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Housing Infrastructure as a Determinant of Quality of Life in Selected Polish Smart Cities

Izabela Jonek-Kowalska

Department of Economic and Computer Sciences, Faculty of Organization and Management, Silesian University of Technology, Roosevelt 26-28 Street, 41-800 Zabrze, Poland; izabela.jonek-kowalska@polsl.pl

Abstract: In the concept of the Smart City, the issue of quality of life of residents is strongly emphasized. In theory and practice, the quality of urban life is determined by a wide variety of factors. This article focuses on housing infrastructure as a determinant of the quality of life in selected Polish Smart Cities and seeks answers to the question: What is the level of variation in the availability and quality of housing infrastructure in the studied cities and against the provinces in which they are located? In solving the research problem formulated in this way, the following were used: (1) Indicators determining the quality and accessibility of housing infrastructure at the level of the studied cities and provinces; (2) a multiple case study (for eight cities from different regions of Poland); and (3) a comparative analysis conducted at the level of the cities and provinces in which they operate. The resulting analyses indicate that there are differences in the availability and quality of housing infrastructure at the level of smart cities and provinces representing the regional average. The analyzed cities—in all the criteria studied (except the area of the apartment)—dominate over the provinces, which means that they have larger and better housing resources than the rest of the region.

Keywords: Polish Smart Cities; urban infrastructure; quality of life; urban governance

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1. Introduction

The main goal of developing and implementing the concept of smart cities is to strive to improve the quality of life of residents [1–7]. Currently, the concept very often emphasizes the sustainability of the activities carried out in this regard and thus demonstrates an enhancement in the quality of life for not only current, but also for future, generations [8–10]. Such an understanding of the smart city idea is often regarded as idealistic or even utopian and has a sizable group of adversaries. Among the reasons for criticism, the most commonly cited are [11–14]:

- Favoring cities operating in highly developed economies, thereby deepening civilizational, social and economic differences.
- Elitism of smart city residents, fostering various types of exclusions [15,16].
- Excessive dependence of city management on the business environment, which can lead to fraud and even corruption.
- Prioritization of modern technologies in city management [17].
- Lack of privacy protection for urban residents [18,19].
- Overlooking the needs of seniors and people with disabilities [20].

A review of the literature on the subject and international Smart City rankings seems to sustain the above argument, as it is dominated by themes related to the—often uncritical—glorification of smart city solutions based primarily on the use of IT and ICT [21–25] applicable to all areas that shape quality of life (economy, finance, environmental protection, transportation, health, sports and recreation or tourism). Moreover, leaders in this field are usually cities operating in Europe, the United States or Australia located in economies with the highest level of civilizational, social and economic development.

Nevertheless, it is worth noting that, without technological progress, it will not be possible to improve quality of life, especially in areas such as health, environmental protection or transportation. Hence, the dominance of the above topics can be considered justified and can be treated as a form of dissemination of best practices. In turn, the leaders of the international Smart City rankings can serve as role models and a benchmark for shaping urban conditions conducive to improving the quality of life of residents.

Given these circumstances, this article focuses on the functioning of smart cities in Poland's developing economy. There were two key considerations in favor of such a research location. First, the need to present the functioning of Smart Cities in less exposed and less spectacular locations. Secondly, the need to empirically verify the thesis of the differentiation of living standards in Smart Cities and their regional environment. Indeed, many of the publications in this area are theoretical and polemical in nature, resulting in a lack of research based on quantitative compilations and comparisons.

In addition, the area of analysis of the determinants of urban quality of life was significantly narrowed, with a focus on the availability and quality of housing infrastructure. Such a restriction was dictated by two considerations. The first was the fact that this is an issue that is far less frequently described in the literature than issues of IT or ICT solutions or environmental protection. Meanwhile, for city residents facing economic and financial difficulties, the state of housing infrastructure is an important determinant of quality of life. The second premise was the result of a multi-faceted study of smart cities in Poland—conducted at the Faculty of Organization and Management of the Silesian University of Technology—which found that the lack of or unsatisfactory quality of urban infrastructure is the most serious barrier to quality of urban life in Polish cities (the study included a representative sample of 280 cities) [26].

The identification of the problem of variation in the availability and quality of urban infrastructure and its empirical exploration provide a rationale for complementing and developing analyses devoted to the basic needs of urban communities, which in developing economies are often poorly met and constitute an obstacle to the development of smart cities. This approach also exposes the need for a balanced approach to the evaluation and creation of smart urban solutions, which should not be available only to countries with a high level of economic and civilizational development, as this promotes the widening of the development gap and social and economic exclusion, which, as already signaled, is often criticized by opponents of the Smart City concept.

Accordingly, the article seeks an answer to the following research problem: What is the level of variation in the availability and quality of housing infrastructure in the studied cities and against the provinces in which they are located? In solving the research problem formulated in this way, the following were used: (1) A multiple case study (for eight cities from different regions of Poland); (2) indicators determining the quality and availability of housing infrastructure at the level of the studied cities and provinces; and (3) a comparative analysis conducted at the level of the cities and provinces in which they operate.

The originality of the considerations and analysis presented is related to:

- Relating Smart City research to developing economies.
- The prominence of issues related to the availability and quality of housing infrastructure in shaping the quality of life of residents, particularly relevant in cities that are slower to aspire to the title of Smart City.
- An empirical analysis of the determinants of quality of life in cities considered smart in international rankings.
- Paying attention to the variation in the quality and availability of housing infrastructure found in Polish cities considered smart occurring at the urban and regional levels.
- A call for the modification of Smart City evaluation methodology with indicators related to the quality and accessibility of urban infrastructure (in particular, ISO 37120: Sustainable social development. Indicators of urban services and quality of life).

The findings of the research contribute to the development of research on the quality of life and its variation in smart cities in developing economies and provide a source of

recommendations to city governments on the direction of necessary measures to improve the quality of urban life.

2. Literature Overview

2.1. Aspects of Smart City Development Differentiation

Previous research shows that variation in the development of smart cities is strongly influenced by socioeconomic conditions [27–29]. The size and financial situation of large cities have a favorable impact on the development potential to be smart, which is due to the greater availability and diversity of resources, especially human and financial resources. Large cities also have the added advantage that, by definition, they tend to be more attractive to potential investors and human capital [30]. As De Marco and Mangano [31] demonstrate, a significant portion of smart city investments, including primarily those related to construction and energy, require significant capital expenditures, resulting in their implementation mainly in cities with high levels of economic prosperity.

Empirical studies also point to differing approaches to the process of creating smart cities. Hu and Zheng [31], comparing smart cities in China and the US, found that the US model for creating smart cities is based on strong community involvement and is participatory in nature. The Chinese model, on the other hand, is hierarchical in nature, with the dominant participation of state authorities and virtually excludes the participation of urban stakeholders. In addition, in the U.S. model, the business environment plays a large role in the creation and implementation of smart city solutions, providing valuable financial support for the implementation of the process. In China, most of the authority in this area is reserved for state authorities.

Bruno and Fontana [32]—like the researchers mentioned above—emphasize that Southern European cities also require a different approach to the creation of smart city infrastructure, as they are distinguished from the leaders of the international Smart City rankings by their medium and small size and centuries-old traditions and customs. Under these conditions, it is difficult to create digitized, contemporary metropolises [33,34]. The results of their research imply a long-term, comprehensive and individualized approach to creating smart city strategies that will be free from incidental, sporadic and political decisions and actions.

Similar conclusions were proposed by Lytras et al., 2019 [35]. Their research shows that residents expect cooperation, participation, creativity and dialogue from a smart city. Technological solutions are not a priority for them. On the other hand, Ji et al. in their research on urban community expectations [36], emphasize the importance of sustainable use of urban resources and the stability and security of the social environment as priorities in ensuring the desired quality of life.

The aforementioned circumstances require cities to take a comprehensive approach to both identifying the needs and expectations of residents and planning and implementing smart city solutions. Meanwhile, as highlighted by Nunes et al. [37], a systematic and comprehensive approach to smart city management is lacking in the literature and practice. This may be a result of the lack of an operationalized approach to defining smart cities and a point-by-point, area-by-area analysis of their operations.

Polish cities—which are the subject of the research in this study—are characterized by a fairly high degree of diversity in terms of size and the income situation of their residents. Of the more than 930 units with city status in terms of population and economic and financial situation, provincial cities (16 units) definitely stand out. Previous research also shows that the implementation of smart city solutions in Poland is mainly influenced by the number of its residents [38]. In addition, the level of sophistication of the level of cities implementing the Smart City concept is rated as average. It is also worth adding that medium-sized cities are familiar with the Smart City concept, and are often also interested in its implementation, but due to economic barriers and many unsolved current problems, they are unable to engage in its practical implementation [39], which is typical of smart cities in emerging and developing economies [40].

The process of creating Poland's smart cities primarily involves municipal and regional authorities due to the decentralization of local government, which points to a model similar to the US and facilitates the strategic planning process, but also involves the need to seek funds for smart urban infrastructure projects on their own. In the last two decades, funds for this purpose have been obtained mainly from EU infrastructure projects such as those described by Orejon-Sanchez et al. in Spain (2022) [41]. Large cities have also succeeded in attracting business investors interested primarily in transportation, mobility and green energy initiatives [42,43].

It is also worth mentioning that municipal authorities in Poland have been making efforts to implement local and regional communities in the process of selecting and planning urban investments, however, these activities are sporadic and do not always enjoy the interest of residents, which indicates a rather low awareness and belief in social causation [44–46].

In light of the above, the differentiation of smart city development can most often relate to the following aspects:

- Model for creating, implementing and financing smart city solutions.
- The level of sophistication (maturity) in being smart.
- Social and economic situation significantly determining the development of Smart Cities.
- Discrepancies in the expectations of city authorities and residents.
- The scope of community participation.

This article also attempts to assess the variation in the availability and quality of urban infrastructure between selected cities associated with Smart Cities and their regional surroundings, which helps to complement the research presented in this chapter on the level and extent of differences in Smart City performance.

2.2. Smart City Evaluation and Quality of Urban Life

There are a number of practical problems associated with the evaluation of smart cities. This is because there are currently a wide variety of evaluation principles and international rankings that group smart cities [47]. Each of these is provided with a set of highly individualized indicators, which complicates comparisons and subjectivizes the results obtained. Moreover, it generates the need to collect, process and monitor large data sets on virtually all spheres of city life [48–50]. Nevertheless, as Caird [51] emphasizes, such evaluation is needed not only for the possibility of being evaluated, but primarily for its diagnostic usefulness and for its use in the decision-making process of city authorities. However, the author emphasizes the need to adjust the scope and timing of the data acquired from the size of the urban projects being implemented and the level of urban management at which the data will be used [52].

In addition, Hajek et al. (2022) [53], after critically analyzing the principles of Smart City evaluation, point out the need to approach the issue holistically and also take into account feedback between different areas and their impact on Smart City performance. The authors also recommend the use of real-time data in the evaluation in order to make the process of conducting the evaluation more dynamic and to obtain results in real time.

It is also worth noting that a common part of the evaluations and rankings carried out are the areas of evaluation, which most often include economy, people, governance, mobility, environment, technology and smart living [54–58]. With that said, a study by Keshavarzi et al. (2021) shows that in practice, Smart City development—and thus its evaluation—is focused on issues related to transportation and the communication network [59]. Utility, services or residents themselves are given far less space and attention, although they are the ones who experience and evaluate the quality of life in the city.

The crucial importance of modern technology and innovation in the development of Smart Cities is also pointed out by Ye et al. (2022) in creating their own ranking for assessing the intelligence of urban structures [60]. In this ranking, they assume that the most important determinants of quality of life in smart cities are digital infrastructure, digital

economy and smart living, and it is these factors that should influence the assessment of the level of sophistication of cities in implementing the Smart City concept.

A slightly different, more humanistic view of assessing living conditions in a Smart City is presented by Shami et al. (2022) [61]. Among the important determinants of quality of life, they list health, safety and sanitation, public education, public participation, culture and sustainable use of natural resources. Interestingly, they are among the few who also pay attention to the development of housing infrastructure, treating it as one of the essential reasons for residents' satisfaction with their living conditions.

The quality of life of residents undoubtedly fits into one of the key areas of smart city evaluation, which is SMART LIVING. However, it is worth looking at the indicators that are reported and evaluated here. As reported by Lombardi et al. [62], the most common parameters in this group in the literature are:

- The size of green areas in the city.
- Number and availability of cultural institutions (movie theaters, theaters, museums, etc.).
- Courses and training to make life easier for people with disabilities.
- Health outlays relative to GDP.
- Facilities for sports, recreation and tourism.

It seems that the issue most widely described among those mentioned above is currently the environmental performance of smart cities. This is largely due to the need to offset the environmental problems generated by cities, such as high consumption of energy, water and other natural resources and significant waste production. Under these circumstances, it is recommended that cities primarily use renewable energy sources and implement circular economy solutions [63–65], with the goal of making them both more sustainable and smarter and improving the quality of life of residents. As Gao and Yuan [66] demonstrate, this is exactly what is happening. The results of their study indicate that smart cities perform better in terms of environmental management than cities that do not have such a status.

Among the above-mentioned determinants of urban quality of life, sports, recreation and tourism have also received considerable attention [67,68]. These are activities related to leisure time management. The availability and quality of smart solutions in this area contributes to the comfort and life satisfaction of residents. Tjønndal and Nilssen [69], using the Norwegian city of Bodø as an example, describe five innovative municipal government projects in the field of sports and recreation that were designed to improve the quality of urban life. Nevertheless, according to the authors, in addition to their undeniable advantages, such as the participation of residents in their creation, they can have a propaganda character that is part of the promotion of the city government, without necessarily meeting the criteria of being smart. Regardless of the circumstances of the implementation of the described investments, they expose the importance of the adjective 'smart' in city management.

An interesting initiative to meet the expectations of the urban community, focused on assessing the quality of life of residents, is the Happiness Driven Smart City (HDSC) index proposed by Zhu et al. [70]. The authors propose to include the following areas:

- Efficient and green physical infrastructure.
- Labor-friendly and innovative economy.
- Inclusive and attractive society.
- Sustainable and eco-friendly natural environment.

Within the framework of the criteria formulated in this way, the importance of the environment and innovation is once again highlighted, which, according to past analyses, is a key determinant of a modern smart city.

The compilation of the areas of smart city assessment and urban quality of life measurement resulted in ISO 37120: *Sustainable social development. Indicators of urban services and quality of life*. This standard is intended to allow a comprehensive and multifaceted assessment of the quality of life of smart city residents in areas directly related to the

previously described aspects of Smart City evaluation [71,72]. The standard includes the following evaluation groups:

- Economy
- Education
- Energy
- Environment
- Finance
- Responding to fire and other hazards
- Administration
- Health
- Recreation
- Security
- Shelters
- Solid waste
- Telecommunications and innovations
- Transportation
- Urban planning
- Wastewater
- Water and sanitation services.

It can be seen from the above summary that this standard directly addresses virtually all the areas of smart city evaluation outlined earlier. At the same time, a lot of space—because there are several evaluation elements—is devoted to the environment. It is also worth noting that the standard additionally pays attention to issues related to public safety and education, which is not always reflected in other evaluation approaches.

Each of the above-mentioned groups includes several evaluation indicators, divided into primary and secondary—allowing for the refinement of the scope of the evaluation to be carried out. Nevertheless, the standard does not take into account the issue of accessibility and quality of housing infrastructure, which, as emphasized in the introduction, is an important determinant of residents' quality of life. This element is also missing from other cited evaluations and rankings, in addition to the approach proposed by Shami et al. (2022) [61]. With this methodological and research gap in mind, the following section of the article assesses and analyzes the accessibility and quality of urban infrastructure using a multiple case study of Polish cities appearing in international smart city rankings and descriptions.

An additional rationale for undertaking this research is that the metrics and principles cited in the previous chapters for evaluating smart cities in terms of quality of life assess aspects that determine a higher standard of living, such as entertainment, culture, attractive living space and land use. Meanwhile, as already mentioned, in developing or emerging countries, residents of even large metropolitan areas struggle to meet more basic needs. This problem needs to be articulated so that socio-economic disparities and the emergence of category A and B smart cities are not further exacerbated.

3. Materials and Methods

3.1. Research Intentions and Methods

Taking into account the presented literature studies and the gap that they help to identify, this article seeks to answer the following research problem: What is the level of differentiation of accessibility and quality of housing infrastructure in the surveyed Polish cities and against the background of the provinces in which they are located? To solve the problem posed in this way, the article uses two groups of indicators relating to, respectively: (1) Availability of urban infrastructure and (2) quality of urban infrastructure.

Thus, to assess the accessibility of urban infrastructure, the three indicators listed below were proposed:

- The average residential area expressed in m^2 that determines the size of living space for one family.

- Average residential space per person expressed in m^2 defining the comfort of living in a given apartment.
- The number of housing units per 1000 residents illustrating the size of the housing stock at the disposal of a given city.

In the case of assessing the quality of urban infrastructure, the degree to which housing is equipped with the following amenities was used:

- Central heating
- Water supply
- Bathroom
- Flushing toilet
- Mains gas.

Data on the above-mentioned indicators are mostly collected at regional and local statistical offices, so they can be easily obtained and observed over time and space.

The indicators outlined above were obtained for the period 2010–2020, and then compared for seven selected Polish cities, thus identifying the level and extent of variation in the availability and quality of housing infrastructure between the cities studied. In addition, this differentiation was also assessed in light of the city–province relationship in order to determine the distance that separates the studied cities from the regional average. Detailed characteristics of the units selected for the study are presented in the next subsection.

The compared cities represent a multiple case study. As a research method, this study allows in-depth analysis and evaluation of housing infrastructure as one of the key determinants of the quality of urban life. It allows a thorough and multifaceted study of a given phenomenon, which makes it possible to better understand and describe previously unknown issues or problems. The method also makes it possible to identify precise recommendations of an individualized nature. Its main drawback, however, is its lack of representativeness, and thus the inability to make broader inferences.

3.2. Selection of Cities for Multiple Case Study

As already mentioned, eight Polish cities were selected for the study. The sampling criteria for the study were as follows:

- The presence in international descriptions and rankings of smart cities.
- Aspiring to be smart and implementing smart city solutions.
- Location in different provinces to allow comparisons between on a regional basis.
- Location in regions with different economic situations (Western Poland—with greater industrialization and income, and Eastern Poland—more agricultural with lower income).

Finally, the following cities were included in the sample: Białystok, Gdańsk, Katowice, Kraków Lublin, Warsaw and Wrocław. Their geographical distribution is presented in Figure 1 and their characteristics are included in Table 1.

Five of the cities surveyed are units with populations exceeding 500,000, so large urban agglomerations. The other three have populations between 292,000 and 328,000, and are therefore smaller units. The surveyed cities are quite diverse in terms of industry. Nevertheless, the industries frequently found in them are chemical, electrical machinery, food and metal industries—characteristic of many regions of Poland. It is also worth adding that these are traditional industries, which do not foster high innovation and by definition may hinder the development of smart cities.

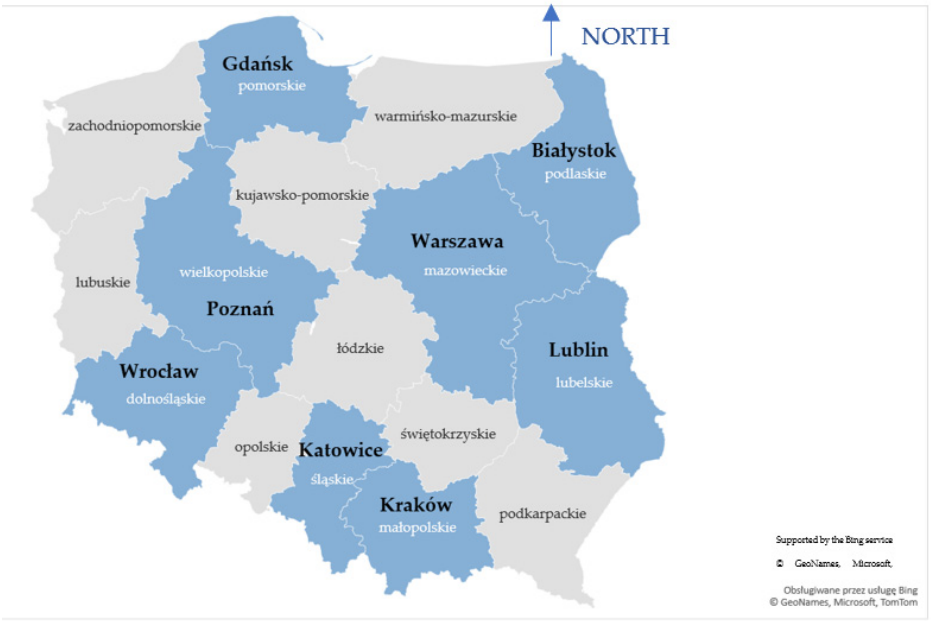

Figure 1. Map of Poland indicating the surveyed cities and provinces (subject of the study).

Table 1. Characteristics of the surveyed cities (as of 2021).

City	Inhabitants	Surface	Industry
Białystok	296,000	102 km^2	Electro-mechanical (electronics, machinery and metal), wood, clothing, food and printing industries
Gdańsk	471,000	263 km^2	Shipbuilding, petrochemicals, energy, apparel, metals
Katowice	292,000	165 km^2	Mining, business services, automotive
Kraków	782,000	327 km^2	Tourism, business services, trade, banking services
Lublin	338,000	147 km^2	Energy, chemical, food, tobacco
Poznań	532,000	262 km^2	Electromechanical, chemical, commercial, transportation
Warszawa	517,000	517 km^2	Electrical engineering, transportation equipment, chemical, food, printing
Wrocław	643,000	293 km^2	Machinery, transportation equipment, food, electro-technical, metal, clothing and chemical industries

4. Results

The following section presents the results of the analyses conducted with comparisons of cities against provinces (regional differentiation) and then individual cities (differentiation at the Smart Cities level).

4.1. Assessment of Housing Infrastructure in Surveyed Cities

The indicators of accessibility and quality of housing infrastructure for the surveyed cities presented in the methodology section (Section 3) are shown in Figures 2–17.

Thus, in Bialystok, a city located in northeastern Poland in a less industrialized region, the average size of an apartment is about 61 m^2, and one city resident has about 26 m^2 of living space at his or her disposal (Figure 2). At the provincial level, these parameters are higher, especially for the area of a single apartment. This is due to the high population density in Białystok, which is the only major urban and economic center in the region. Outside the city, low-density agricultural areas (a small number of apartment blocks and housing estates) dominate.

Nevertheless, the housing stock in Bialystok is more than 15% higher than the average for the Podlaskie Province, reflecting the dominance of the large city in terms of housing infrastructure availability (Figure 2).

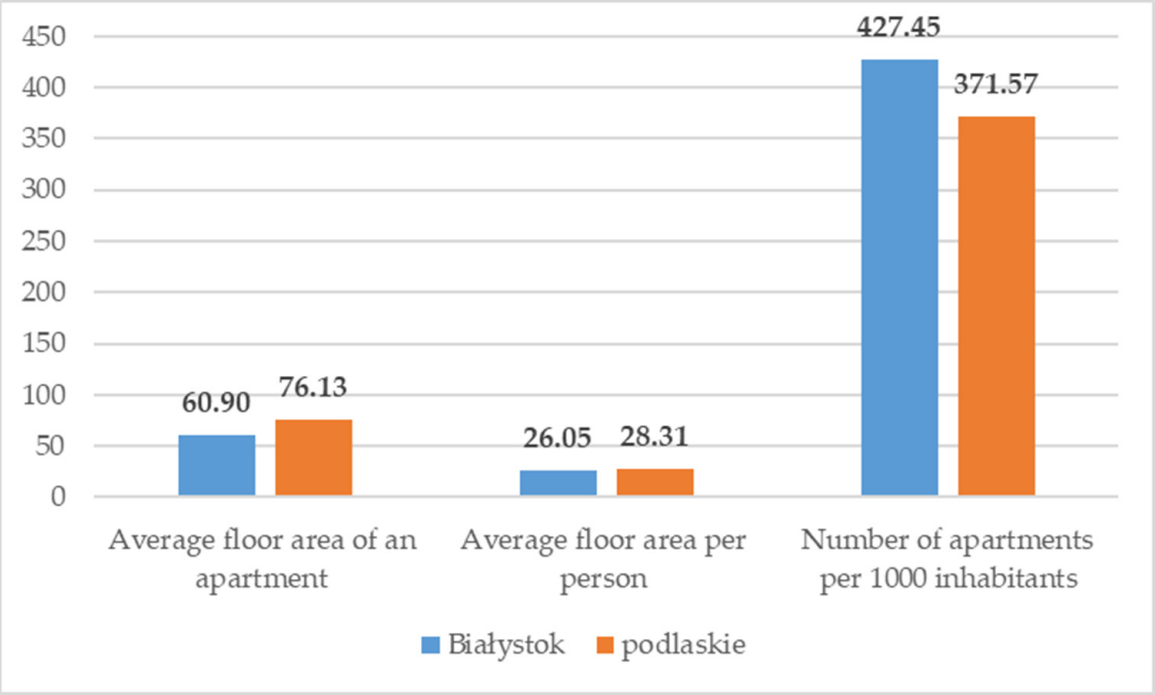

Figure 2. Indicators of housing infrastructure availability in Białystok and the Podlaskie Province.

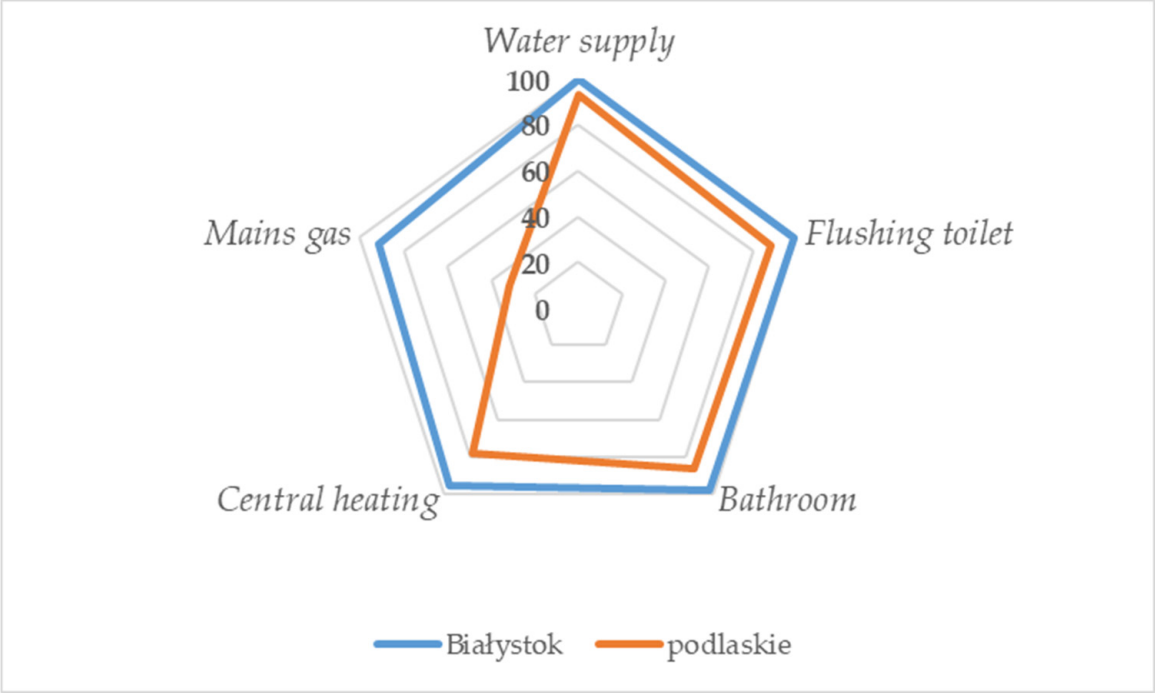

Figure 3. Indicators of housing infrastructure quality in Białystok and the Podlaskie Province.

The quality of housing infrastructure in Bialystok is also significantly better than the provincial average, as shown in Figure 3. This is particularly true of the availability of mains gas and central heating. Outside the city, residents are most likely to use traditional stoves for heat, mostly coal, but also gas or oil, and less often—due to cost—heat pumps. Differences also appear in the level of equipment of units with bathrooms, flush toilets and water supply, but they are much smaller.

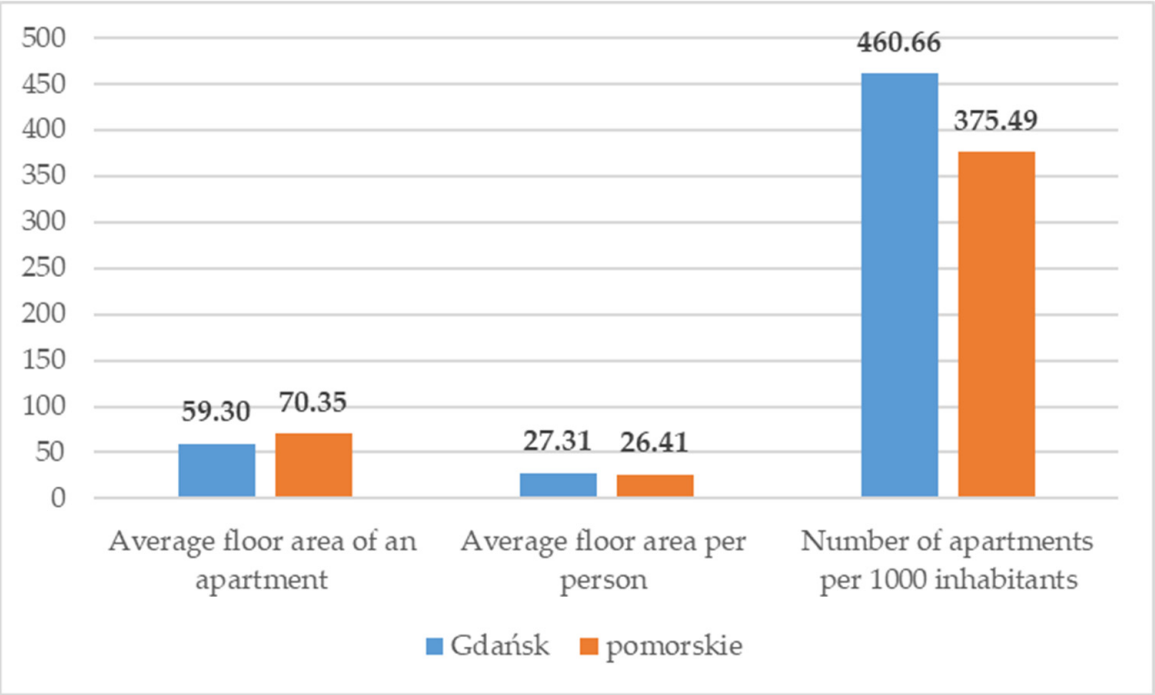

Figure 4. Indicators of housing infrastructure availability in Gdańsk and the Pomeranian Province.

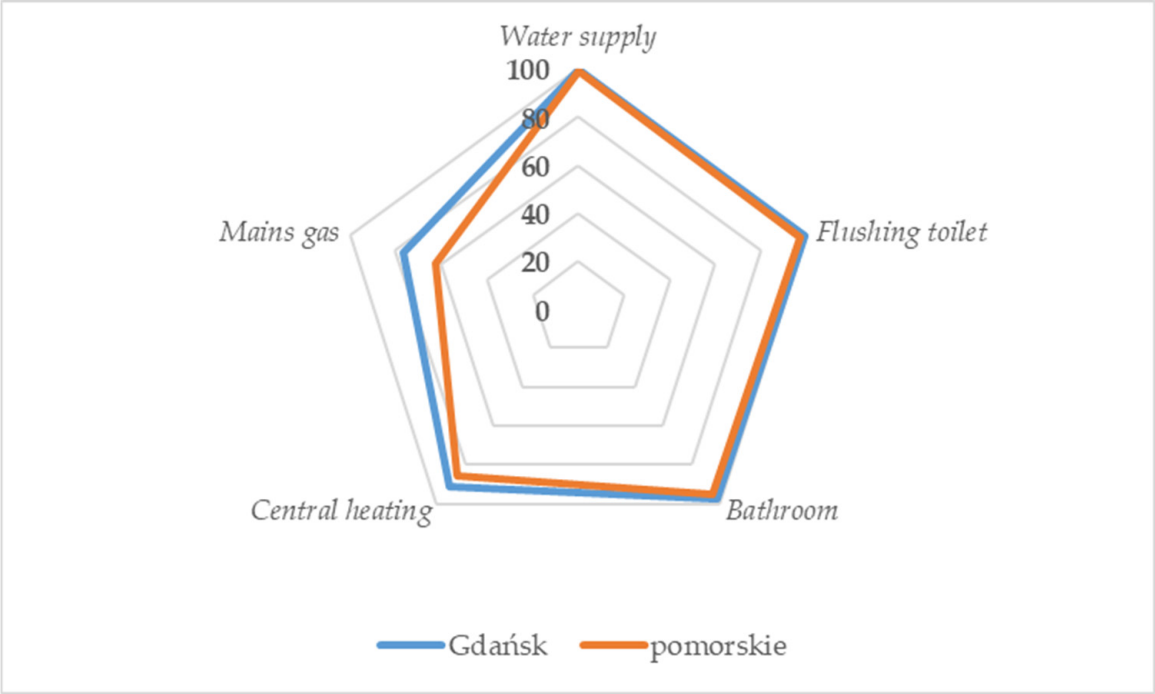

Figure 5. Indicators of housing infrastructure quality in Gdańsk and the Pomeranian Province.

The second city studied is Gdańsk, located in northern Poland on the Baltic Sea. It is a large industrial and tourist center with rich culture and history and is one of the most economically developed cities in Poland. The data presented in Figure 3 show that the usable floor area of one apartment in the city is lower than in the province (similar to that of Białystok), but the metric area per one person is already slightly higher in Gdańsk than in the Pomeranian region. In addition, the size of the city's housing stock exceeds the provincial average by more than 22%. Therefore, the situation of the city, often identified

as smart, is better than the regional average within two of the three criteria of urban infrastructure availability.

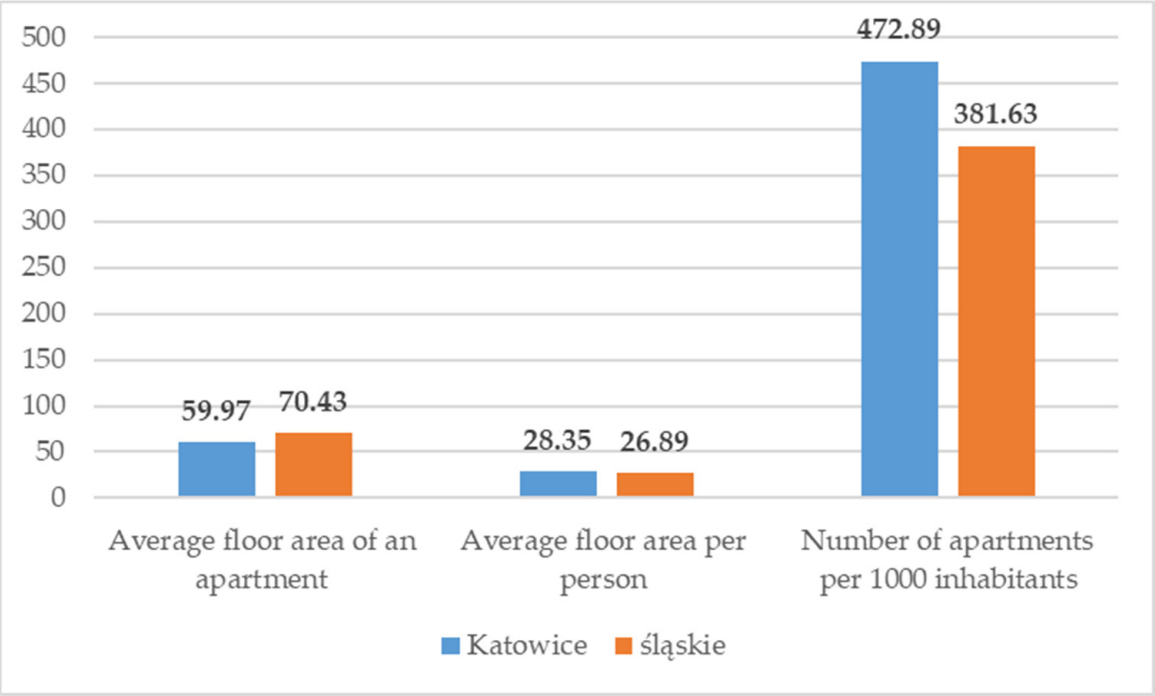

Figure 6. Indicators of housing infrastructure availability in Katowice and the Silesian Province.

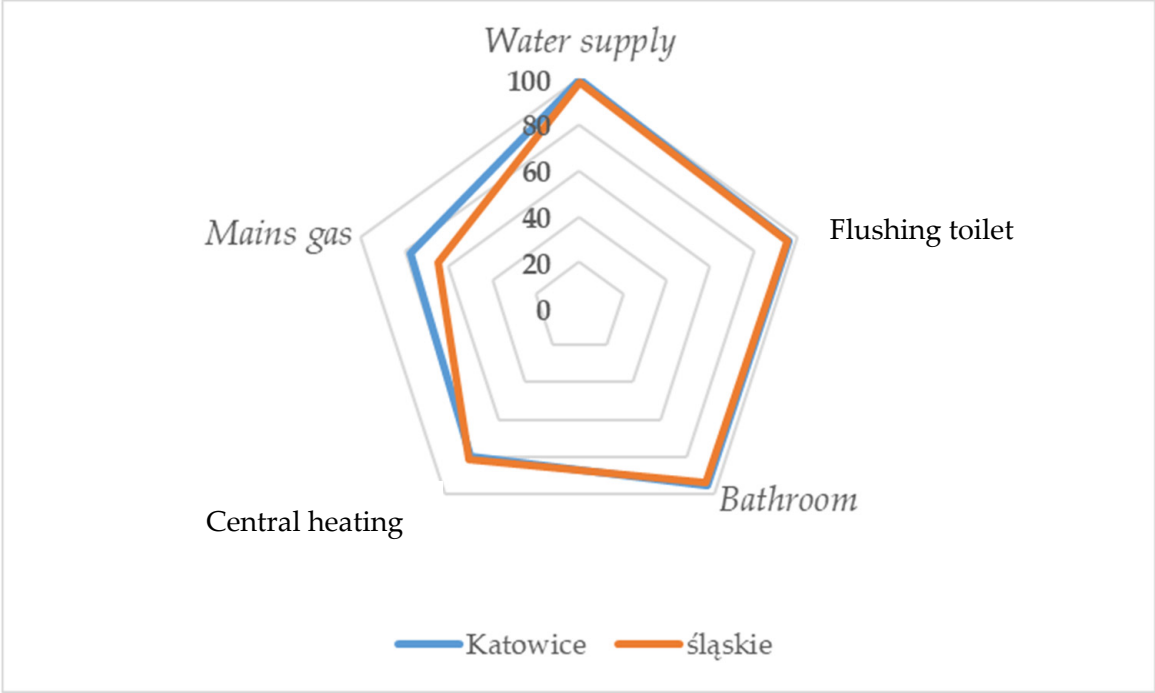

Figure 7. Indicators of housing infrastructure quality in Katowice and the Silesian Province.

The differences in the quality of housing infrastructure between Gdańsk and Pomeranian Province are not that significant (Figure 4). Virtually all units at both levels of analysis are equipped with a bathroom, a flush toilet and have access to a water supply. The only major differences are in central heating equipment and mains gas supply.

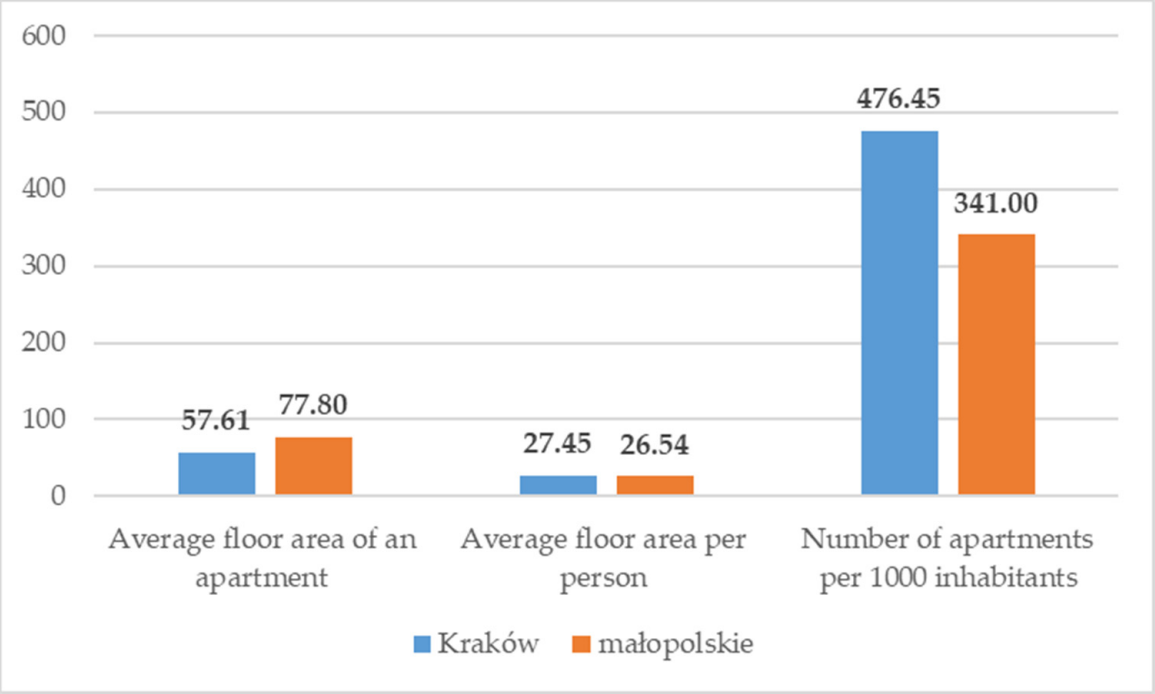

Figure 8. Indicators of housing infrastructure availability in Kraków and the Małopolska Province.

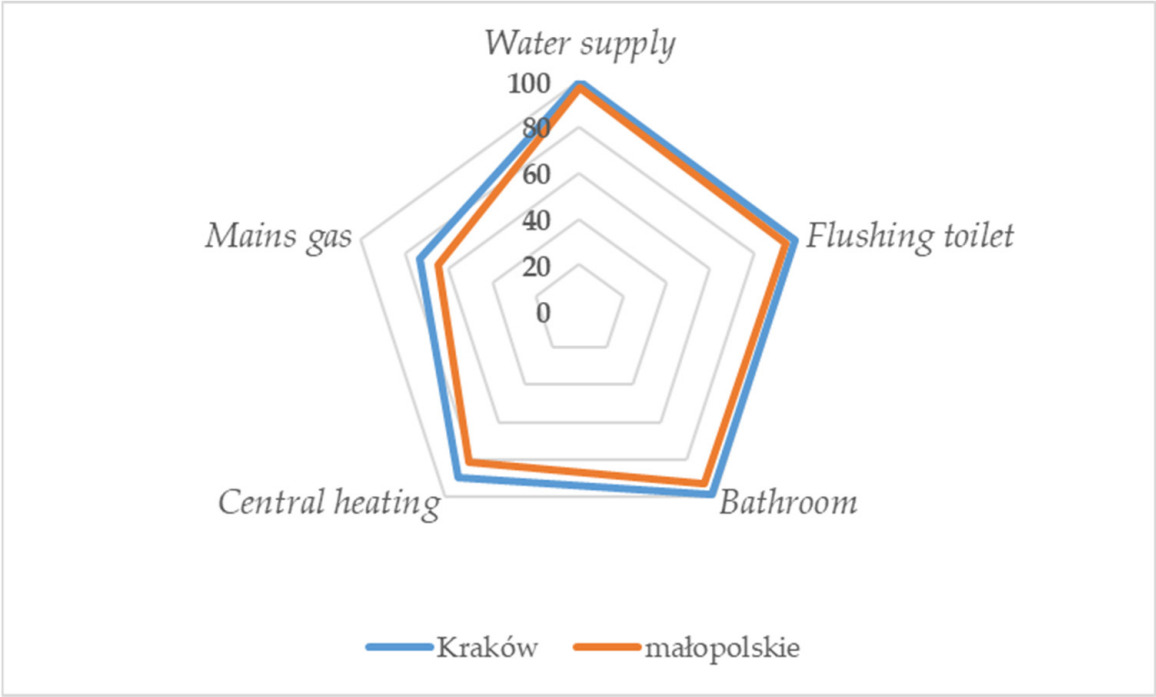

Figure 9. Indicators of housing infrastructure quality in Kraków and the Małopolska Province.

The next city studied is Katowice, located in the Upper Silesian Coal District, where hard coal has been mined for the Polish power and heating industries for many years. It is a well-industrialized and fairly prosperous region of Poland. In terms of the availability of housing infrastructure, Katowice towers over the province in terms of the average usable area of an apartment and the number of apartments per 1000 residents, which is more than 23% higher than the average housing stock in the Silesian Province (Figure 6).

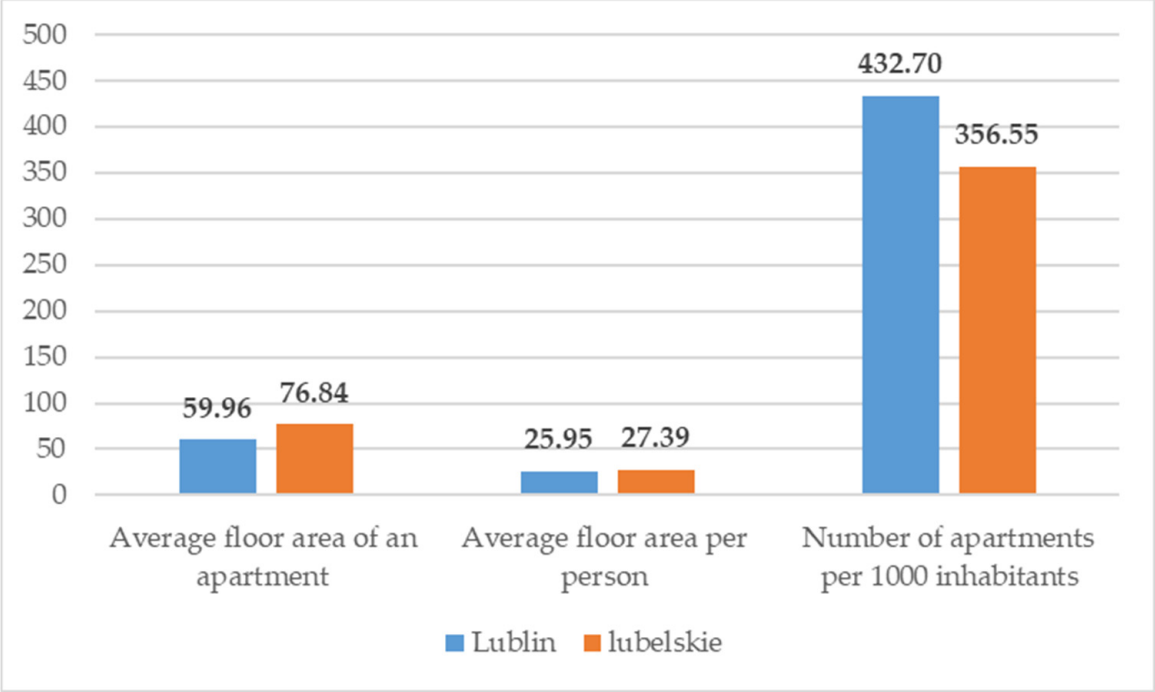

Figure 10. Indicators of housing infrastructure availability in Lublin and the Lublin Province.

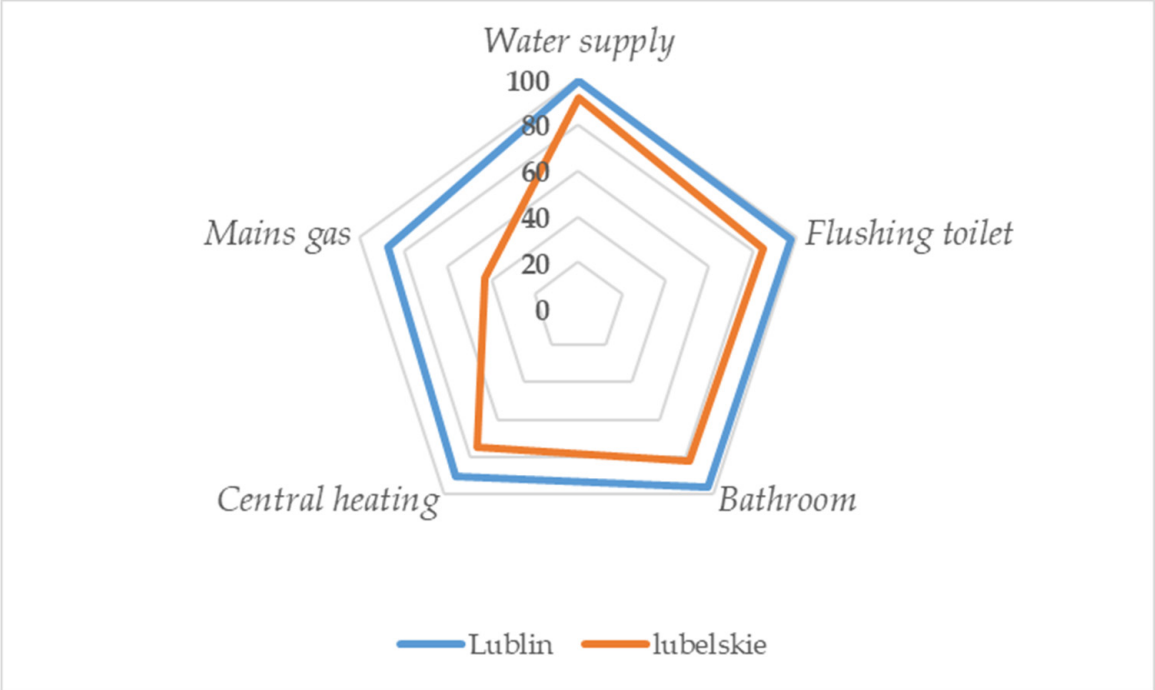

Figure 11. Indicators of housing infrastructure quality in Lublin and the Lublin Province.

The quality of housing infrastructure at the city and provincial levels is very similar in this case. The only significant difference is in access to mains gas, which is lower at the provincial level.

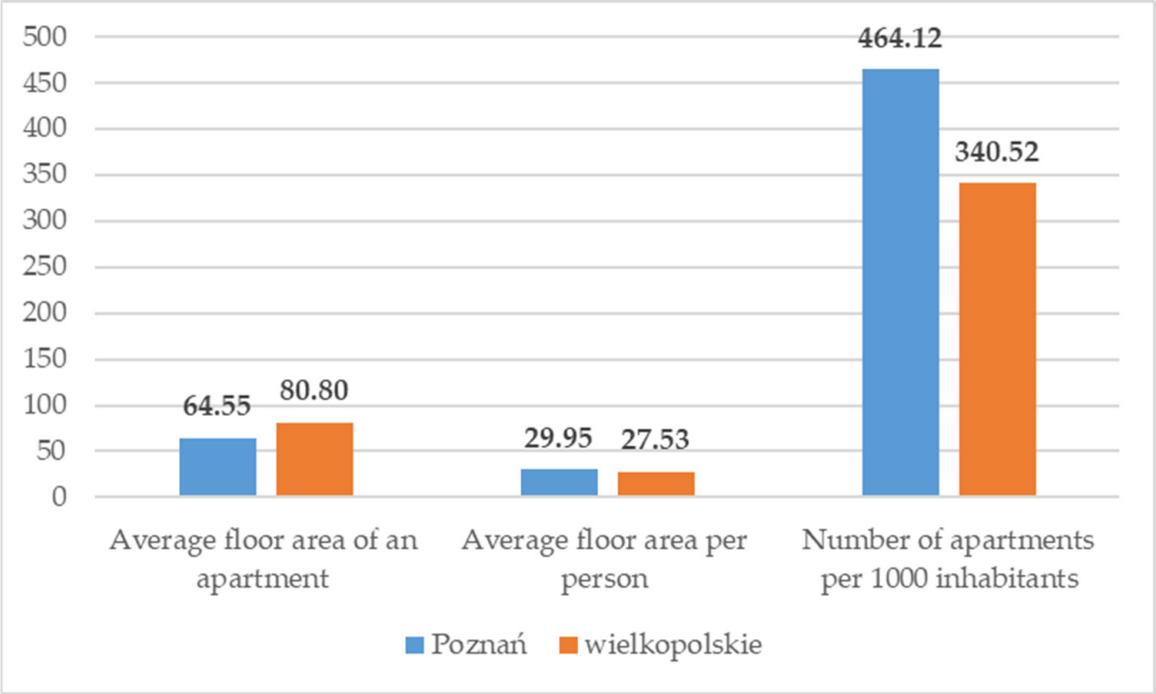

Figure 12. Indicators of housing infrastructure availability in Poznań and the Wielkopolska Province.

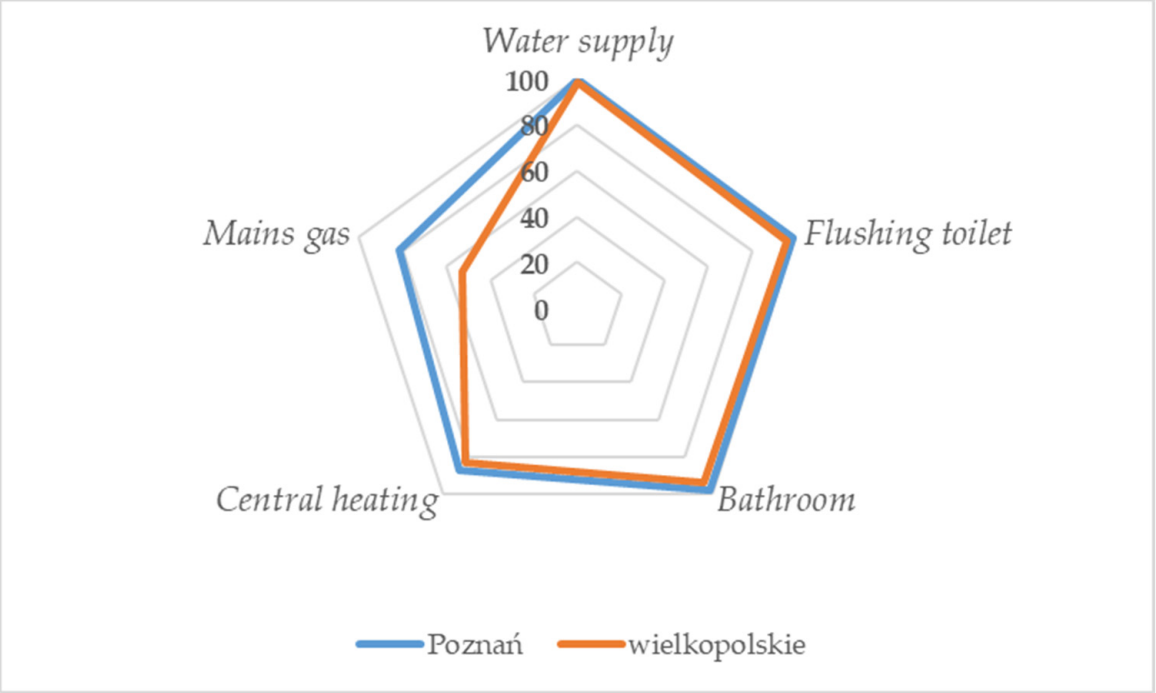

Figure 13. Indicators of housing infrastructure quality in Poznań and the Wielkopolska Province.

The fourth of the eight cases analyzed is Kraków, located in southern Poland's Małopolska Province. It is a major tourist destination, internationally recognized, with a very rich culture and history. It is also seen as one of the most attractive cities in Poland in terms of housing. This is clearly reflected in the number of apartments per 1000 residents, which is as much as 40% higher than the average for the province. Also, the housing space per person in Kraków is slightly higher than in the region. However, the average usable floor area of an apartment is much smaller (by about 35%), which is due to the

need to meet the considerable demand for apartments in Kraków with limited territorial possibilities (Figure 8).

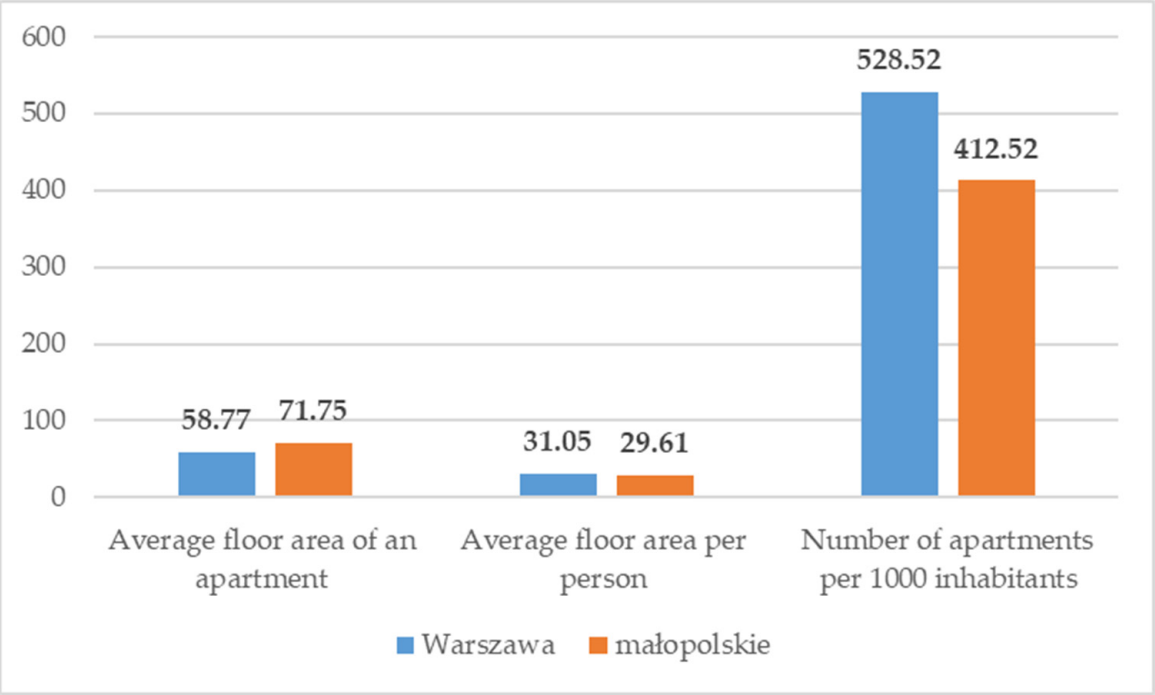

Figure 14. Indicators of housing infrastructure availability in Warsaw and the Mazovian Province.

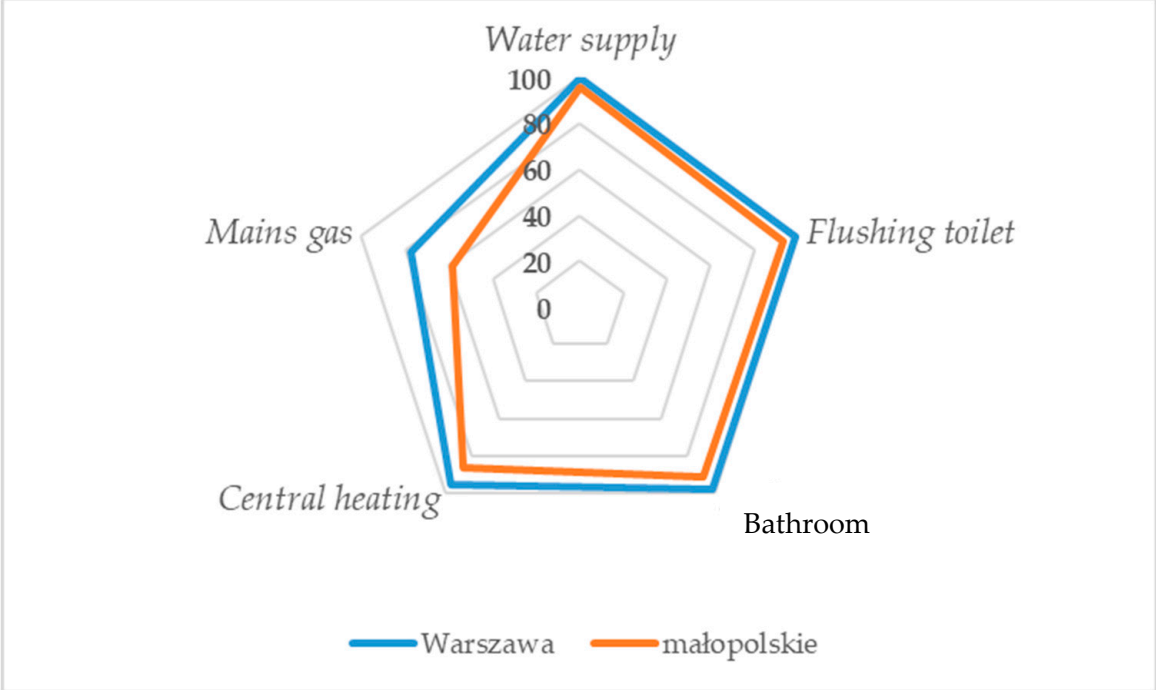

Figure 15. Indicators of housing infrastructure quality in Warsaw and the Mazovian Province.

The quality of housing stock in Kraków and Małopolska Province is similar (Figure 9). There is greater variation, as in the cases already analyzed, in access to mains gas and central heating.

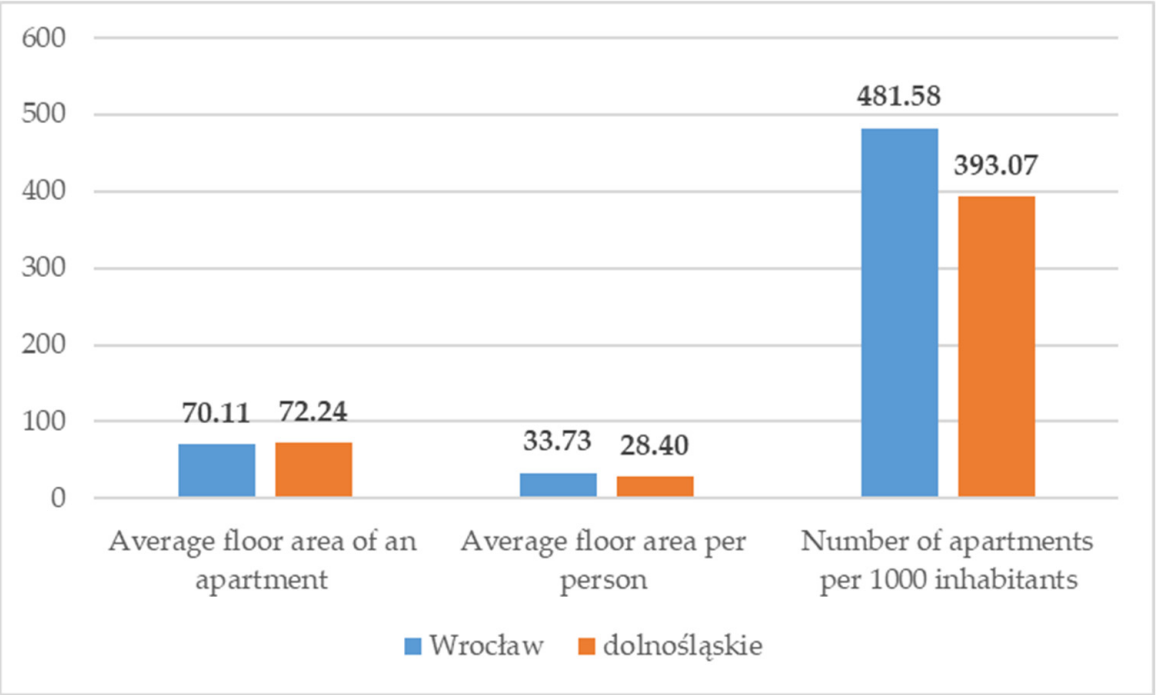

Figure 16. Indicators of housing infrastructure availability in Wrocław and the Lower Silesian Province.

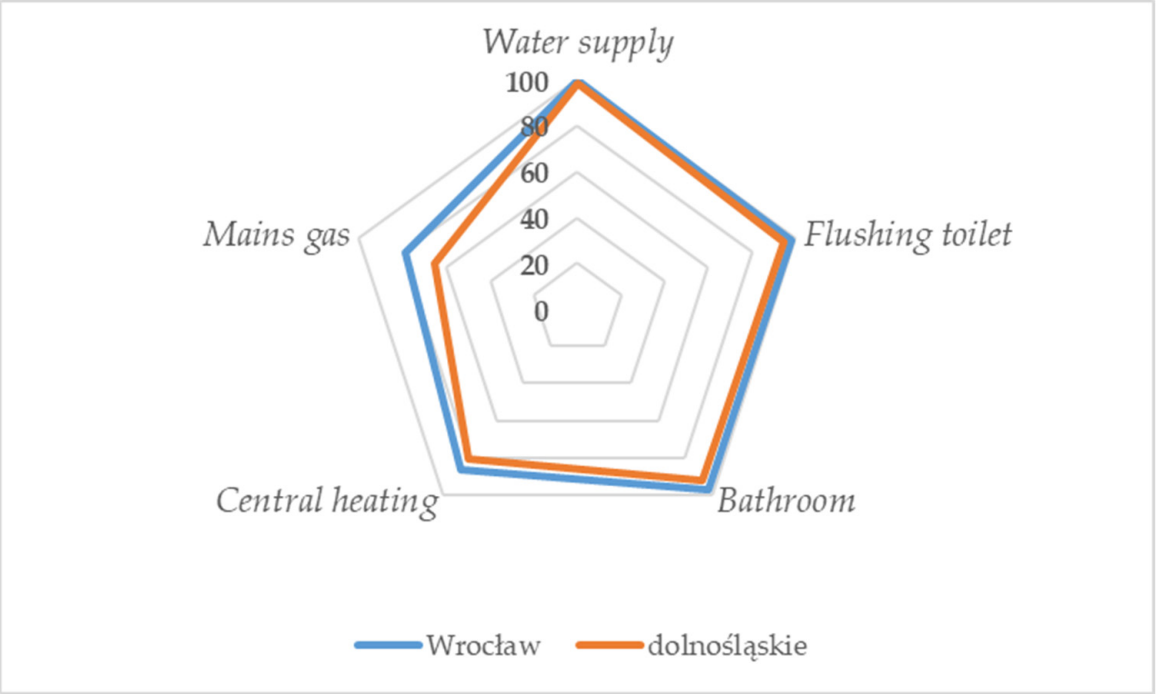

Figure 17. Indicators of housing infrastructure quality in Wrocław and the Lower Silesian Province.

Lublin is located in southeastern Poland and has similar conditions to Białystok. Nevertheless, it is also an important tourist and historical center on the map of Poland. In terms of housing infrastructure, Lublin exceeds the provincial average only in the category of the number of apartments per 1000 residents. The city's resources in this regard are higher than the regional resources by about 21%. Both the average size of a dwelling and the average floor area of a dwelling per one person are lower than the figures characteristic of the province. This is due to the high population density in the city, which is perceived

as an important and attractive place to live, especially compared to less urbanized areas located in the Lublin Province (Figure 10).

When it comes to the quality of housing infrastructure, Lublin and the province share quite significant differences (Figure 11). They appear already at the level of equipment with water supply, bathroom, flush toilet and increase in the case of access to central heating and mains gas. This indicates large qualitative differences between the city and the province.

Data for the next city studied—Poznań—and the Wielkopolska Province are presented in Figures 12 and 13. Poznań is a city located in western Poland in an economically well-developed and industrialized area. Like the previously studied cities, it has a housing stock that is about 29% higher than that of Wielkopolska Province. It also offers a slightly higher housing area per capita than the regional average (Figure 12). However, due to high population density and limited capacity to meet housing demand, the average housing area is lower than the provincial average.

The quality of housing infrastructure in the Wielkopolska region is lower than in Poznań in the case of access to mains gas and central heating. In other areas, the quality parameters of this infrastructure in the city and the region are similar (Figure 13).

Warsaw, for which the parameters of accessibility and quality of research infrastructure are shown in Figures 14 and 15, is the capital of Poland located in the center of the country. It is a modern, recognizable business and cultural center attracting both residents from other regions of Poland and domestic and foreign tourists. This is reflected in the number of apartments per 1000 residents, which is more than 28% higher than the provincial average. Also higher than the provincial average is the average floor area of an apartment. On the other hand, the average area of an apartment is lower than the provincial average, as it is in all cities studied so far (Figure 14).

The quality of research infrastructure in the province and the city overlap only in the case of access to water supply. Differences are evident in the remaining criteria, the largest in the case of mains gas and central heating. These are due to the very high percentage of apartments equipped with a bathroom, flush toilet and central heating in Warsaw (Figure 15).

The last of the surveyed cities is Wrocław, a major cultural, tourist and economic center located in western Poland. As Figure 16 shows, this city has a higher number of housing units per 1000 residents than the provincial average (by more than 22%). Also higher than in the region is the average floor area per person. Quite similar and significant in both the province and the city is the area of one apartment, which distinguishes Wrocław from other cities in the sample.

Differences in the quality of housing infrastructure in Wrocław and the Lower Silesian Province are insignificant. Only access to mains gas is more differentiated (Figure 17).

The presented analysis shows that in each of the analyzed cases the quality of city infrastructure was higher than the province average. Smart cities therefore offer better living conditions, but this also makes them a source of regional unsustainability. The differences in the quality of infrastructure between the city and their province were greatest in the Podlaskie and Lubelskie provinces, i.e., in the less economically developed regions, which means that they are more exposed to the effects of regional stratification.

Taking into account the criteria for assessing the quality of housing infrastructure, the greatest differences between cities and provinces concerned the equipment with central heating and mains gas. In the case of a bathroom, a flushing toilet and a water supply, the differences were much less significant. This illustrates the lack of development of the housing infrastructure at the level of individual provinces. It also reflects the lack of satisfaction of basic housing needs in many Polish towns. For emerging and developing economies, this is one of the key barriers to the creation of smart cities.

All the examined cities also offered a larger number of flats per 1000 inhabitants than the average number in the province. The differences found within this criterion reached several or more percent. This is the result of the fact that large cities—due to better socio-economic conditions—attract the inhabitants of the region and this is conducive to

construction and development investments. Often the demand for housing in cities exceeds the supply. The described phenomenon is another manifestation of the unsustainability of smart cities on a regional scale.

However, it is worth adding that all examined cities offer their inhabitants a smaller floor area of an apartment than the average for the province. This, in turn, results from the limited urban space and the high price of a square meter of housing in the city deteriorating the possibility of acquiring buyers.

However, the above does not mean that the inhabitants of smart cities have a smaller living area per one person. The research shows that only in Białystok and Lublin was the floor area per one person lower than the province average. This may mean that fewer people live in apartments in smart cities especially in economically more developed regions. It may also result from the fact that in agricultural regions (Lubelskie and Podlaskie) a significant part of the population lives in rural households or single-family houses.

Summarizing the above comparisons, it can be stated that the cities studied are characterized by a higher availability and quality of housing infrastructure compared with the provinces in which they are located. These differences are very distinct in the case of economically less developed regions.

4.2. Comparative Analysis of Surveyed Cities in Comparison with Individual Provinces

In the next stage of the research, a comparative analysis was carried out between the studied cities. The results of this analysis are included in Table 2.

Table 2. Indicators characterizing the availability and quality of housing infrastructure in the surveyed cities and provinces—comparative summary.

Specification	Cities							
	Białystok	**Gdańsk**	**Katowice**	**Kraków**	**Lublin**	**Poznań**	**Warszawa**	**Wrocław**
Percentage of apartments equipped with water supply	99.70	99.90	99.80	99.60	99.10	99.90	99.70	99.80
Percentage of apartments equipped with a flush toilet	98.80	99.50	96.10	99.20	98.00	99.00	99.30	98.30
Percentage of apartments equipped with a bathroom	98.10	98.20	95.60	98.90	96.50	98.30	98.30	97.40
Percentage of apartments equipped with central heating	96.20	92.50	81.40	90.70	91.80	88.40	96.00	88.60
Percentage of apartments equipped with mains gas	90.70	74.50	76.20	66.60	87.20	83.10	71.90	72.80
Average floor area of an apartment [m^2]	61.40	59.10	60.10	57.60	60.20	64.40	59.00	68.40
Average floor area per person [m^2]	28.40	30.40	31.00	30.50	28.30	32.80	33.50	37.40
Number of apartments per 1000 inhabitants	461.70	515.20	515.60	528.90	470.20	509.90	568.80	547.00

According to the data in Table 2, the largest apartments are available in Wrocław, Poznań and Białystok. Their average area exceeds 60 m^2. Wrocław and Poznań are also distinguished by the largest usable area of an apartment per capita. Wrocław and Warsaw have the largest housing stock with 547 and 569 apartments per 1000 residents, respectively. It follows from the above that Wrocław has the best housing infrastructure.

The weakest performance in terms of housing infrastructure availability is found in Białystok and Lublin. The number of apartments per 1000 residents is lower than 500 in these cities, and the usable area of a dwelling per capita is about 28 m^2. These are the lowest values in the surveyed group of cities, quite significantly different from the other surveyed cities.

In terms of the quality of housing infrastructure, access to a water supply system, which in all surveyed cities exceeds 99% (the lowest is in Lublin and the highest in Gdańsk and Poznań), should be rated very well. The housing infrastructure of the surveyed cities is also distinguished by a high level of bathroom facilities ranging from 95.60% (Katowice) to 98.90% (Kraków) and a flushable toilet from 96.10% (Katowice) to 99.50% (Gdańsk). Worse and more varied is already the evaluation of the extent of access to central heating.

The minimum requirement in this regard is represented by Katowice (81.40%) and the maximum by Białystok (96.20%). An even higher differentiation level can be seen in regard to connections to mains gas, which is lowest in Kraków (66.60%) and highest in Białystok (90.70%).

In line with the above, the worst quality of housing infrastructure is found in Katowice, despite the city's significant level of industrialization and good economic situation. This may be a result of the existence of old post-mining housing infrastructure in a city that is not adapted to modern socio-civilizational requirements. It may also suggest the city's lack of attention to the quality of its housing stock. Białystok, Gdańsk, Poznań and Kraków boast a good quality of housing infrastructure.

5. Discussion

The results of the received analyses indicate that there are differences in the availability and quality of housing infrastructure at the level of smart cities and provinces representing the regional average. The analyzed cities—in all the criteria studied (except the area of the apartment)—dominate over the provinces, which means that they have larger and better housing resources than the rest of the region. This confirms previous conclusions about the elitism of smart cities discussed in the literature by [15,16], and others.

Research and comparisons of smart cities in Poland also show that socioeconomic conditions are an important determinant of urban quality of life, as western, more developed regions have seen higher values for parameters describing the availability of urban infrastructure than eastern, agricultural and less economically attractive regions. This confirms (but only partially) earlier conclusions regarding better investment and resource conditions in smart cities obtained by: [29–31].

Nevertheless, it is worth adding that smart cities located in less developed regions—thanks to primary infrastructural conditions and efficient management—are able to match national leaders, as illustrated by the example of Białystok. Therefore, one can venture to say that it is possible to reduce the diversity of smart cities even with less favorable initial conditions.

The sample included cities with diverse traditions, culture and history, which, according to [32–34] implies the need for a different approach to the creation of smart city solutions. This is confirmed by the example of Białystok, the youngest of the surveyed units, where housing infrastructure was already created largely under the influence of modern civilization, and which has achieved better results than the more economically developed Katowice in terms of the quality of this infrastructure.

Despite a certain optimism in the above conclusion, it should be noted that the very fact that smart cities differ from one another nevertheless illustrates the distance separating even large units from other large ones, further exacerbating the differences already existing in Poland between west and east and smaller cities operating in these areas.

Among the recommendations for improving housing infrastructure in Polish Smart Cities, it is also worth highlighting the theme of involving residents in the discussion of its condition, expectations and needs. The necessity of such an approach in the process of creating sustainable smart cities has also been pointed out by [35,36]. Public participation allows the building of cities that foster an improved quality of life. Additionally, it enables a more holistic and integrated view of the process of creating smart city solutions raised in the literature by [37].

Referring to the methodology for evaluating the performance of smart cities, it is important to emphasize the need to collect and analyze data on the availability and quality of housing infrastructure in cities, since this infrastructure is an important determinant of the quality of urban life. This should be taken into account within the framework of smart living, monitored and compared over time and between units.

Data and indicators on this infrastructure and used in this article are generally collected at the city level, but few studies or analyses pay attention to them [54–58]. Within the literature review conducted in this article, only [61] draws attention to this aspect of smart cities.

Such an evaluation would also be a useful enhancement to the area of efficient and green physical infrastructure included in the Happiness Driven Smart City (HDSC) index proposed by Zhu et al. [70]. According to the author, it should also be enshrined in ISO 37120: *Sustainable social development. Indicators of urban services and quality of life* [9,71,72], as it is an important factor in ensuring the comfort of residents.

6. Conclusions

Summarizing the results of the conducted analysis, the following conclusions can be made with regard to the differentiation in the smart city—province (region) system:

- The variation in infrastructure availability between cities and provinces relates primarily to the number of housing units per 1000 residents, which in all analyzed cases is higher in the cities studied than in the region.
- The usable floor area of a dwelling per capita is higher in cities located in provinces with a higher level of economic development operating in western Poland (Gdańsk, Katowice, Kraków, Warszawa, Wrocław).
- The floor area of an apartment, due to high population density and limited land for development, is always lower in the surveyed cities than in the provinces.
- The quality of housing infrastructure in all surveyed cities in every criterion is better than the regional average.

In the case of variation at the level of smart cities in the sample, in turn, it can be said as follows:

- The availability of housing infrastructure is highest in the cities of western Poland, which are well-developed in economic and industrial terms; in the cities of so-called Poland B (Lublin and Białystok) it is much lower.
- The quality of housing infrastructure is no longer so closely linked to the level of economic development and industrialization, the example of Białystok shows that cities with lower levels of economic development can also offer modern housing.
- The quality of housing infrastructure can be influenced by the historical conditions of urban development, the shorter the history of the city the higher the quality of this infrastructure (Katowice vs. Białystok).

The main limitations of the research stem from the use of multiple case studies, which does not allow a generalization of the findings to a wider population, and from the narrowing of the study area to Poland. Further analyses should therefore take into account international comparisons and qualitative analyses oriented toward the creation of smart housing infrastructure oriented toward improving the quality of life of residents.

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