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OPERATIONAL PROGRAMS AS A DRIVING FORCE FOR THE DEVELOPMENT OF SMART CITIES IN POLAND

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Purpose: This article aims to explain the role of operational programs in developing smart cities and show how they support the financing of key infrastructure projects. The article presents how operational programs in smart cities have changed from 2018-2023.
Design/methodology/approach: The article uses a quantitative data analysis approach to examine the use of operational funds in the largest Polish cities. Data from 2018-2023 were analyzed regarding the value of operational programs and their impact on infrastructure development, digitalization, and innovation. Comparative analysis was used to identify cities leading in the use of funds and to determine what factors may affect the differences in the financing level.
Findings: The analysis results indicate that operational programs play a key role in developing smart cities in Poland. It was identified that the largest Polish cities, such as Warsaw, Krakow, and Rzeszow, use operational funds effectively, contributing to modern infrastructure development and innovative solutions. The values of operational funds increased in 2018-2023 in all the cities studied, indicating the intensive development of projects related to digitalization, renewable energy, and modernization of urban infrastructure. Cities such as Rzeszow and Lublin used the highest operational funds per capita, while Krakow stood out with the fastest growth rate. The analysis also shows that despite its role as the capital, Warsaw has a lower use of operational funds per capita than other cities. That may be because projects implemented in Warsaw are more complex and require a greater outlay of funds, which may affect their pace of implementation. Sustainable development was noted in cities such as Poznań and Wrocław, with investments focusing on modernizing public transport, developing intelligent energy management systems, and improving communication infrastructure.
Originality /value: The originality of this article lies in the analysis of the use of operational programs in the development of smart cities in Poland.
Keywords: smart cities, GDP, smart city index, operational program.
Category of the paper: Research paper.

1. Introduction

In the era of dynamic technological changes, more and more cities worldwide are taking steps to become "smart." Smart cities are places where technology supports the lives of residents, optimizes resource management, and contributes to increasing the efficiency of urban infrastructure. Thanks to modern solutions based on data analysis, cities can better plan spatial development, manage transport, energy, and waste management, and improve public safety. All these elements contribute to the creation of a space that is more friendly to residents and environmentally sustainable. At the center of these processes are operational programs that play a key role in integrating systems and introducing data-based solutions. These programs enable cooperation between various urban sectors, such as transport, energy, waste management, emergency services, and city administration. Thanks to this, cities can respond faster to the changing needs of residents and better manage resources in a sustainable and efficient way.

In Poland, introducing the smart city idea is becoming increasingly common, and the role of operational programs is invaluable in implementing this process. They include support for projects in the field of communication infrastructure, ecological energy, and digitalization of public services, as well as innovative initiatives related to improving the efficiency of city management. Thanks to funds and strategies, cities such as Warsaw, Wrocław, or Gdańsk can introduce modern technologies that contribute to greater involvement of residents and optimization of city services.

This article aims to present operational programs in smart cities and analyze their use in the budgets of Polish smart cities.

2. Methods of financing the development of smart cities

The methods of financing the development of smart cities are diverse. They are based on using various sources of financing to implement projects related to modern infrastructure, digital technologies, and sustainable development. The main and most important source of income is the income of cities. These funds enable large-scale investments to improve residents' quality of life by modernizing infrastructure, increasing energy efficiency, and implementing digital technologies.

The revenues of cities, or local government units in Poland, include several key sources of financing that enable municipalities, counties, and provinces to carry out public tasks. The first is their revenues, i.e., funds obtained independently by local government units, such as local taxes, including property tax, tax on means of transport, and civil law transactions. Additionally, these units obtain revenues from local fees, such as fees for perpetual usufruct, market,

and parking fees, as well as income from assets, such as the sale of real estate or the rental of buildings. The second source of income is general subsidies provided by the state, which units can use for any purposes related to their activities. These subsidies include an educational part aimed at financing schools, a balancing part, supporting units with lower incomes, and an equalization part. Another source is earmarked subsidies, which implement specific tasks like educational programs, infrastructure investments, or social assistance. These subsidies can come from the state budget and EU funds allocated to implement selected projects. Another important element is the EU funds that local government units can obtain to implement development and infrastructure projects, often requiring co-financing from their own resources. The structure of local government units' revenues varies depending on the unit type, whether it is a commune, district, or province, as well as the region's wealth level, which affects the diversity and specificity of individual budgets.

An important financing mechanism is public-private partnerships (PPP), which allow the public sector to cooperate with private enterprises to implement joint investments, sharing costs and risks. These partnerships enable the implementation of large-scale projects that may be too expensive or risky for local government units to implement on their own. Another way of obtaining funds is through city bonds, which are a financial instrument that allows for raising the capital necessary to implement investments in infrastructure development, such as the modernization of energy networks, the expansion of public transport, or the implementation of modern urban traffic management systems. Venture capital funds and private investments are an important source of financing for startups and innovative technological projects in smart cities. These projects are often characterized by high development potential and the ability to generate significant profits, which attracts private investors ready for risky investments. In the form of grants and subsidy programs, government support also plays a significant role in financing innovative city projects and supporting activities in digitalizing city services, energy innovations, and sustainable development. Crowdfunding, although a less popular source of financing for smart city projects, can provide significant support for smaller local initiatives of a social nature. Thanks to the involvement of residents, it is possible to finance projects such as electric vehicle charging stations, the installation of smart lighting, or the development of urban micro-infrastructure. Profits generated by municipal services, such as fees for energy, water, or waste collection, can be reinvested in the development of smart city infrastructure, which allows for self-financing of part of the investment. Bank loans and financing from international financial institutions, such as the European Investment Bank, are another source of financial resources for implementing smart city projects. This type of financing is particularly beneficial in the case of large investments of strategic importance for the city, where long-term savings and revenues are expected to be generated, making the investments more profitable. Thanks to various financing methods, cities can implement comprehensive smart city projects, which not only improve the quality of life of residents but also increase the efficiency of resource use and contribute to a better organization of urban space, which is important in the context of the sustainable development of modern agglomerations.

The article focuses on using operational programs: Infrastructure and Environment, Smart Growth, Digital Poland, and Knowledge Education Development. The Operational Programme Infrastructure and Environment (POIiŚ) is Poland's most extensive EU program, supporting infrastructure development and environmental protection. Its aim is sustainable development through transport, energy, environmental protection, health, and cultural heritage investments. The program includes, among others, the modernization of roads and railways, the development of renewable energy sources, improving waste management, air protection, and thermal modernization of buildings. It is financed by the Cohesion Fund and the European Regional Development Fund, supporting investments implemented by public institutions, enterprises, and non-governmental organizations to benefit residents and the environment. Another program is the Operational Programme Smart Growth. The Operational Programme Smart Growth (POIR) is one of the key EU programs in Poland, supporting innovation and competitiveness of the economy. It aims to develop enterprises through research, development, and innovation and to support cooperation between the science and business sectors. The program finances research projects, the creation of modern technologies, the implementation of innovative solutions, and the development of startups. POIR uses European Regional Development Fund funds to support Polish companies, scientific units, and research consortia to accelerate their development and increase their potential in domestic and international markets. In turn, the Digital Poland Operational Program (POPC) supports the development of digitization in Poland. Its goals include ensuring universal access to fast internet, developing e-administration, and raising the digital competencies of society. Thanks to POPC, projects were implemented to build broadband networks, implement public e-services, and digitize cultural resources, which contributed to technological development and increased citizens' quality of life. The European Regional Development Fund financed the program. In turn, the Knowledge Education Development Operational Program (POWER) supports the development of human resources in Poland, increasing their competencies and opportunities in the labor market. It includes education-related projects, improving qualifications, supporting employment, and social inclusion. POWER is financed by the European Social Fund, supporting students, employees, unemployed people, and educational institutions in improving skills, professional activation, and social innovation.

3. The use of operational programs in Polish smart cities

The article focuses on the value of funds from operational programs for the cities of Kraków, Warsaw, Poznań, Wrocław, Gdańsk, Lublin, Bydgoszcz, Katowice, and Rzeszów in the years 2018-2023. Four operational programs were analyzed: Infrastructure and Environment, Smart Growth, Digital Poland, and Knowledge Education Development.

Table 1.

The total value of operational programs in individual cities in 2018-2023 [PLN]

	2018	2019	2020	2021	2022	2023
Infrastructure and Environment	31491216153	32576499795	34527529393	35060695142	41241440848	42060111270
Intelligent development	8922772698	11844527672	15698129336	18708235546	18544858116	18491756723
Digital Poland	164050124	195884881	173323427	174317723	173614067	173264612
Knowledge Education Development	362510235	433906359	637532978	725384702	734436257	720113842

Source: Own study.

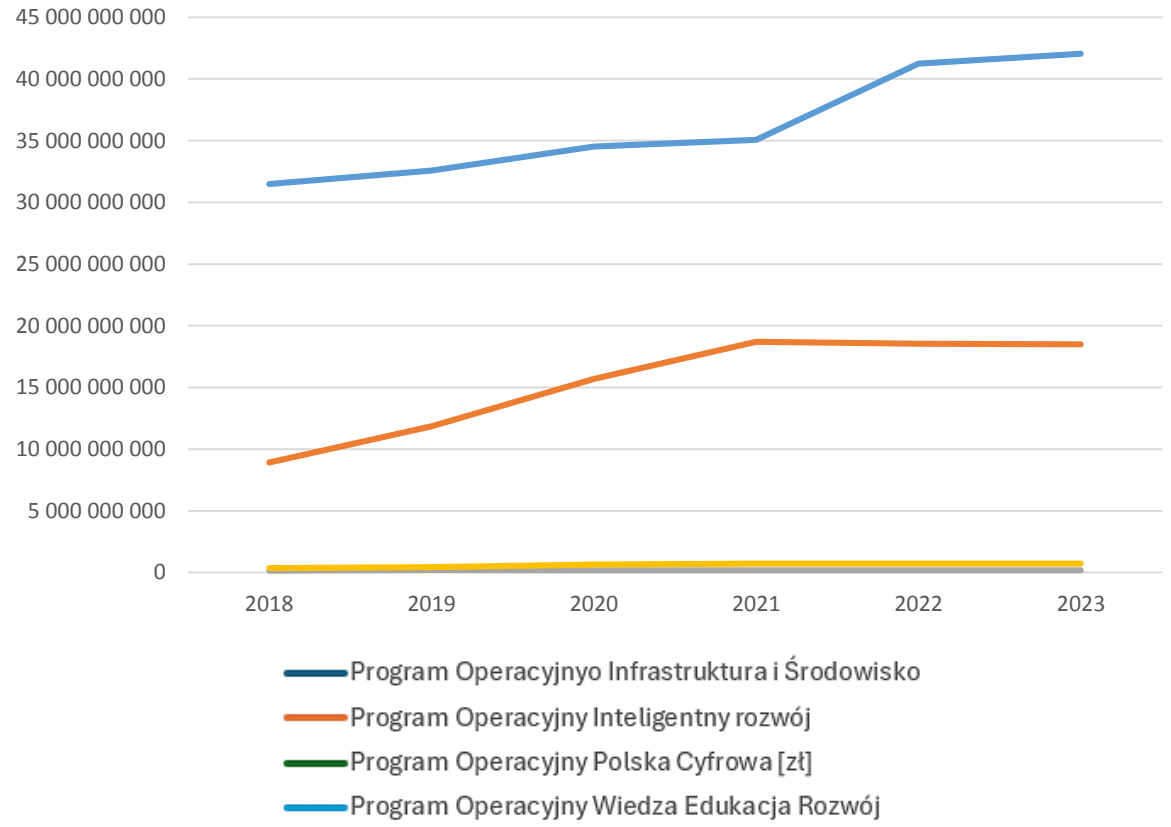


Figure 1. Use of operational programs in subsequent years.

Source: Own study.

Table 1 and figure 1 present operational programs in smart cities in subsequent years. Data on financing individual operational programs in Poland in 2018-2023 indicate a systematic increase in expenditures, especially in infrastructure, environment, and innovative development. The "Infrastructure and Environment" and "Smart Development" programs recorded the most significant increases, which indicates strong support for infrastructure modernization and innovation in Polish cities. The "Digital Poland" program shows stability, which may mean achieving the goals in the scope of essential digitization. In turn, the "Knowledge Education Development" program significantly increased its financing,

which may be related to the need to invest in human capital and education development in the context of growing challenges related to technology and innovation.

First, the total value of operational programs in individual cities was analyzed. That allowed us to find cities that use funds from operational programs. Table 2 and figure 2 show the data on the use of operational programs in Polish smart cities. In all cities, we observe a steady increase in the value of funds from operational programs, which suggests intensive development in infrastructure, digitalization, energy, and innovation. These investments may be related to smart city projects, which aim to improve residents' quality of life and modernize cities.

Table 2.
The total value of operational programs in individual cities in 2018-2023 [PLN]

	2018	2019	2020	2021	2022	2023
Cracow	7501262780	9228363471	11391034920	12653571324	15711641072	15926425751
Warsaw	19641837798	19916682424	21233417630	21781870579	24484962262	24622527264
Poznan	5285118798	6387578138	7303407893	8074558306	8329403321	8712968631
Wroclaw	5678483803	6905564109	8205714271	9061897536	9130205360	9433937897
Gdansk	4386396459	5328538736	5909133994	6355758638	6481647746	6671635592
Lublin	4609466667	5369241148	6259232622	6801895187	7231622733	7333207181
Bydgoszcz	2966465287	3424375856	4192142708	4639061324	4693997310	4800924179
Katowice	2732052496	2843039078	3461018592	3739044014	3921405056	4037126719
Rzeszow	3101300520	3554013014	4283489299	4628605594	5295160630	5369403113

Source: Own study.

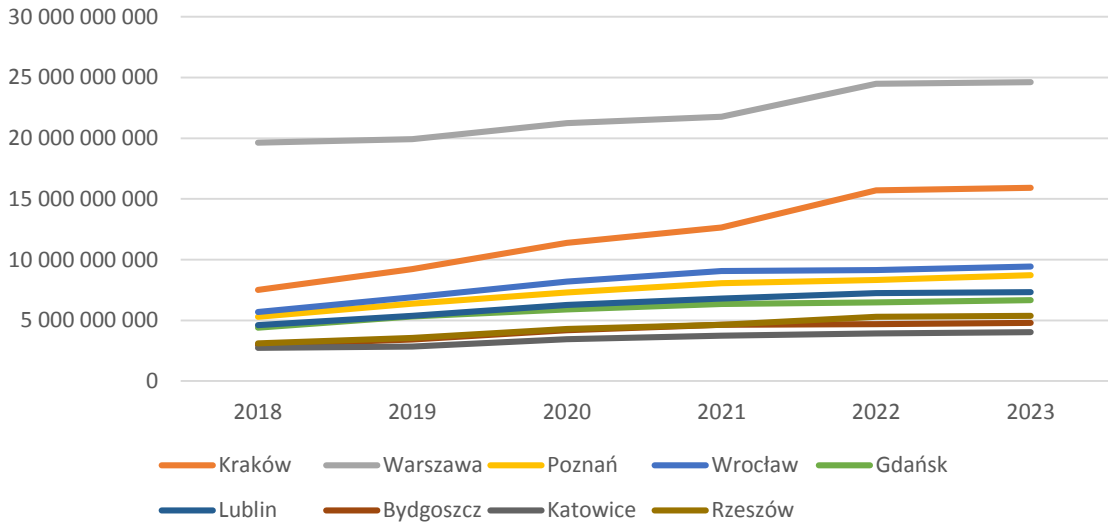


Figure 2. The use of operational programs in Polish smart cities.

Source: Own study.

Warsaw has the highest value of funds compared to other cities, which results from its role as the capital of the country and a key economic center. The value increased from about PLN 19.6 billion in 2018 to over PLN 24.6 billion in 2023. This significant increase suggests that the city is investing intensively in infrastructure development and other strategic projects. That is also confirmed by the cluster analysis presented in Figure 2. Warsaw is a single bond

and significantly lags behind other cities, as the capital city clearly dominates in terms of investment value. That is understandable, considering the size of the city and its economic and administrative importance. It also means a greater demand for modern infrastructure and innovation investments.

The second city in Poland in terms of the use of operational programs is Kraków. The use of operational programs in the case of Kraków is also systematically growing, from about PLN 7.5 billion in 2018 to over PLN 15.9 billion in 2023. The level of use of operational programs in Kraków may indicate a large number of development and modernization projects in this city.

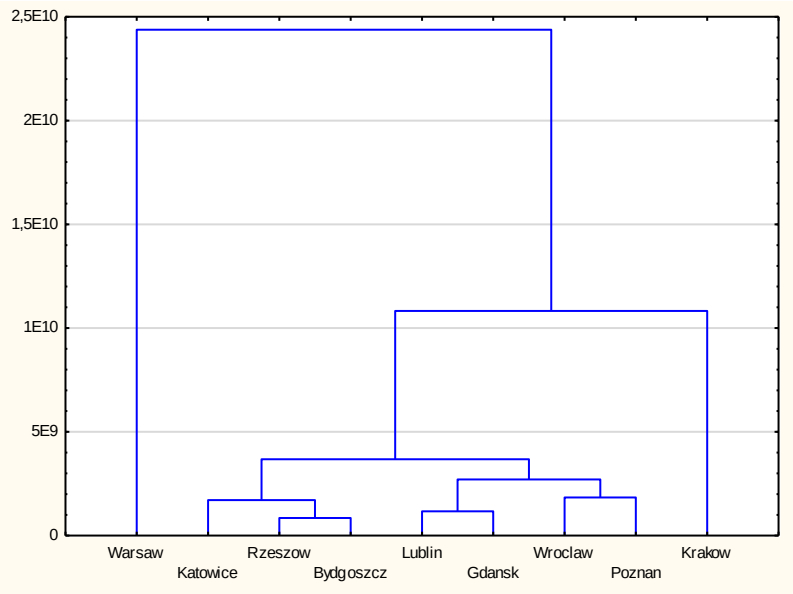


Figure 3. Dendogram of Polish smart cities using operational programs.

Source: Own study.

Kraków's second place among cities regarding the value of funds reflects its development ambitions and growing importance as a cultural and economic center. It is also one of the most important cities in Poland in terms of tourism and education, which increases its investment needs. The next cities are Poznań, Wrocław, Gdańsk and Lublin. Funds values for these cities have also been growing over the years. Wrocław and Poznań have similar values, which increase from around PLN 5.7 billion to almost PLN 9 billion by 2023. Gdańsk and Lublin have also recorded growth, although at a lower level than Kraków and Warsaw. The group that uses funds from operational programs the worst includes Katowice, Bydgoszcz, and Rzeszów. These cities have lower funds values, but they also show gradual growth. Katowice increased its funds from around PLN 2.7 billion in 2018 to over PLN 4 billion in 2023. It seems that the cities that use funds from operational programs the worst are Rzeszów and Bydgoszcz.

To better illustrate the use of operational funds in Polish cities, the use of operational funds per 1 city resident and the growth rate in the years 2018-2023 were calculated. The calculations of the indicators are presented in the table 3.

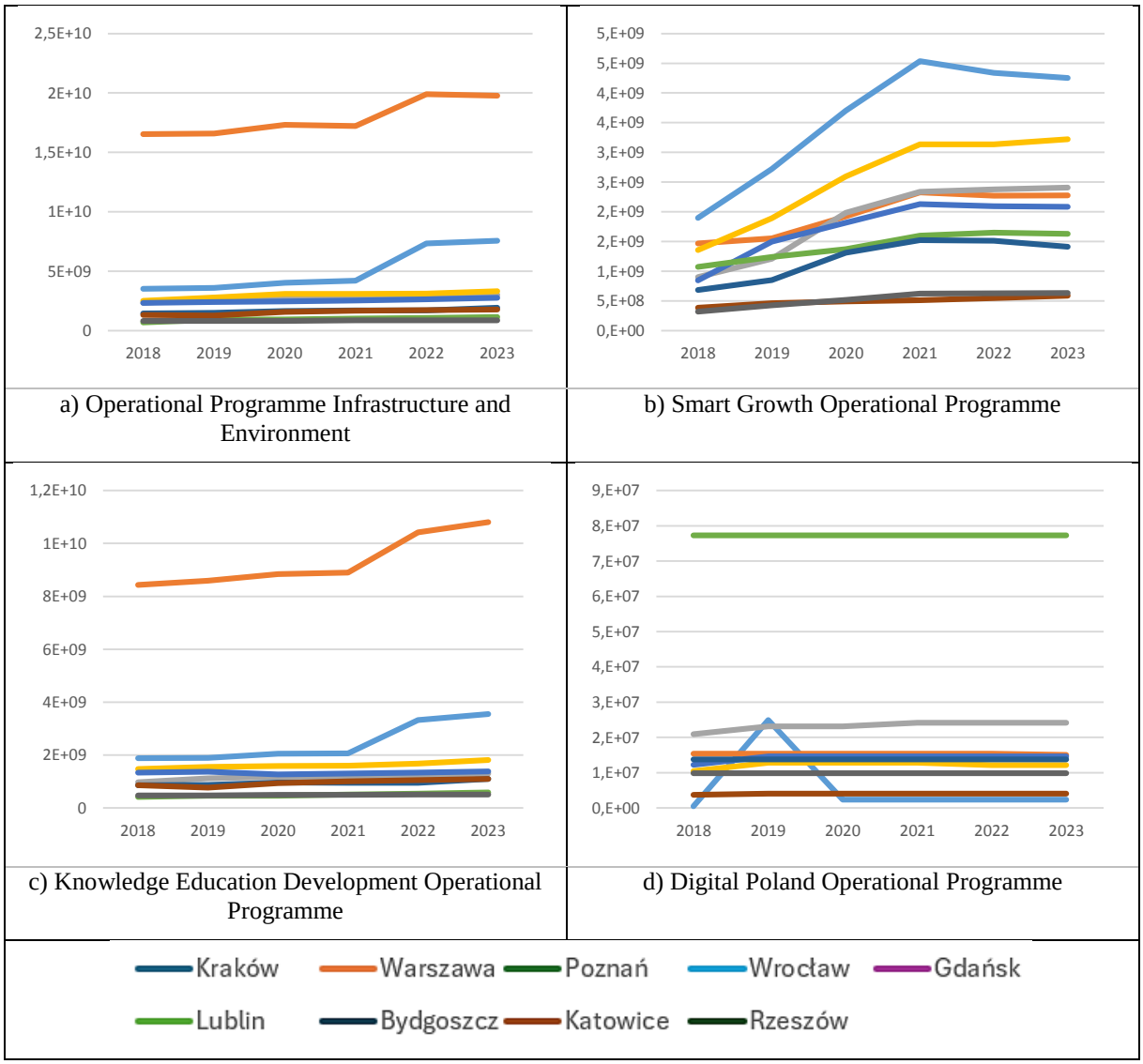
Table 3.
The indicator of the use of operational funds per capita [PLN]

City	Use of operational funds per capita [PLN]	Average growth rate 2018-2023
Rzeszow	27218,82	1,12
Lublin	22251,17	1,10
Cracow	19754,91	1,16
Poznan	16181,90	1,11
Bydgoszcz	14707,18	1,10
Katowice	14460,14	1,08
Wroclaw	14002,28	1,11
Gdansk	13689,03	1,09
Warsaw	13226,55	1,05

Source: Own study.

Rzeszow achieves the highest utilization of operational funds at PLN 27,218.82 per capita, indicating an intensive investment level. At the same time, the average growth rate for Rzeszow is 1.12, which means dynamic development and well-balanced investments in relation to the population. Lublin is in second place with a value of PLN 22,251.17, with an average growth rate of 1.10. That indicates an intensive allocation of funds to the city's development, which allows for maintaining a high level of investment. Krakow ranks third in terms of the utilization of the value of funds, amounting to PLN 19,754.91 per capita, but at the same time shows the highest average growth rate at the level of 1.16. That may mean that Krakow uses operational funds to a large extent and develops the fastest, which may be the effect of effective investment programs and growing economic activity. Poznań, with a value of PLN 16,181.90 per capita and a growth rate of 1.11, shows balanced development, similar to Wrocław, which achieved an average growth rate of 1.11, with a value of funds of PLN 14,002.28. Bydgoszcz and Lublin have similar average growth rates of 1.10, respectively, suggesting stable investments in the city's development, although Bydgoszcz, with a value of PLN 14,707.18 per capita, invests less than Lublin. Katowice records a relatively low use of funds, amounting to PLN 14,460.14 per capita, and their average growth rate is 1.08, indicating a moderate pace of city development. Gdańsk, with a value of funds of PLN 13,689.03, achieves an average growth rate of 1.09, indicating stable investments, although their scale is smaller than in other cities. Warsaw has the lowest operational funds per capita use, at PLN 13,226.55, with an average growth rate of 1.05. That may indicate a greater concentration of investments in other areas, perhaps more extensive infrastructure programs, which are not reflected in operational funds per capita, but also greater needs related to the large population of the capital.

Polish cities participated in the Infrastructure and Environment Operational Programme, the Smart Growth Operational Programme, the Digital Poland Operational Programme, and the Knowledge Education Development Operational Programme. Figure 4 presents the level of use of operational programmes in individual cities from 2018 to 2023.



a) Operational Programme Infrastructure and Environment

b) Smart Growth Operational Programme

c) Knowledge Education Development Operational Programme

d) Digital Poland Operational Programme

Figure 4. Use of operational programs.

Source: Own study.

Warsaw best uses the Infrastructure and Environment Operational Programme (Figure 4a). Warsaw has consistently high values, with a slight increase until 2021 and a slight decrease in 2023. Kraków is characterized by a systematic increase in financial values, with a clear jump between the fifth and sixth year, which may indicate a sharp increase in investment or financing. Poznań has a steady, moderate increase, with a clear increase between 2022 and 2023. Wrocław shows a trend similar to Kraków, with a systematic increase, exceeding 3 billion in 2023. Gdańsk has a stable, slow increase, without large jumps in value. Lublin starts with the lowest value but steadily increases, especially between 2019 and 2020. Bydgoszcz, like Gdańsk and Lublin, shows a systematic increase, with a more significant increase in the last year. Katowice has a more variable trend than other cities, with an initial decrease, after which values increase. Rzeszow shows relatively stable financial values without significant changes. The largest increase in financial values can be observed in Krakow and Warsaw, while Poznan, Wroclaw,

Gdansk, and Bydgoszcz show predictable growth. Katowice and Rzeszow remain more stable or show minor fluctuations.

In the Smart Growth Operational Programme (Figure 4b), Kraków is characterized by systematic growth until 2021, followed by a slight decline in value but stabilization at a high level. Warsaw shows moderate growth until 2021, followed by a slight decline and stabilization. Poznań has dynamic growth until 2021, with the later years bringing milder increases in value. Wrocław has shown strong growth, reaching a stable level of over 3 billion in recent years. Gdańsk shows increasing values until 2021, followed by a slight decline and stabilization at a slightly lower level. Lublin starts with moderate values, systematically increasing until the fifth year and then slightly declining. Bydgoszcz had an apparent increase until the fourth year, but then the values decreased slightly. Although starting with low values, Katowice shows stable growth throughout the period, reaching almost 600 million in 2023. Rzeszów, like Katowice, shows steady growth with slight differences, reaching a value of around 633 million in 2023.

Similarly to the Smart Growth Operational Programme in the Knowledge Education Development Operational Programme, Warsaw is the city that uses financial resources the most. Warsaw showed a steady increase in value until 2021, but there has been a slight decrease in recent years. Similarly, Krakow is characterized by a dynamic increase in financial values until 2021, after which the values stabilize at a high level. Poznań maintains relatively stable financial values, with a slight increase in recent years. Wrocław records a significant increase until 2020, after which the financial values remain at a similar level, with slight fluctuations. Gdańsk is characterized by stable growth throughout the period, with moderate differences.

On the other hand, Lublin shows a sharp increase until 2021 and then stabilizes the values. Bydgoszcz and Katowice significantly increased until 2020, when the values stabilized. Rzeszów shows a steady increase until 2021, and then the values stabilize at a level of around 54 million.

In the Digital Poland Operational Programme, Kraków recorded a sharp increase between the first and second year, followed by a decrease and stabilization at around 2.39 million. Warsaw maintains stable financial values throughout the period, with a minimal decrease in the last year. In contrast, Poznań shows a systematic increase in financial values, stabilizing around 24 million in recent years. Wrocław records an increase between 2018 and 2019, after which the values stabilize but decrease slightly after 2019. Gdańsk follows a similar trend to Wrocław, with an initial increase, followed by stabilization with a slight decrease in recent years. Lublin maintained constant values throughout the period with no changes. Bydgoszcz has also had constant values throughout the years. On the other hand, Katowice recorded a small increase at the beginning, after which the values stabilized at around 4 million. Rzeszów maintains stable financial values for most of the period, with a minimal decrease in the last two years.

Conclusions

The analysis presented in this article shows that operational programs significantly contribute to the development of smart cities in Poland, especially in large agglomerations such as Warsaw and Krakow. The general trend of increasing the use of funds in all cities suggests increasing resource availability and greater demand for investments, especially in infrastructure, sustainable energy, and technology. These investments are crucial for transforming cities into more modern and user-friendly environments, consistent with the smart city concept.

Cities such as Rzeszow, Lublin, and Krakow used the most operational funds per capita, with Krakow showing the fastest growth rate. In contrast, despite its role as the capital, Warsaw allocates the least operational funds per capita, which may be due to the specificity of larger and more complex projects. Operational programmes have proven to be an effective tool in supporting the strategic transformation of Polish cities into smart cities, responding to technological and sustainable development challenges. By providing the necessary financial support, these programs enable cities to better respond to the needs of their residents, promoting sustainable development and improving the quality of life in cities. That indicates that further expansion and improvement of these programs can play a key role in ensuring that Polish cities continue to thrive in an increasingly digital and resource-conscious world. Future research could focus on a deeper examination of individual projects financed by operational programs and their direct impact on urban life, such as mobility, energy efficiency, and public safety. That would allow for a more comprehensive understanding of the outcomes and broader implications of smart city initiatives in Poland.

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