STRATEGIC DIRECTIONS FOR SUSTAINABLE DEVELOPMENT OF METROPOLITAN AREAS WITH PARTICULAR FOCUS ON DEVELOPMENT OF SPATIAL INTERACTIONS BETWEEN CENTRE-PERIPHERY SYSTEMS

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Abstract. Nowadays, global economic and social changes are leading to significant regional disparities in many countries, which have a fundamental impact on the competitiveness of the states. In this approach, the development of territorial units can best be analysed through the individual growth poles or centre-periphery systems. The individual growth poles are primarily characteristic of the spatial structure of developed countries, while the centre-periphery dichotomy refers to the spatial problems of catching-up nation states. In our study, we aimed to develop sustainable development paths for city-centre areas, as the inequalities created by the growth of the prominent central role of the large cities contribute to the overall disparities within the country. In addition, they have an impact on inequalities of opportunity and are also detrimental to economic efficiency. Examining the spill-over effect of cities, we can conclude that they can hold back overall economic growth and, more broadly, cause further social tensions. They can also have a centralising effect, contributing to deepening regional inequalities, increasing polarisation and threatening the social structure of countries. The focus of our current research is to analyse the economical, social and sustainable processes of centre-periphery relations in order to formulate development directions that, through their interconnection system, can contribute to the improvement of centre-periphery interactions and the increase of living standards of people living in metropolitan and non-metropolitan areas.

Keywords: regional inequalities, centre-periphery system, metropolitan areas, sustainable development.

Introduction

The study of sustainable development in modern cities is a priority, influenced by global challenges, climate change, social inequalities and changes in economic competitiveness. Urbanisation has accelerated worldwide, making cities increasingly central actors in the development of sustainable development strategies. Sustainable urban development now encompasses not only environmental aspects, but also integrates social and economic dimensions, with a particular focus on the links between centre-periphery systems. In this context, the centre-periphery model provides a relevant framework for understanding urban development by distinguishing between urban areas in the centre, which are generally more economically developed and provide a higher standard of living, and peripheral areas, which are often deprived. The interactions between these two spatial categories have profound implications for sustainability: the dynamic development and innovation potential of centre areas can contribute to the economic uplift of peripheral areas, while the persistent underdevelopment of peripheral areas is an obstacle to holistic urban development [1].

It is crucial for cities to develop integrated strategies to improve centre-periphery interactions, as improving transport infrastructure, green solutions and involving local communities in decision-making processes are key. These strategies not only contribute to sustainability goals, but also help strengthen social cohesion, stimulate the local economy and improve quality of life [2].

Cities are key axes of the modern economy and society, as they account for a significant share of global GDP, R&D&I and jobs. The dense population and concentrated economic activities in urban centres allow for rapid spread of innovation, cultural encounters and social mobility. However, the sustainability of cities is facing serious challenges as population explosion, urbanisation and industrialisation are rapidly increasing the infrastructural burden on cities, which can lead to environmental, economic and social problems. In our study, we analysed the complex environmental impacts, which include air pollution, water and soil pollution and the effects of climate change. A number of national and international publications have analysed these factors and examined their interrelationships [3; 4].

The amount of carbon dioxide emitted by large cities is significant and they play a key role in the fight against climate change. Outdated transport systems, high energy consumption and waste management problems combine to put the sustainability of urban living spaces at risk. Our analysis has also shown that transport pressures are significantly associated with social inequalities and housing crises, as agglomeration pressures in large cities play a prominent role in the tensions that affect

communities in large cities. In order to address sustainability challenges, cities need to adopt a holistic approach that integrates economic, environmental and social aspects, making active citizen participation in decision-making a key factor, alongside green urban development, sustainable transport and increased energy efficiency [5; 6].

The environmental impacts of metropolitan areas are multidimensional and complex, as the strategic implementation of urban development has not only economic but also significant ecological and social consequences. In our study, we analysed the effects of public transport in the urban development strategy of Budapest, which significantly influences the existing centre-periphery relationship due to population density, catchment area and increased economic and social involvement. Our research has demonstrated that without sustainable development of public transport systems, often concentrated in the centres of cities, they will not be able to meet the growing demand in the long term. In addition to all these negative impacts, we are also witnessing a loss of urban green space, which contributes to biodiversity loss and water cycle disruption [7]. Consequently, sustainability challenges inevitably require rethinking urban planning practices to preserve ecological balance and minimise environmental impacts. This demonstrates that integrated management of urban ecosystems is key to achieving sustainable development, including the use of renewable energy sources, greening of transport infrastructure [8].

Our research shows that the main objectives of sustainable urban development are to increase the resilience of communities, protect natural resources and promote social justice, while keeping in mind the economic development of cities and the modernisation of transport networks. In addition to rationalising the transport sector, the development strategy should pay particular attention to waste management, which we consider to be one of the greatest environmental challenges facing the urban environment. The growing population and, alongside it, consumption, is generating waste production that requires a transition to a circular economy, where the main objective is to recycle waste and achieve minimum production pressure. We therefore believe that cities should actively participate in reducing their environmental impact, taking into account both global and local aspects [9].

The analysis of centre-periphery systems is at the heart of modern urban development strategies, as these structures shape and often determine the economic, social and environmental dynamics between different regions. Such systems tend to have five basic characteristics: centres function as economic and political centres, while peripheries often suffer from economic, infrastructural and service deficiencies. Centres tend to have higher levels of resources, technological development and innovation potential, while the role of peripheries is often limited to providing labour and raw materials and clarifying social systems. When examining spatial interactions, we need to understand that these systems interact dynamically with each other. The mechanisms of these interactions are manifested in different dimensions, including the movement of people, economic relations and technological flows. Interactions between centres and peripheries strongly influence development: while centres attract labour, knowledge and investment, the development of peripheries often depends on the supply of services and products demanded by centres [10-12].

The third dimension of these interactions is the integration of sustainability aspects, which requires taking into account environmental impacts and ensuring a balance between economic growth and social welfare. For centre-periphery systems to develop in a truly sustainable way, it is necessary to rethink the mechanisms of spatial interactions. To facilitate the development of such systems, it is essential to foster closer cooperation between different levels of government and local communities, and to develop regional development strategies that focus on creating harmonious links between centres and peripheries. These approaches could result in not only economic benefits but also social inclusion and environmental sustainability in future urban regions [13].

Integrated planning and development strategies are key elements of sustainable urban development, aiming to create coherence between different areas and exploit synergies. They represent a holistic approach to urban development, taking into account economic, social, environmental and cultural aspects. Our research shows that one of the primary tasks of integrated urban planning is to actively involve local communities in the planning process. In the application of integrated economic development strategies, it is important to ensure that different sectors such as transport, housing, environment and economic development work together seamlessly, and we therefore consider it a priority to analyse the interrelationships between them. In addition, these strategies aim to implement

the principles of sustainability in all these sectors, with a particular focus on the development of public services and transport systems [14; 15]. The integration of innovation, research and new technologies is essential to achieve sustainable urban development, allowing existing systems to be optimised and sustainable solutions to be sought. Our research has also demonstrated that integrated planning approaches should pay attention to the interactions between centre-periphery systems, to strengthening the links between urban and rural areas and to promoting sustainable development in rural areas. These processes help to promote the competitiveness of local economies and social cohesion. The implementation of such strategies is particularly important in metropolitan areas, where population density, transport challenges and environmental problems form a complex system and where the need for an integrated approach becomes essential for sustainability and social well-being [16; 17].

Materials and methods

In our study, we have analysed the commuting datasets of the last two Hungarian censuses (2011, 2022) related to Budapest and its agglomeration, and carried out a comparative analysis of these datasets. The municipal-level commuting data used for the statistical analysis were provided by the Hungarian Central Statistical Office. Based on the methodologies used in the literature on the subject, we analysed the centrality of Budapest and the correlates of its change after defining the labour market catchment area of Budapest, and from this analysis we made suggestions for strategic directions for sustainable urban development.

Results and discussion

Technologies and solutions developed from innovative research results related to sustainable urban development play a key role in improving the liveability and environmental performance of modern cities. Such solutions include the SMART city concept, which builds on the integration of a range of network technologies and data collection systems. Sensors and IoT devices can be used to collect real-time data on urban infrastructure, transport systems, street lighting conditions and waste management. This data will enable better urban planning, strategic decision-making and optimisation of public services, thus reducing the ecological footprint of cities. The integration of renewable energy sources is also key to urban sustainability. By harnessing solar and wind energy, cities can become more independent from fossil fuels. One form of this is green roofs, which not only provide energy benefits but also contribute to increasing urban biodiversity and improving air quality. In addition, sustainable transport solutions, such as electric vehicles and a network of cycle paths, can significantly reduce carbon emissions in cities, while promoting healthier lifestyles for the population.

It is through the interconnection of all these innovative techniques and a close network of natural, economic and human factors that an integrated development strategy can be developed. One of the milestones is the combination of digital technology and the principles of the circular economy, which will help cities use their resources in a more sustainable way. Through waste recycling, composting and reuse schemes, cities can minimise waste generation and reduce the need for new raw materials by using recycled materials. In addition, innovative sustainable building technologies, precision construction and modular building systems, also help to make development processes more efficient while reducing environmental impacts. Building sustainable cities of the future will therefore require not only technological innovation, but also an integrated approach to a complex ecological and social system that takes into account community needs.

Our research has shown that community participation and the involvement of local communities in development processes is an essential element in sustainable urban development, as the lack of active participation of local people can often lead to unacceptable projects and a disregard for local needs. The extent and quality of participation is not only linked to transparency in decision-making and democratic values, but also to strengthening the identity of communities, increasing social cohesion and promoting social innovation.

The first step in ensuring effective community participation is to promote openness of information. This includes keeping local communities informed about development plans, expected impacts and implementation timeframes. Participatory methods, such as public hearings, workshops and consultation forums, play a key role in ensuring that the voices of local communities are heard and incorporated into development objectives. In addition, it should be stressed that involving local communities in

development projects can not only serve to preserve local values and traditions, but can also stimulate new innovations, solutions and approaches. Community-relevant issues, such as improving transport infrastructure, preserving green spaces or expanding social services, can only be achieved with the active involvement of local residents.

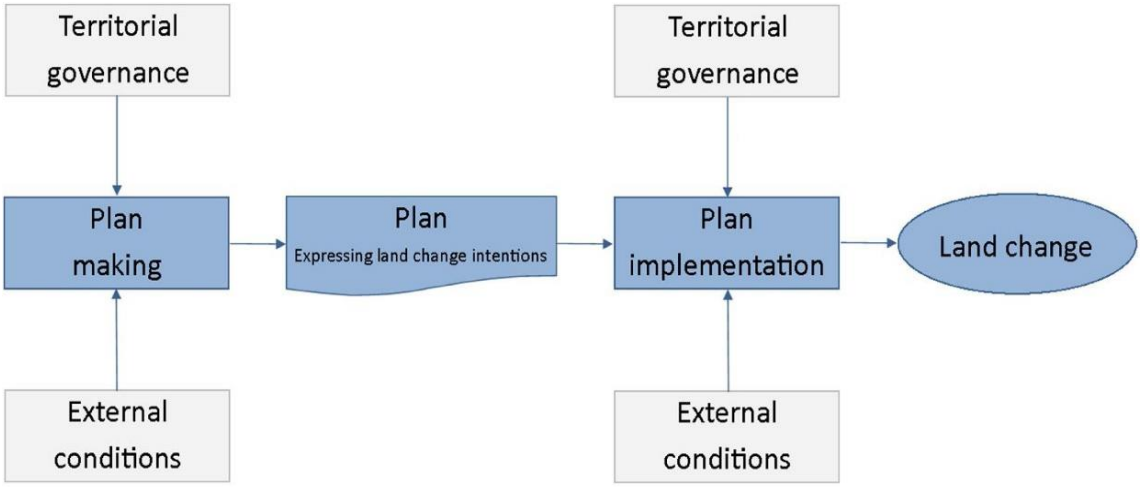

Fig. 1. **Conceptualizing the impact of spatial planning on land change through spatial information expressed in plans, territorial governance, and external conditions [18]**

All this suggests that the field of urban development, theories of centre and periphery, face complex and diverse challenges, which public policies and regulations play a crucial role in the life of modern cities. These policies do not only concern the infrastructural development of cities, but also have a significant impact on social, economic and environmental aspects, thus requiring an integrated approach to urban development. Taking into account the different needs and conditions in different countries, regions and cities, public policy frameworks should be developed around specific objectives, tailored to local or regional specificities. Urban development strategies are typically based on cooperation between local authorities and public institutions, in which public policies shape legislation such as spatial planning laws, urban development programmes or guidelines and recommendations incorporating the principles of sustainable urban development.

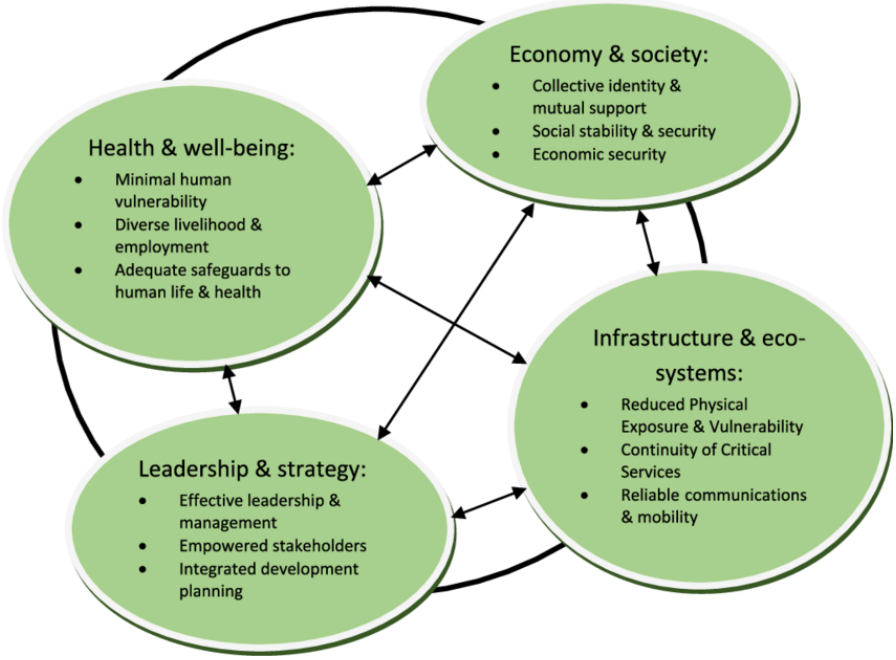

Fig. 2. **Four dimensions of the city resilient goals [19]**

These laws aim at optimising the use of the urban environment, improving the quality of life of the population and reducing social and economic disparities, which are increasingly emphasised in modern

urban models (Figure 1). The development of integration programmes is not only intended to promote the mobility of urban residents, but also to encourage the development of peripheral areas, thereby reducing social tensions and contrasts between the centre and the periphery. All of these factors illustrate that the resilience of the centre is highly dependent on the state of the periphery.

The systems theory of urban development is about understanding the 'state' and 'nature' of the system. The primary task is to identify each problem analytically on the basis of dependent and independent variables. The former can be directly addressed, the latter cannot. The basic variable systems diagram in Figure 2 shows the interrelationship of the system structure. This figure shows four dimensions and their associated objectives that lie at the boundaries of the system. The purpose of the diagram is to show which aspects directly related to the objectives are feasible within the system (these are the dependent variables). The other variables are outside the system and thus have an impact on the analysis, but cannot be directly influenced (these are the independent variables). All of these networks of relationships illustrate the factors that need to be taken into account for future planning of urban development, which relate well to a better understanding of the centre/periphery systems.

Our analysis shows that Budapest has further strengthened its role as an economic centre in the period under review, with a significant labour drain on its immediate surroundings. The increase in the population of the agglomeration and of the settlements in the labour market catchment area generated a significant labour potential for Budapest, thus strengthening the central role of these settlements compared to those in rural Hungary. All this suggests that the potential for developing centre-periphery systems is a key element of sustainable urban development, aiming at reducing territorial disparities and strengthening regional cohesion.

As a result of our research, it can be concluded that the development of centre-periphery systems is a key element of sustainable urban development, aiming at reducing territorial disparities and strengthening regional cohesion. Modernisation of transport networks in large cities, including rail, bus and cycling, not only improves accessibility to peripheral areas, but also allows for the integration of local transport systems. It can be seen that the development of territorial cooperation and partnerships is essential for successful development of centre-periphery systems, and closer cooperation between local authorities, economic operators, NGOs and public service providers could be the key to achieving common goals. Our research shows that interregional cooperation can strengthen the position of peripheral regions, increase their competitiveness and promote the diversification of local economies.

Conclusions

1. Our research suggests that the effectiveness of urban development relies not only on the well-being of the urban core, but also of the surrounding peripheral areas. Therefore, it is recommended that the strategic planning of cities should not only focus on the economic growth of the centre, but also on the integrated development of the whole region, as strengthening the periphery contributes to increasing the social cohesion and economic stability of local communities, and thus to the economic and social development of the catchment areas.
2. We have identified the importance of building sustainable transport systems to reduce urbanisation pressures and improve mobility. In addition to improving public transport and extending pedestrian and cycle routes, it is necessary to plan for the integration of alternative means of public transport.
3. Our analysis shows that strengthening the institutional framework is essential for sustainable development. A new integrated planning approach that takes into account the views of local communities is needed to promote cooperation between local authorities and civil society. Our research has shown that the suction effects of centres are related to a number of endogenous sources, such as the outflow of human capital, the concentration of disposable income, foreign working capital and innovative economy.

Author contributions

Conceptualization, L.B. Cs.T. and K.J., Data collection and Methodology, L.B., Formal analysis, K.J. Cs.T., Investigation, L.B. Cs.T. and K.J., Writing-review and editing, K.J. Cs.T., Visualization, L.B. All authors have read and agreed to the published version of the manuscript.

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