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How to reverse urban sprawl: The smart blue-green city

Abstract: The phenomenon of urban sprawl is relatively widespread. At its root are a number of factors that have caused people to leave cities and settle relatively close to them. There are both positive and negative consequences of urban sprawl, but the latter are far more numerous, so solutions are needed. Therefore, four questions have been formulated for this paper: 1. What are the negative consequences of urban sprawl? 2. Are there positive aspects to the phenomenon? 3. Do the negative consequences outweigh the positive ones? 4. What should be done to mitigate the negative consequences of urban sprawl? This study aims to identify a set of actions that can reduce the identified negative consequences of urban sprawl. We believe that the key at the planning level is to implement the concept of the smart blue-green city, which respects social needs. The elements of the proposed solution have been selected with a view to reducing the phenomenon of urban sprawl, i.e. keeping people in the city, rather than designing the urban and suburban structure.

Key words: blue-green network, city of the future, smart growth, sustainable development, urban sprawl

Introduction

According to Jadach-Sepioło and Legutko-Kobus "urban sprawl" is "the extreme form referred to as suburbanisation" and is considered a negative phenomenon (2021, p. 15). In turn suburbanisation, according to Harasimowicz, is "the urbanisation of the suburban zone"(Harasimowicz 2018, p. 116). "Urban sprawl is most commonly understood as a suburban development characterized by low density, automobile dependency and segregated land uses around the periphery of cities" (Cocheci, Petrisor 2023). In the case of urban sprawl, rural areas and small towns are being developed, as well as open spaces and areas on the urban-rural continuum where residential neighbourhoods are being created (Jadach-Sepioło, Lehutko-Kobus 2021, p. 16). It is also characterised by low-density housing, single-use zoning and increased reliance on the private car for transport

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(Rafferty 2024). The origins of urban sprawl go back to the 19th century and are linked to several factors that encouraged people to leave cities and settle relatively close to them. However, the term was not used until later. According to Thomas J. Nechyba and Randall P. Walsh, the modern use of the term "sprawl" was coined in 1937 by Earle Draper, one of the first urban planners in the southeastern United States (2004). It was then used negatively by The Times in the 1950s to describe the rapidly expanding suburbs of London (Huvos 2020). Initially a phenomenon identified only in the United States, over time its manifestations have been diagnosed in other countries. It varies according to the reasons why people move to the suburbs and the different spatial arrangements. For example, according to "in Western Europe suburbanization took place in an environment of strong population and economic growth, while in post-socialist countries, there has been population stagnation and economic transformation" (Repaská et al. 2017, p. 290). *Inevitability theory* suggests that urban sprawl is a natural stage of development present in all societies that have achieved an appropriate degree of prosperity. However, studies indicate that urban spread is not inevitable, and the process has been effectively countered in some areas in Europe. Furthermore, considering its negative consequences, there remains a need to identify effective methods to reduce it further (Lewyn 2009).

The literature on urban growth includes works by economists, geographers, and planners, with Anas et al. (1998), Brueckner (2000), Nechyba and Walsh (2004), and Anas and Pines (2008) being notable works describing the key issues underlying the phenomenon. Some authors take up the question of definition, looking for the origins of the phenomenon (Yasin et al. 2021), including assessment of factors and causes based on literature (Rosni, Noor 2016). Others go further and analyse the impact of the phenomenon, but focus mainly on these negative effects. For example the negative impacts of urban sprawl on the environment have been analyzed in various papers, including Czech et al. (2000), Johnson (2001) and Robinson et al. (2005), and the rising social costs were examined by Hasse and Lathrop (2003). Other papers, such as Batty et al. (2003), Phelps and Parsons (2003), Holden and Norland (2005), Travisi et al. (2010) and Pirotte and Madre (2011), attempted to investigate the process of urban expansion in Europe, focusing on uncontrolled urban development in particular regions or cities, while Patacchini and Zenou (2009), Arribas-Bel et al. (2011) and Oueslati et al. (2015) provided a more general overview of the issue in Europe.

Urban sprawl has been studied from various angles, ranging from defining the processes that contribute to urban expansion and the changes that promote population decline in the central districts of a city to the decentralization of the city itself, where the role of the center is transferred to the suburbs. An interesting point was raised by Charmes et al. (2020), who indicated that while some metropolitan territories, such as Lyon, benefit from urban sprawl, the compromises made are doubtful and raise questions about spatial justice.

A deeper analysis of the urban sprawl indicates that it is a complex process caused by a range of macroeconomic factors (i.e., globalization, economic development, European integration), microeconomic factors (i.e., increasing living

standards, land price, availability of cheap agricultural land, competition between municipalities), and demographic factors. (i.e., population growth, growing number of households). To this list should be added changes in housing preferences (i.e., a desire for more space per person), the intrinsic problems of the city (bad air quality, noise, small apartments, dangerous social groups, social problems, a lack of open green space, poor quality of schools), the development of transport (easier access to one's own car, the development of road infrastructure, relatively low fuel costs fuel, poor quality of public transport) and a liberal regulatory framework that enables the escalation of urban sprawl, i.e., poor spatial planning, poor enforcement of existing plans, and a lack of coordination (EC 2006).

Available analyses indicate that urban sprawl leads to a reduction in pedestrian travel, greater air pollution caused by increased use of passenger vehicles, a higher unit cost of transport, a deterioration of overall health, limited access to services, and economically ineffective expansion of technical, transport, and social infrastructure. Oueslati et al. (2015) proposed that the cost of urban sprawl should also take into account agricultural land productivity, as this can significantly increase the associated cost of sprawl.

For this article, the following four questions have been formulated:

1. What are the negative consequences of urban sprawl?
2. Are there positive aspects to the phenomenon?
3. Do the negative consequences outweigh the positive ones?
4. What should be done to mitigate the negative consequences of urban sprawl?

The study aims to identify a set of actions that can reduce the identified negative impacts of urban sprawl and keep people in the city. One of them, which is particularly promoted by the authors of the smart blue-green city concept, is linked to sustainable development. The proposed solution is to meet all the needs of residents so that they do not want to leave the city in search of green and blue areas. The dangerous negative consequences of urban sprawl require the introduction of solutions to reduce the phenomenon while respecting social needs. The research method used in the article is desk research, which involves the use of secondary data.

The genesis and concept of urban sprawl

Other terms for urban sprawl are sprawl or suburban sprawl (The problem of urban sprawl, http). "Its origins in the 19th century and its main cause was the emergence of increasingly efficient forms of transport for city dwellers" (Nowak 2015, p. 133). The sources of the phenomenon are diverse. For example, the origins of the sprawl in the United States are identified with the flight to the suburbs that began in the 1950s because "people wanted to live outside of city centers to avoid traffic, noise, crime, and other problems, and to have homes with more square footage and yard space" (Resnik 2010).

According to Lityński: "Urban sprawl is related to the deconcentration of buildings, population and employment in suburban municipalities under the

influence of the core city" (Lityński 2022, p. 7). A review of the literature leads to the conclusion that there is an array of definitional approaches (Table 1).

Table 1. Definitions of urban sprawl phenomenon

Author	Definition
Lityński 2022. Mechanizmy finansowe zjawiska urban sprawl. Perspektywa gospodarstw domowych i przedsiębiorstw. Wydawnictwo Naukowe Scholar, Warszawa, p. 11.	"(…) the chaotic changes in the spatial structure of suburban municipalities that have occurred as a result of suburbanization, with a low degree of spatial policy control over these processes. Urban sprawl can be treated statically as a spatial development, a specific spatial configuration of an urban area at a certain point in time, and as a process – a change in the spatial structure of an urban area over time".
The problem of urban sprawl (https://www.britannica.com/explore/savingearth/urban-sprawl)	"(…) the rapid expansion of the geographic extent of cities and towns, often characterized by low-density residential housing, single-use zoning, and increased reliance on the private automobile for transportation".
EEA: Urban sprawl (https://www.eea.europa.eu/help/glossary/eea-glossary/urban-sprawl)	"The physical pattern of low-density expansion of large urban areas under market conditions into the surrounding agricultural areas".
Burchell et al. 1998. The costs of sprawl-revisited. Report 39. Transit Cooperative Research Program, Transportation Research Board. National Academy Press, Washington DC, [quoted from:] Brody S. 2013. The Characteristics, Causes, and Consequences of Sprawling Development Patterns in the United States. Nature Education Knowledge, 4(5): 2.	"Low-density, haphazard development spiraling outward from urban centers".
Sprawozdanie z realizacji projektu badawczego na temat: „Analiza zjawiska niekontrolowanego rozprzestrzeniania się miast na przykładzie warszawskiej dzielnicy Białołęka" wykonanego przez Koło Naukowe Gospodarki Przestrzennej Politechniki Warszawskiej, p. 9 (https://www.kngp.gik.pw.edu.pl/wp-content/uploads/2014/02/Tekst-Analiza-urban-sprawl-KNGP-PW.pdf; accessed: 24.05.2024).	"is a process of spontaneous, unplanned expansion of development to areas located in the immediate vicinity of cities – on the outskirts or a short distance from them".

Source: own study.

Based on these definitions of urban sprawl, it is possible to identify elements that are repeated:

- reasons for its development
- negative consequences
- how it develops.

These elements can be compared with Brody's more detailed definition (Brody 2013):

- Low-density, single-family dwellings;
- Automobile dependency even for short trips;

- Spiraling growth outward from existing urban centers;
- Leapfrogging patterns of development;
- Strip development;
- Undefined edges between urban and rural areas.

The first two characteristics are particularly evident in the case of urban suburbs in the United States (as it was mentioned in the introduction). The other problems are related to the income situation of the movers. The following features of urban sprawl have been identified in the development of urban sprawl: the chaotic dispersion of development, low housing density indicators, a lack of spatial continuity in development, the dependence of society and the economy on mechanized transport (car, rail) (Lityński 2022, p. 7), and a desire for increased living space and other residential amenities (The problem of urban sprawl, http).

Consequences of urban sprawl

To systematize the consequences of urban sprawl, social, economic, and environmental dimensions were distinguished, divided into positive and negative aspects (Table 2). This is intended to provide some order and fill a gap in the literature, as the authors, as indicated in the introduction, focus mainly on the negative effects of the urban sprawl.

As mentioned above, urban sprawl affects the economy of the city and its suburbs, and it negatively affects the environment. To better illustrate this interdependence, in Figure 1, the consequences of urban sprawl have been grouped into three areas: city, society and sustainability, and peri-urban areas (Fig. 1).

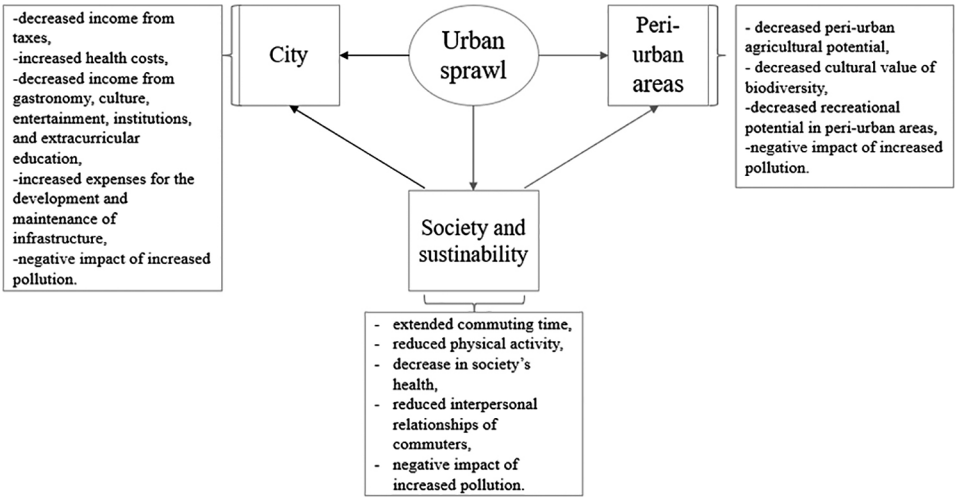

Fig. 1. Urban sprawl – the chain of negative connections
Source: own study.

Table 2. Positive and negative aspects of the social, economic, and environmental dimensions of urban sprawl

Dimension	Positive aspects	Negative aspects
Social	• improved housing conditions • the development of services	• health problems, including obesity, diabetes, cardiovascular disease, and respiratory diseases • separation of the city into functional zones that are dependent on and adapted to the traffic system • negatively affects the quality of life – a higher car utilization rate contributes to bothersome traffic jams, which waste energy and free time (negative impact on time budgets, less direct interpersonal contacts)
Economic	• lower land prices • lower taxes than in the city • the development of infrastructure	• losses of human and financial capital from a city • losses of fertile soils reduce the potential for food production and expand food transportation pathways to the city • increased health care costs • decreased peri-urban agricultural potential • decreased tax income • decreased income from gastronomy, culture, entertainment, and extracurricular education • increased expenses for the development and maintenance of infrastructure
Environmental		• degradation in the city and areas adjacent to the city • increased air pollution • increased water pollution • changes in land use structure, which has a negative impact on biodiversity • the loss or disruption of environmentally sensitive areas • reduced open space • increased flood risks • increased land surface temperature

Source: own study based on: Brody (2013, p. 2); Resnik (2010); Das et al. (2023); Kacprzak, Głębocki (2016, p. 101); Nowak (2015, p. 136).

Urban sprawl lowers a city's tax revenues through the outflow of human capital. It also reduces income in sectors such as culture, gastronomy, and extracurricular education, as people from the outskirts do not return to the city after getting home from work. Urban sprawl also increases the intensity of traffic jams, which can affect the economy by incurring higher infrastructure expenditures. Problems with extended travel time also negatively influence time budgets, directly impacting interpersonal contacts and physical activity, i.e., the time that a person could spend on physical activity or socializing is spent in the car. Urban sprawl also affects the natural environment (higher CO_2 emissions from car use, degradation of natural ecosystems), and it negatively impacts society's health (lower physical activity, higher stress levels).

Solution

While the consequences of urban sprawl are undeniable, a complete eradication might not be realistic or desirable. Freedom of choice must be taken into account. Rather than limiting the phenomenon, any orders and prohibitions may lead to resistance within society. Therefore, the focus should be on controlling and limiting urban sprawl through appropriate solutions that consider social needs.

City authorities can play a key role in reducing the negative effects of urban sprawl by implementing specific regulations that favour the shaping of spatial order. Samuel Brody suggests the following:

1. Regulatory Measures: Effective tools include subdivision regulations, zoning provisions, building permit limits, and urban growth boundaries. These tools establish clear guidelines for development.
2. Incentive-based techniques: Offering tax breaks for specific development types (e.g., clustering houses) or development density bonuses can encourage responsible building practices. Transferring development rights from rural to urban settings can be beneficial.
3. Infrastructure-based policies: Targeted public investments, capital improvement programming, phasing of development, and urban service areas can provide proactive approaches to guiding growth away from environmentally sensitive areas.
4. Land acquisition: These methods vary from outright purchase of land parcels to conservation easements that can preserve ecologically valuable areas.
5. Educational and outreach programs: Community outreach programs can raise awareness about the impacts of sprawl and encourage responsible development choices.

Another, more complex solution that encompasses positive aspects in the three areas (society, economics, and the environment) and is closely tied to efficient management is the concept of smart growth. Resnik (2010) defines it as "a policy framework that promotes an urban development pattern characterized by high population density, walkable and bikeable neighborhoods, preserved green spaces, mixed-use development (i.e., development projects that include both residential and commercial uses), available mass transit, and limited road construction". This concept is often associated with sustainable development (Alexander, Tomalty 2010).

In line with the above, we propose the creation of a Smart Blue-Green City as a vision for the future. The proposed solutions have the potential to reduce the negative consequences of urban sprawl presented in Table 2 and keeping residents in the city. The city would incorporate at the planning level the following elements:

1. A smart city: Defined as a city that achieves good results now and in the future, created thanks to the intelligent combination of resources and decision-making activities, independent and committed citizens (Caragliu et al. 2011; Pardo, Nam 2011; Dameri 2013). This is made possible by "basing the development strategy on the use of information and communication

technology in such areas as the economy, natural environment and quality of life, mobility, management, with the aim of changing urban infrastructure and services" (Bakici et al. 2013).

2. The Blue-Green City emphasizes the importance of green infrastructure, which is fundamental for ensuring city attractiveness and health, thus reducing urban sprawl. The Blue-Green Network is a project embedded in the context of the local natural system and one that integrates and expands on previous planning documents concerning natural elements and those of the green architecture of a city. The existing system of rivers and adjacent green areas creates a basis for a functional, economical, logical, and user-friendly arrangement of urban space that provides multiple benefits to the city residents. These benefits include enhanced stormwater retention and purification, the prevention of flooding and drought, improved microclimate, improved air quality and decreased risk of allergy and asthma, improved resistance and reduced maintenance costs of urban greenery, and space for recreation and spending time actively. It also provides increased flexibility for the city in adapting to global climate change, reduces the heat island effect and the emission of pollutants, and improves the attractiveness of urban space to residents and investors (Zalewski et al. 2012).

The proposed concept of the Smart Blue-Green City is as follows:

- It is a transdisciplinary concept based on the ecohydrological approach (Zalewski 2014, 2021). Hence, the restoration strategy must integrate measures at all scales and generate positive economic feedback: (1) The catchment scale: increase stormwater retention in a city by re-shaping landscape vegetation and river restoration; (2) The floodplain scale: phytoextraction of heavy metals using willows (bioenergy) and native plant communities (biodiversity and ecological restoration); and (3) The local scale: using sewage sludge to fertilize bioenergetic plantations to increase productivity, reducing the problem of sewage sludge utilization
- It provides a protective zone around a treatment plant. Bioenergy also produces revenue for the local economy while reducing capital outflows for fossil fuel.
- Smart blue-green cities act as an adaptation mechanism to climate change, improving air quality and reducing airborne particle levels thanks to the activity of plants and the process of transpiration. Heat islands are also reduced, and these cities support the environmental education of urban residents (Zalewski 2021).
- It is a systemic mathematical model for a decision support system that accounts for the constraints and opportunities available, and its synergistic integration should be used for testing the decision-making process.

All the above measures have to be implemented to ensure water quality, flood mitigation, and biomass/biodiversity enhancement (Zalewski, Wagner 2005). The implementation of the Smart Blue-Green City concept can only be achieved through close cooperation between city authorities and citizens. Education and awareness-raising about the negative impacts of urban sprawl on all of the above

are essential. Public administration should also set an example for residents by implementing low-emission solutions, e.g., public buildings should be transformed into passive buildings using renewable electricity sources, reversible heat pumps, external walls made of silicate brick, insulation in accordance with passive building standards, hybrid outdoor lighting and natural lighting, and a roof based on reversible roof technology. These buildings should also implement approaches for the management and optimization of energy demand. This is in line with the idea of the circular economy of minimizing energy and resource consumption in the use phase.

Public administration should also implement circular economy principles, allowing the efficient use of resources, reducing waste, and providing financial and substantive support for city residents who are interested in improving the thermal and energy efficiency of their homes.

The city authorities should promote the role of bicycle and pedestrian traffic in the urban transport system, creating a bicycle and pedestrian-friendly infrastructure, reducing car use, and increasing social activity. Other necessary activities include promoting the bicycle as a means of transport, as well as reducing the number of accidents involving cyclists and pedestrians.

The introduction of the blue-green city concept also requires taking into account its limitations. Counteracting urban sprawl requires going beyond the presented concept, i.e. expanding it to include actions that enable cooperation between city authorities, residents and business partners, as well as the introduction of coherent policies and regulations. Social acceptance and raising social awareness of the benefits of long-term spatial planning, costs and use of resources is nessery. In order to reduce urban sprawl, it is necessary to build/expand a network of urban railways that will enable daily journeys between the city (work) and its outskirts (home), which is something that cycling does not make possible over long distances.

Another element that the city authorities should consider is the implementation of elements of the Green Economy, i.e., ensuring the appropriate spatial development of an area, renovating existing green spaces, such as parks, to encourage residents to spend their free time there, and eliminating concrete elements from green belts. In addition, planning regulations should consider the high local and ecological value of agricultural production, especially soft fruit and salad vegetables, which are susceptible to damage during transport. Increasing the productivity of agricultural land not only increases the opportunity cost of selling it for development but also increases the self-sufficiency of the region while reducing the economic costs and environmental impact of transport.

The above concept is reflected in the practice of the two cities of Singapore and Tianjin (China). Despite being dependent on water imports from Malaysia (at 60%), Singapore has an extensive blue infrastructure, i.e. fountains, ponds and water features. In addition, there are rainwater reservoirs, a water plant. The green infrastructure of Singapore is characterised by a high green index. The development of blue-green infrastructure in Singapore is linked to the extensive development pipeline designed and implemented since Singapore's independence

(Szyja 2016). On the one hand, it aims to secure water resources (this is achieved, among other things, by the water plant – a complex of five plants that purify, even treat and bottle water) (PUB NEWater, http); on the other hand, it aims to provide decent living conditions for the local population and to encourage potential investors. Based on the Green View Index, Singapore was characterised by the highest density of greenery in 2017 (Choo 2017). The concern for greenery is primarily dictated by the need for protection from ultraviolet radiation, but also to provide opportunities for recreation and leisure. In turn, Tianjin is a project realised by two governments, China and Singapore. The Sino-Singapore Tianjin Eco-city site is 40 km from Tianjin city centre and 150 km from Beijing city centre, and is located within the Tianjin Binhai New Area. The Chinese government had two criteria when choosing the site – land is non-arable, and facing water shortage. The aim was to create a new, sustainable city despite the unfavourable conditions associated with these restrictions (MND, http). The project was launched in 2007. In 2022, its realisation has contributed to 130,000 people living or working there and 23,000 registered businesses. Singapore is an interesting example because, despite its limited land area, it is still making an effort to green areas rather than creating urban spaces. It is one of the best examples of a sustainable city in Asia. Tianjin, on the other hand, is an example of a process of controlled urban emergence based on the idea of sustainable development (Three interesting…, http).

Conclusion

Studies suggest that in many cities, urban sprawl may be associated with an increase in wealth. Therefore, there is a risk that a policy that limits the expansion of urban areas may lead to a slowdown in economic growth through the flight of businesses to other cities, where there is still space for new investments on the outskirts of a city. Therefore, these proposed solutions should be accompanied by efforts to raise public awareness of the negative impact of urban sprawl on the environment, the economy, and societal health, thus allowing city residents to see the potential benefits of the solutions for individuals. These solutions should reduce the outflow of human capital from the city.

This research highlighted the interconnected consequences of urban sprawl and how it negatively impacts several key areas. The summary of the negative impacts presented below can serve as a starting point for further research:

- Economic potential: The outmigration of households with higher mean monthly incomes results in lower employment in the city, lower potential tax revenues and potentially lower revenues for gastronomy, culture, extracurricular education and entertainment.
- Healthcare: The decrease in the number of people registered in cities causes an increase in the cost of outpatient special care..
- Quality of life and health: Increased traffic congestion, lower physical activity, and higher stress levels negatively impact the well-being of residents and commuters. Smog from vehicle emissions further exacerbates health concerns.

- The natural environment: Urban sprawl contributes to an increase in CO_2 emissions in and around the city, which has a negative impact on health and intensifies processes related to climate change.
- Time budgets: Extended commuting times make direct human contact difficult and limit opportunities for physical activities.

The study identified a web of consequences of urban sprawl that are mutually reinforcing. Despite societal needs, the negative consequences of urban sprawl require solutions to limit the problem. The introduced solution should focus on keeping residents in the city so that they are not interested in blue-green areas outside the city. Moreover, our proposed solution focuses on saving resources, mainly energy and water, with the right infrastructure to cope with the effects of climate change while creating a city of the future that responds to contemporary social needs. This requires both awareness-raising among residents and an understanding of the concept and a commitment to its implementation by local authorities in cooperation with residents.

Conflict of interest / Authors' input

The authors declare that they have no conflict of interest and assures that the work is the result of his own creation.

The division of work on the article was as follows:

- conceptualisation: DM, PS
- methodology: DM, PS
- research organisation: DM, PS
- formal analysis: DM, PS
- writing: DM, PS

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Jak odwrócić niekontrolowany rozwój miast: inteligentne niebiesko-zielone miasto

Zarys treści: Zjawisko rozlewania się miast jest stosunkowo powszechne. U jego podstaw leży szereg czynników, które spowodowały, że ludzie opuszczają miasta i osiedlają się blisko nich. Istnieją zarówno pozytywne, jak i negatywne konsekwencje rozlewania się miast, jednak te drugie zdecydowanie przeważają, więc potrzebne są odpowiednie rozwiązania. W związku z tym w artykule tym sformułowano cztery pytania: 1. Jakie są negatywne konsekwencje rozlewania się miast? 2. Czy istnieją pozytywne aspekty tego zjawiska? 3. Czy negatywne konsekwencje przeważają nad pozytywnymi? 4. Co należy zrobić, aby złagodzić negatywne konsekwencje niekontrolowanego rozwoju miast? Niniejsze badanie ma na celu zidentyfikowanie zestawu działań, które mogą zmniejszyć negatywne skutki rozlewania się miast. Uważamy, że kluczem do tego jest wdrożenie koncepcji Smart Blue-Green City, która uwzględnia potrzeby społeczne.

Słowa kluczowe: niebiesko-zielona sieć, miasto przyszłości, inteligentny wzrost, rozwój zrównoważony, niekontrolowany rozwój miast