sustainable approach to development in shrinking cities (Hackworth, 2015), thus the need continues for alternative strategies to cope with urban shrinkage. In particular, although recent responses focus on strategies to balance multiple policy agendas for urban issues rather than a sin-

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** Ph.D. Candidate, Graduate School of Environmental Studies, Seoul National University (First Author: jjsk0327@snu.ac.kr)
*** Ph.D. Candidate, Graduate School of Environmental Studies, Seoul National University (stsweety@snu.ac.kr)
**** Associate Professor, Graduate School of Environmental Studies, Interdisciplinary Program in Landscape Architecture, Integrated Major in Regional Studies and Spatial Analytics, and Environmental Planning Institute, Seoul National University (Corresponding Author: taehyoung.gim@snu.ac.kr)

gular agenda, the existing urban systems of shrinking cities are considered to have limitations of their integrated management (Bernt et al., 2014).

Also, urban shrinkage emerges from a complex interaction among various drivers (Wolff and Wiechmann, 2018), but most shrinking cities are facing insurmountable problems in the process of change, regardless of what causes their shrinkage and their geographical context (Eraydin and Özatağan, 2021). Meanwhile, transforming traditional cities into smart cities (hereafter, "SCs") is regarded as a socio-cultural process for more sustainable urban development, rather than as a static outcome (Lee et al., 2023). Against this backdrop, the global attention to redeveloping cities (including shrinking cities) into SCs has increased significantly with the availability of cutting-edge technologies, notably the emergence of the Internet of things (IoT) (Wey and Peng, 2021).

In the context of urban shrinkage, SC technologies are expected to become promising tools for systematic management (Ma et al., 2020). Such technologies can provide various functions to achieve multiple agendas effectively, via the use of optimized measures. In particular, SC development in shrinking cities could contribute to promoting sustainable economic growth and advanced infrastructure capabilities (Ghosh et al., 2019), as well as improving the urban environment and public service, as their main challenges (Liu et al., 2020). However, SC development also faces limitations such as financial sustainability, functional suitability, and reproducibility[1] that need to be solved (Araral, 2020; Han et al., 2022). Thus, further discussions are needed to develop strategic options for addressing urban shrinkage, on the basis of transitioning toward a new urban system.

Among the primary studies analysing SC approaches to shrinking cities, Ghosh et al. (2019) and Schackmar (2020) conducted case studies to identify SC strategies in shrinking American and European cities with a developed theoretical SC framework. Han et al. (2022) analysed the effect of smart city pilot projects on urban shrinkage in China, using difference-in-differences (DID) analysis as a quasi-experimental design. These studies, however, have tended to treat SC discourses and shrinking city discourses separately, then synthesizing them into a theoretical background. Moreover, few studies analyse the types and contexts of SC approaches to urban shrinkage, and there is a need to determine the main topics and structural features constituting the relationship between the discourses of the two city models, including a consideration of relationships among the components.

Recently, for discourse analysis, text mining and bibliographic analysis have been used to identify relevant terms and characteristics without the intervention of researchers' prior knowledge, utilizing a large dataset of literature (Altaweel et al., 2019; Wiedemann, 2019). Text mining techniques, particularly network analysis, are suitable for examining links, mechanisms, and intersections of discourses across different fields, topics, and subjects, compared to conventional content analysis (Cheng et al., 2018).

This study therefore aims to analyse the topics and features of SC discourses that consider it as an alternative to a shrinking city, conducting a network analysis on a total of 264 sources—119 journal articles, 111 conference papers, and 34 books—that discuss SC approaches in response to urban shrinkage. The findings could contribute to a basis for a typology of SC approaches and for evaluating the smartness of policy and planning factors in shrinking cities.

This article is structured as follows. The next section offers a review of the literature on policy responses to urban shrinkage and SC approaches as strategic solutions for it. Then, a methodology is presented for data collection, pre-processing, and network analysis. The results cover keyword analysis for frequency and centrality, and network cluster analysis for structural features among the main topics. The study concludes with a summary and a discussion of policy implications.

II. Literature Review

1. Policy Responses to Urban Shrinkage

Bias towards any singular agenda in shrinkage cities can only lead to short-term effects in response to urban shrinkage, and recent responses have tended to centre on developing strategies to balance different policy agendas (Han et al., 2022). Thus, Eraydin and Özatağan (2021) argued that a critical review is needed to identify which challenges are addressed in policy making, and how they are transformed into policy agendas and evaluated in shrinking cities. Moreover, the attention on urban shrinkage has shifted from its causes to its context and dynamics (Großmann et al., 2013).

Hence, it is becoming important to understand how the structural features of urban shrinkage result from different drivers (Wolff and Wiechmann, 2018), in order to respond effectively to different policy agendas in shrinking cities.

Policy responses to urban shrinkage are classified according to how they react: by (1) trivializing shrinkage, (2) countering shrinkage, (3) accepting shrinkage, and (4) utilizing shrinkage (Hospers, 2014). Shrinking cities have adopted different paths to recover their local economies and quality of life, in line with their contexts (Hollander and Németh, 2011). Although adaptive response efforts (accepting shrinkage, e.g. smart decline) have been promoted rather than pro-growth policies (countering shrinkage), a limitation is that they are currently often considered as transitional strategies for urban regrowth, i.e. a restoration of the previous status quo (Coppola, 2019). As argued by Hackworth (2015), the current adaptive strategies of shrinking cities lack the capability for more sustainable development trajectories, and it is, therefore, vital to develop alternative strategies that lead toward new directions.

Property abandonment and environmental degradation are the major issues to be addressed in policy responses to urban shrinkage (Ortiz-Moya, 2020). Specifically, infrastructure, housing, and transportation, as social environment factors, directly influence both residents' quality of life and enterprise production in shrinking cities (Wang et al., 2020b). However, their infrastructures have tended to be lacking, both qualitatively and quantitatively (Batunova and Gunko, 2018), expressing a need for structural improvement.

Also, shrinking cities are considered as "vulnerable places" (Raco and Street, 2012) which should both respond to the consequences of shrinkage and develop resilience for the future. Regarding urban shrinkage, recent discussions on resilience address ways to improve environmental capacity (via restoring the environment) as well as the economic and social sectors (Eraydin and Özatağan, 2021). But, for now, the existing urban systems limit any practical and systematic response to the infrastructure and environmental issues discussed above. Hence, new policy responses are required to facilitate the transition towards a sustainable urban system, particularly for improving the quality of the natural and built environment in shrinking cities.

2. Smart City Approaches in Response to Urban Shrinkage

Schackmar (2020) argued that optimized measures, such as SC approaches, could be an alternative to overcome the limitations of current policy responses to urban shrinkage, and transform them in a sustainable way. With the wide application of Information and Communications Technology (ICT), a SC provides a creative systematic solution to deal with urban issues effectively (Department for Business, Innovation and Skills, 2013). Furthermore, SC transformation is regarded as a socio-cultural process for promoting more sustainable urban development, rather than as a static outcome (Lee et al., 2023). SCs have offered various alternative paradigms for developing innovative solutions and planning strategies to achieve their urban agendas (e.g. sustainability, resilience, and greenness) (Oliveira Neto and Kofuji, 2016). Hence, new concepts for different purposes have been presented in the form of SC branches (e.g. sustainable SC, resilient SC, and green SC) over the last decade (Patrão et al., 2020). SC approaches are considered particularly effective in helping cities to improve their economic sustainability and their residents' quality of life (Neirotti et al., 2014).

In the context of urban shrinkage, applying SC technologies could be a promising approach for managing cities in a systematic way (Ma et al., 2020). They provide a functional way of achieving multiple agendas for shrinking cities effectively, based on optimized measures. Also, SC development in them could contribute to diversifying and upgrading local industries and improving wages for workers, as well as enhancing the urban environment and public services (Liu et al., 2020). Prevalent trends in SC approaches to shrinkage have formed in response to the forces of population, job loss, industrial decline, and suburbanization, along with the sharing economy (Ghosh et al., 2019). Pittsburgh, PA is the most prominent case of industrial transformation with SC strategies for brownfield redevelopment, urban greening, and economic transformation, in response to urban shrinkage resulting from deindustrialization and globalization (Ghosh et al., 2019).

However, applying SC approaches to shrinking cities has shown some limitations: (1) SC construction comes at a high cost, and requires a larger population and market in shrinking cities, which are commonly facing funding constraints

(Araral, 2020); (2) Among the various SC mechanisms, which ones actually affect urban shrinkage should be identified (Han et al., 2022); (3) whether the SC approaches adopted in a specific shrinking-city case are transferable to other regions, needs to be reviewed (Han et al., 2022). Additionally, these issues–(1) financial sustainability, (2) functional suitability, and (3) reproducibility–have been commonly found in shrinking cities, according to their project scale, political consistency, and others factors.

In particular, discussions of financial sustainability and functional suitability should be prior to those of the reproducibility, based on empirical studies. Pursuing such topics would contribute to theoretical and practical implications for the feasibility of SC approaches in shrinking cities, from an integrated viewpoint of the discourses on the two city models.

As a study on SC approaches to urban shrinkage, Ghosh et al. (2019) conducted a case study to identify the SC strategies in Pittsburgh in the framework of SC components and regional planning factors, and discussed implications for several challenges (e.g. aging population and vacant lands) to tackle urban shrinkage in Pittsburgh. They showed that Pittsburgh has adopted planning strategies for economic transformation and brownfield redevelopment (e.g. commercial corridor revitalization and establishment of eco-Innovation district), and urban greening (e.g. county-wide stormwater management), based on local community involvement and ICT use.

Also, Schackmar (2020) developed new revitalization approaches for shrinking cities with SC applications through a literature review, and analysed the SC strategies in Cincinnati, OH in the USA and Bochum in Germany, based on structural economic changes such as substitute industries. Cincinnati promoted a revitalization of blighted neighbourhoods and the smartness of city administration for economic and population regrowth through a mix of SC strategies and public–private partnerships. Bochum has applied SC technologies widely for adjacent industries and educational institutions as well as urban infrastructure, while establishing innovative start-ups and enterprises in the SC field.

Han et al. (2022) analysed how introducing SC pilot projects in China in 2013 affected urban shrinkage, using difference-in-difference (DID) analyses on 34 shrinking cities (an experimental group)[2] and 46 shrinking non-pilot cities (a control group). SC development had significant effects on shrinking cities, in facilitating sustainable economic growth by upgrading and diversifying local industries, promoting economic growth, and improving the quality of life for residents in relation to the urban environment, public services, and wages.

Overall, previous studies examined SC and shrinking city discourses in separate contexts, and synthesized the results for building a theoretical background. Moreover, such results were derived based on conventional literature analysis, which is not free from reflecting the researcher's subjective viewpoint (Borgatti et al., 2009). A further limitation is that they have tended toward identifying SC strategies in certain cases of shrinking cities.

To fill the gap, it is necessary to select literature which addresses SC discourses in terms of urban shrinkage, and to analyse SC approaches with a more comprehensive and objective framework. In addition, given the complexity both of SC mechanisms to solve urban issues (Petroccia et al., 2020) and of the interactions among different drivers that cause urban shrinkage (Wolff and Wiechmann, 2018), studies are required to analyse the structural features of the network consisting of the discourses based on the relationship among their components. In this regard, network analysis, a prominent text mining technique, is recognized as suitable for analyzing discourses due to its effectiveness in examining their links, mechanisms, and intersections across various fields and subjects, utilizing extensive literature datasets (Cheng et al., 2018).

Ⅲ. Methods

Network analysis has been suggested as a suitable approach to compensate for the researcher subjectivity inherent in conventional literature analysis (Ingwersen and Serrano-López, 2018; Zheng et al., 2020). This technique can identify key themes and cross-topics in large amounts of unstructured textual data, using keyword-driven linking relationships (Wang et al., 2020a). This study conducted data collection, preprocessing, and network analysis, with the literature which addressed SC approaches in the context of a shrinking city (see ⟨Figure 1⟩).

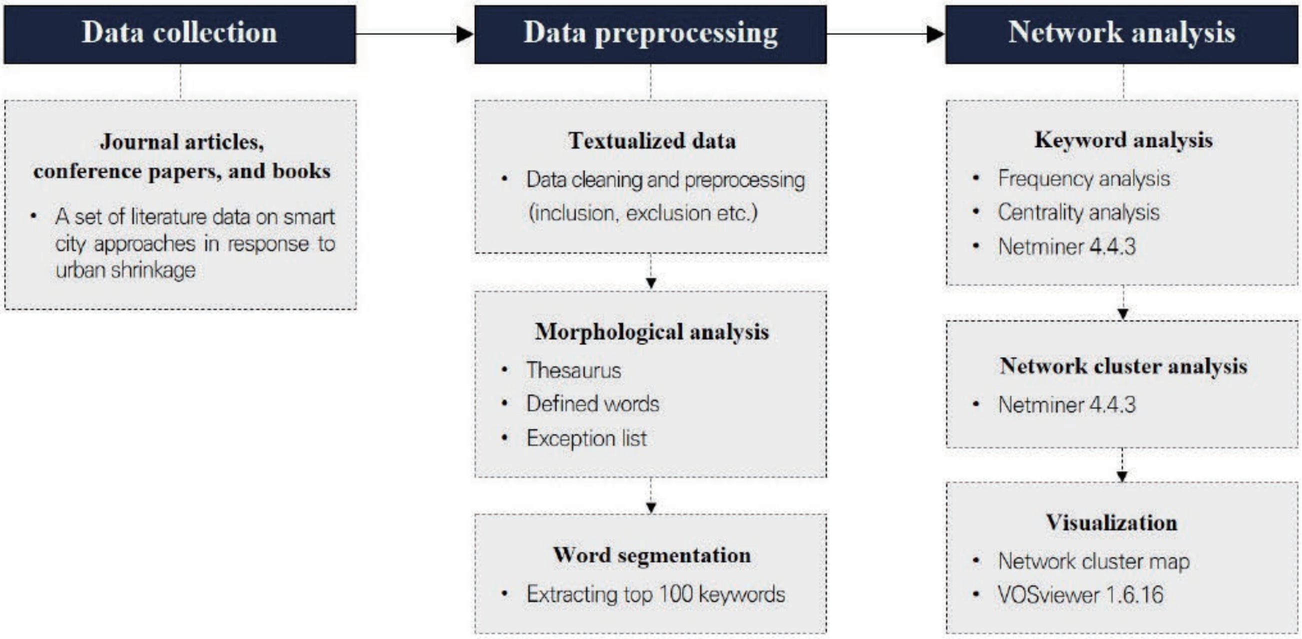

Figure 1. Flow chart of analysis process

1. Data Collection and Preprocessing

The dataset includes journal articles, conference papers, and books that addressed SC approaches in the context of shrinking cities. The search period was set to cover the entire period (until 24 June 2022), and only publications written in English were considered.

〈Figure 2〉 shows the data collection process. The data collection process was performed as follows: (1) To create an initial data set, a total of 198 pieces was collected using the initial search term "smart cit*[3]" AND ("shrink*" OR "declin*") in titles, abstracts, and keywords from the Web of Science and Scopus databases; (2) by further searching for documents containing words similar to the initial search terms (e.g. "digital cit*" AND ("shrink*" OR "declin*")) in their titles, abstracts, and keywords, an expanded set of 1,204 pieces was created, including the 198 pieces in the initial set; (3) By excluding 928 less-relevant or duplicated documents identified through full-text review, the selection was refined (e.g. the documents that contain the search terms in their titles, keywords, or abstracts, but do not address these terms as key concepts in the main text). Subsequently, 28 more relevant documents were added through forward and backward citation tracing from the refined set, resulting in the final set of 264 documents. This set comprises 119 journal articles, 111 conference papers, and 34 books.[4]

In the next step, a morphological analysis was performed to preprocess the collected data. Morphological analysis divides the text into morphemes and extracts, from each part of speech, meaningful information from a large number of unstructured documents (Lee and Kim, 2020). Therefore, to extract the main principal controls from the literature of the final sentence, noun phrases were extracted, and baseline data were collected. In morphological analysis, a *thesaurus list* was set to process a large number of words with similar meanings into a single word, and *defined words* were set to specify words so that technical terms and compound words would not be extracted separately. In addition, an *exception list* was specified to exclude words with unclear meaning and words (e.g. city, smart city) that are common but do not have significant meaning in the analysis results. Detailed information about the final data set can be found online.[5]

2. Data Analysis

Data analysis was performed in four steps: frequency analysis, network centrality analysis, network cluster analysis, and visualization. First, a frequency analysis was performed on the preprocessed data to identify the most important keywords in the dataset. Then, keywords with a frequency of 25 or more were used to create a correlation matrix for network analysis (also available through the online link in the footnote). Network centrality analysis and cluster analysis were also conducted to identify the core topics and structure

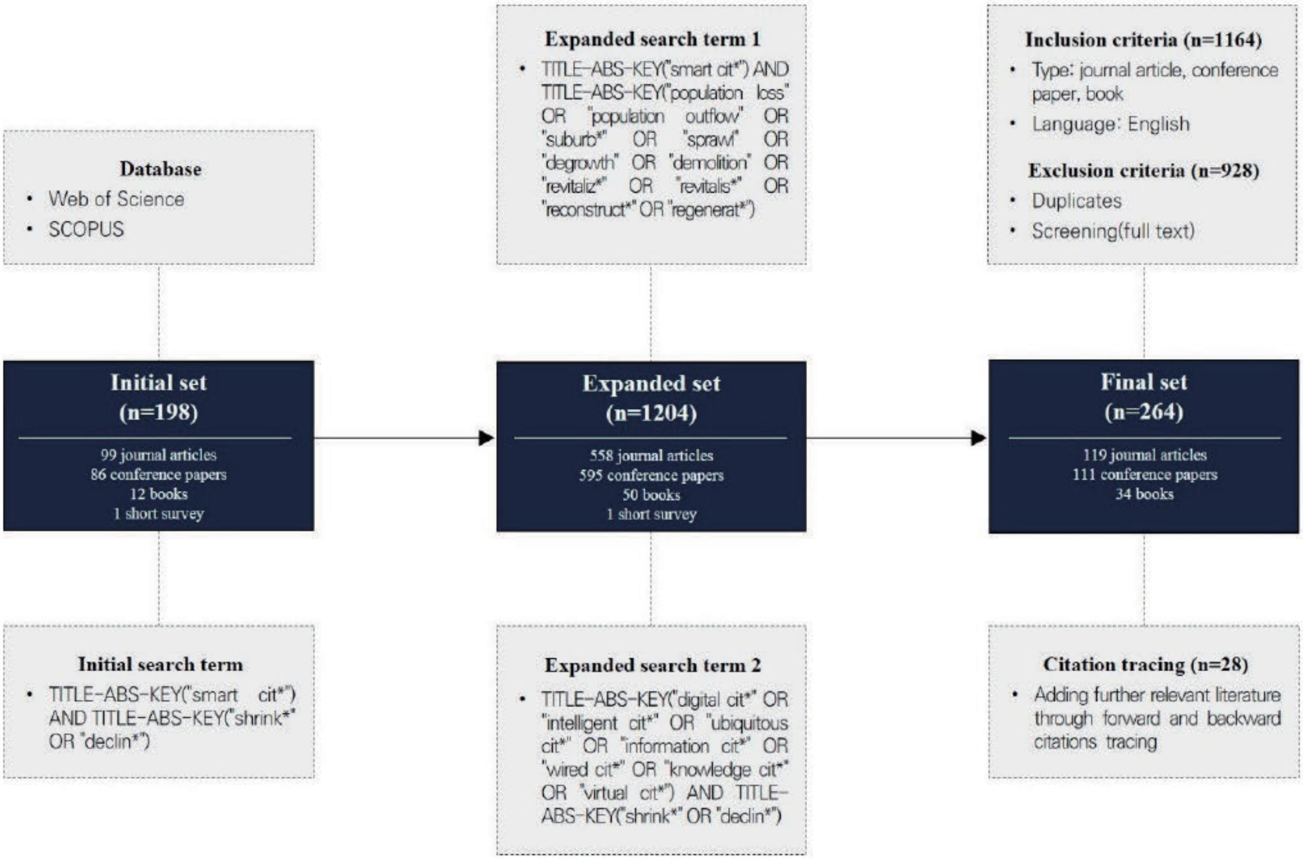

Figure 2. Data collection process

of the network, based on the correlation matrix.

In network centrality analysis, degree centrality measures the degree to which a word is directly connected to another word, and it is suitable for identifying the key topics of the network structure because the network's dominant structures can be found around the topic with the highest degree of connection (Yigitcanlar et al., 2021). Therefore, degree centrality was analysed to find key topics in the collected dataset. However, since frequency and centrality values alone are limited in identifying key topics and sub-topics of the network, network cluster analysis was also performed.

Network cluster analysis quantitatively computes the words in the documents to infer the key topics and semantic structures hidden in the document data (Ingwersen and Serrano-López, 2018). Accordingly, network cluster analysis can be used to identify the sub-topics that compose the key topics, and the connecting relationships between the key topics. For this purpose, correlation analysis was repeatedly performed between nodes to cluster keywords with high similarity, focusing on how similar the relationship pattern between nodes was derived in the middle of the correlation matrix. Finally, the analysis results were visualized with a network cluster map and a keyword density map.

Ⅳ. Results

1. Keyword Analysis

A total of 3,822 keywords with more than one occurrence were derived from the frequency analysis of 264 literature sources. 〈Table 1〉 shows the frequency and degree centrality analysis results of the top 40 keywords related to the SC discourse for shrinking cities.

The frequency and centrality of urban system (frequency = 294, degree centrality = 0.055), big data (313, 0.051), ICT (253, 0.032), sustainability (168, 0.031), and transportation (156, 0.029) were all high. However, quality of life (120, 0.019) and management (114, 0.017) showed high frequency but low centrality, while IoT (98, 0.022), mobility (97, 0.021), and citizen (89, 0.018) found low frequency but high centrality. While resilience (56, 0.011), decision-making (56, 0.009), and investment (50, 0.008) are low in frequency and centrality, these terms recently emerged as significant concepts in the relevant literature.

Table 1. Results of keyword frequency and centrality analysis

Rank	Word	Frequency	Word	Degree centrality
1	big data	313	urban system	0.055
2	urban system	294	big data	0.051
3	ICT	253	ICT	0.032
4	sustainability	168	sustainability	0.031
5	transportation	156	transportation	0.029
6	quality of life	120	IoT	0.022
7	management	114	energy	0.022
8	housing	107	housing	0.022
9	energy	107	mobility	0.021
10	climate change	104	quality of life	0.019
11	community	98	climate change	0.018
12	IoT	98	citizen	0.018
13	mobility	97	community	0.017
14	service	96	service	0.017
15	population	96	management	0.017
16	policy	95	revitalize	0.015
17	solution	91	urbanization	0.015
18	revitalize	91	population	0.015
19	environment	91	environment	0.014
20	citizen	89	infrastructure	0.014
21	network	85	network	0.014
22	governance	82	resource	0.014
23	infrastructure	81	urban sprawl	0.013
24	urban sprawl	77	policy	0.013
25	ecosystem	71	governance	0.013
26	urbanization	69	design process	0.012
27	design process	68	innovation	0.011
28	resource	66	economy	0.011
29	shrinkage	63	resilience	0.011
30	paradigm	63	investment	0.010
31	goal	63	ecosystem	0.010
32	resilience	56	water	0.010
33	decisionmaking	56	context	0.010
34	construction	56	waste	0.010
35	innovation	54	suburb	0.009
36	waste	53	construction	0.009
37	economy	53	decisionmaking	0.009
38	investment	50	knowledge	0.009
39	context	50	solution	0.009
40	suburb	44	disaster	0.008

Note: 'High frequency-low centrality' describes a keyword that frequently appeared in the final set of literature but was not significantly connected to other keywords in the overall network. On the other hand, 'low frequency-high centrality' refers to a keyword that occured less often in the final set of literature but maintained a high relevance to other keywords.

2. Network Cluster Analysis

〈Figure 3〉 shows the results of the network cluster analysis. Clusters were formed around the 100 most frequent nodes, covering five topics, with a total of 903 links between nodes and a total link strength (TLS)[6] of 5,370. The specific descriptions of each cluster are as the following sections. (Below, the nodes in the network structure are presented in *italics* and the description of each cluster are given based on the nodes with a high degree of connection.)

1) Cluster 1: Urban System

The red cluster consists of 19 nodes and 264 links, and its TLS is 1,252. This cluster had the highest TLS among all the clusters, revealing that this topic is the most covered in the selected literature corpus. The nodes have the highest level of connectivity related to *sustainability* (links = 40, link strength = 168) and *quality of life* (40, 120), which focus on the *urban system*. Meanwhile, nodes such as *measurement* (6, 19) and *simulation* (6, 20) show that they are included in cluster 1, although the degree of connectivity is low.

This result represents that an *urban system* transition based on the optimized *measurement* and *simulation* of SCs is needed to improve *sustainability* and *quality of life*, which are the major paradigms of shrinking cities. Furthermore, according to the outcome of the *measurement* and *simulation*,

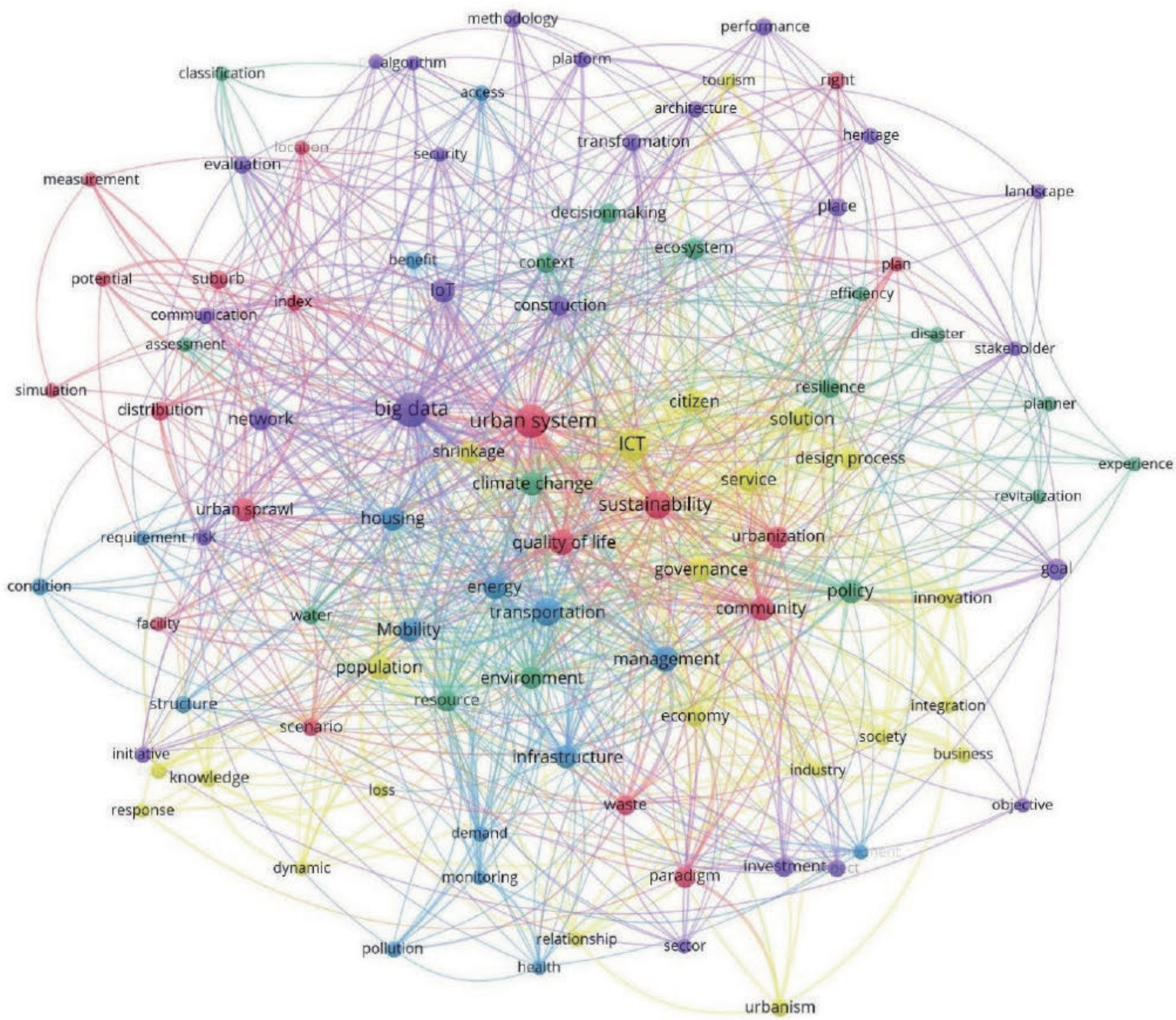

Figure 3. Network cluster map

Note: The network cluster map includes nodes and edges representing keywords and connectivity between nodes, respectively. The node sizes reflect frequency of the associated keywords, and line thicknesses indicate the degree of connection between the nodes. The color of the node is determined by the cluster to which the keyword belongs.

SC approaches could provide suitable policy tools (e.g. a *plan*, *index*, and *scenario*) for responding to causes of urban shrinkage, such as *suburb* and *urban sprawl*.

2) Cluster 2: Innovation

The yellow cluster consists of 22 nodes and 185 links; TLS = 1,246. This has the second-highest number of nodes and TLS, making it one of the key topics in the field. In this cluster, the nodes have the highest degree of connectivity in terms of *ICT* (links = 48, link strength = 253), *governance* (34, 82), *service* (33, 96), and *citizen* (30, 89) of SCs centring on *innovation*. On the other hand, nodes such as *industry* (15, 22) and *business* (11, 30) are included in cluster 2, although the degree of connection is low.

This shows the necessity of developing *industry* and *business* models to revitalize shrinking cities, through *ICT*-based *governance* of SCs and *integrative innovation* in the *economy* and *society* sectors. Particularly, the result indicates that such models could offer urban *services* for simultaneous *solutions* of shrinking city issues (e.g. *population loss* and transition of urban *dynamics*) and SC issues (e.g. a *citizen*-based *design process*), as illustrated in 〈Figure 3〉. It implies that the role of SC approaches would be expected to analyse political interaction among major stakeholders in shrinking cities and discover context-based *solutions* with cooperation from them.

3) Cluster 3: Infrastructure

The blue cluster consists of 16 nodes and 118 links, and TLS = 925. This cluster appears to have a lower number of nodes and link strength than other clusters, indicating that this topic is discussed at an exploratory level. In the network structure, the nodes have the highest degree of connectivity in terms of *transportation* (links = 39, link strength = 156), *management* (33, 114), *housing* (30, 107), and *mobility* (25, 97); this cluster centres on *infrastructure*.

Such a result indicates that the *structure* and *condition* of *infrastructure* in shrinking cities could be improved through SC approaches, by reflecting the *requirements* and *demands* for *access*, *energy*, *pollution*, and *health*, as the main problems of the *infrastructure* such as *transportation*, *mobility*, and *housing*. That is, it implies that the systematic and efficient *management* of the *infrastructure* could provide practical *benefits* to residents in shrinking cities.

4) Cluster 4: Environment

The network of the green cluster consists of 16 nodes and 121 links, and TLS = 775. This cluster, like cluster 3, has a low number of nodes and link strength, showing that the discussion on the environment is in its early stages in the related fields. In this network structure, the nodes have the highest degree of connectivity in terms of *climate change* (links = 37, link strength = 104), *policy* (31, 95), *ecosystem* (24, 71), and *resilience* (24, 56); the cluster centres on the *environment*.

This represents the need for *policy* responses to the *environment*, *ecosystem*, and *climate change*-related issues in shrinking cities, with the *planner's* professional *experience* as well as *decision-making* and *assessment* tools for them, as shown in 〈Figure 3〉. On this basis, it implies that *resilience* strategies could be established in consideration with the *context* of shrinking cities and applied to improve their environmental *efficiency* as a *revitalization* approach.

5) Cluster 5: Big Data

The purple cluster consists of 25 nodes and 215 links, and TLS = 1,172. This cluster has the most nodes among all clusters, indicating that big data has been discussed from various perspectives through literature in the related fields. In the network, the nodes have the highest degree of connectivity in terms of *construction* (links = 27, link strength = 56), *IoT* (24, 98), and *network* (23, 85) centring on *big data*. Meanwhile, nodes such as *risk* (16, 26), *investment* (11, 50), *platform* (11, 29), and *algorithm* (11, 20) are included in cluster 5, although the degree of connection is low.

This result shows that the *construction* of the urban information *network* using *IoT*-based *big data* could provide a *methodology* for responding to the following shrinking city issues: (1) developing strategies for achieving urban *objectives* and *goals* through *algorithm*-based urban *performance* evaluation; (2) constructing a *platform* for *communication* among various *sectors* and *stakeholders*; (3) developing *place-based initiatives* with the use of *landscape*, *heritage*, and *architecture*-related resources; (4) improving *security* by systematic urban *risk* management; (5) attracting *investment* for urban development through a *transformation* to the data economy.

Ⅴ. Discussion and Conclusions

There is an increasing need for strategic alternatives in response to urban system transformation in shrinking cities, as the attention on urban shrinkage has shifted from analysing its causes to the context and dynamics. Hence, SC approaches are being presented as an alternative solution that overcome the limitations of the current policy responses to urban shrinkage by applying ICT-based optimized measurement. Thus, this study analysed the main topics and structural features of SC discourses as an alternative to a shrinking city, conducting network analysis with a total of 264 publications that discussed SC approaches in the context of urban shrinkage.

The results show that the main topics came together into five clusters as follows: (1) urban system, (2) innovation, (3) infrastructure, (4) environment, and (5) big data. Among these, the systematic ones (urban system, innovation, and big data) have more nodes and higher link strength than the physical ones (infrastructure and environment). Based on the results, the policy implications for applying SC approaches to shrinking cities are suggested below.

First, the network of cluster 1 (urban system) has the highest TLS, compared to other clusters. It indicates that the urban system is the most frequently addressed topic in the discourses regarding a shrinking city and SC. Cluster 1 represents the transition towards the urban system based on optimized measurement and simulation for improving sustainability and quality of life in shrinking cities. In line with Neirotti et al. (2014), this result means that SC approaches would be a suitable means for helping cities enhance economic sustainability and quality of life. Also, the measurement and simulation, as nodes in the cluster, are considered to provide optimization as a functional means of SC approaches in response to urban shrinkage, as discussed by Han et al. (2022). Furthermore, Eraydin and Özatağan (2021) argued that how the challenges in policymaking are shifted into policy agendas and evaluated, in shrinking cities, should be discussed critically. It implies that the use of policy tools such as a plan, index, and scenario (the nodes in the cluster) based on the optimized measurement and simulation, could contribute to establishing the urban system to examine the validity of agenda setting and manage the performance by index assessment in shrinking cities.

Second, cluster 2 (innovation) has a relatively high number of nodes and TLS. In the network structure, the nodes for innovation, ICT, governance, service, and citizen are highly connected. This cluster refers to the strategies for revitalizing a shrinking city through SC governance based on ICT and integrative innovation of the economy and society sectors. Therefore, as suggested by Wey and Peng (2021), SC approaches not only provide efficient services to citizens through the application of ICT, but also improve the competitiveness of shrinking cities by promoting creative industries with cooperation from various stakeholders. Also, the issue of reproducibility, as noted by Han et al. (2022) as a main limitation in applying SC approaches to shrinking cities, could be addressed through the development of industry and business models. Notably, these models can be successful only if they are customized for cases in shrinking cities, which have a similar type of urban shrinkage and industrial structure, and expanding their prototype to fit the context of each city.

Third, cluster 3 (infrastructure) has a lower number of nodes and link strength, and indicating that its topic has been discussed at an exploratory level in the discourses. This cluster has substantial connectivity among the nodes of infrastructure, mobility, housing, energy, and management. The finding is in line with a study by Wang et al. (2020b), that identified transportation, housing, and infrastructure as the social environment factors to provide life satisfaction to residents and a material guarantee for enterprise production in shrinking cities. However, systematic and efficient management of infrastructure is required to offer practical benefits to residents because shrinking cities typically have poor quantitative and qualitative levels of infrastructure (Batunova and Gunko, 2018). This implies that the ICT-based management system of SCs could provide planning solutions and tools to decide whether to demolish or renovate the unused infrastructure in shrinking cities.

Fourth, cluster 4 (environment) has fewer nodes and weaker link strength, as such cluster 3. This cluster represents the importance of the means for establishing a resilience policy in response to the environmental issues of shrinking cities. Environmental degradation is a major issue in shrinking cities (Ortiz-Moya, 2020), and they generally lack the environmental capacity to maintain their original functions when internal and external shocks occur. To this end, strategies to improve environmental capacity in shrinking cities by transforming abandoned and vacant land into green infrastructure could be applied, as in the case of Pittsburgh. Additionally, Eraydin and Özatağan (2021) conceptualized shrinking cities as vulnerable places that require policy responses to improve resilience as well as overcome the devastating consequence of the forces that cause urban shrinkage. Accordingly, SC approaches are expected to contribute to developing a resilience policy by identifying environmental risk factors and opportunity factors as a result of a systematic analysis of the environmental influencing factors in shrinking cities.

Lastly, cluster 5 (big data) has the most nodes among all the clusters, showing that the application of big data has been discussed from different perspectives in the discourses. In the network structure, the connectivity among the nodes of big data, IoT, network, construction, and algorithm is quite high. It is considered that the use of algorithm-based big data would be able to effectively respond to the complexity of SC mechanisms, which is one of the limitations of SC approaches pointed out by Han et al. (2022), by identifying optimized mechanisms to achieve varied agendas in shrinking cities. Also, shrinking cities are generally faced with financial limitations, so it is difficult to afford the high construction costs of SC infrastructure (Araral, 2020). In this regard, big data analysis allows for the systematic investigation and management of various abandoned properties and land in shrinking cities, enabling the attraction of outside investment based on the potential for their alternative utilization in the future.

Unlike as discussed in the section "Policy responses to urban shrinkage", which stressed the need for improving the condition and structure of the physical elements (infrastructure and environment) in shrinking cities, the clusters regarding systematic elements (urban system, innovation, and big data) have more nodes and higher link strength. This illustrates that discussions of SC approaches in the literature have primarily focused on their systemic applicability to shrinking cities. However, although some smart city projects may indeed lack real-world context awareness (i.e. physical elements), this dose not indicate that smart city approaches themselves overlook such considerations. Moreover, when addressing issues related to applying SC approaches to shrinking cities, factors such as project scale and political consistency should also be considered, encompassing both physical and systematic elements.

The limitations of this study are as follows. First, the selected database for data collection may not provide comprehensiveness on the subject of this study, particularly the theoretical connection between a shrinking city and SC. Second, the forward and backward tracing process for collecting the additional literature may not completely exclude the possibility of researcher bias. Third, the validity of the results and arguments should be confirmed by experts in the related fields. Thus, they should be discussed in future studies with respect to verifying and complementing the results based on empirical analysis, and then developing the evaluation framework for the performance of SC approaches in shrinking cities. Fourth, there is a limitation in significantly dividing the publication years based on periodic characteristics for a chronological analysis aimed at examining the significance and relationships of the keywords. This is primarily because over 75% of the selected literature was published in the most recent five-year period. Similarly, as the discourses are still in their infancy, one could hardly analyze which types of policy responses to urban shrinkage have been addressed in the literature and to compare their characteristics. Lastly, as this study concentrated on smart city approaches as alternatives to shrinking cities, it did not extensively consider the diverse contexts of shrinking cities in the literature selection process. Hence, for a comprehensive literature overview, future studies are recommended to conduct a detailed bibliographic analysis considering publication years and authors' affiliations, with a greater focus on policy responses to urban shrinkage.

Note 1. Reproducibility means whether SC approaches applied to a specific case of shrinking cities also could be a solution for other cases.

Note 2. The experimental group includes of shrinking pilot cities that meet at least one of the following two requirements (Han et al., 2022): (1) The population of the city in the urban area was smaller in 2013 than it was in 2004; (2) The fertility rate in urban areas fell for three straight years, or was 10% lower than the year before, between 2004 and 2013.

Note 3. In the search operator, an asterisk (*) is used to search for any terms that begin with a certain word (e.g. shrink*=shrink, shrinks, shrinking, shrinkage).

Note 4. Over 75% of the 264 pieces of literature in the final set were published in the past five years (2018-2022), up to the collection date of 24 June 2022. Consequently, the discourse on SC approaches as an alternative to shrinking cities is considered a relatively recent development in the literature, with a significant number of publications within a short period.

Note 5. See here: https://drive.google.com/drive/folders/13z-Rkrg5R-KOTBy0GkcsLddM3-r5cE0t?usp=sharing

Note 6. The link strength represents the number of links between one node and another node, and the total link strength (TLS) represents the sum of the link strengths of all nodes.

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