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HOSPITAL DISTRIBUTION IN POLISH PROVINCES AS A FACTOR OF SMART LIVING

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ABSTRACT. The primary aim of this research paper is to investigate the distribution of hospitals across different regions in Poland. It provides an in-depth analysis of hospital distribution in Poland, emphasizing the significance of taking into account factors such as population size and accessibility when assessing the quantity of hospitals as a determinant of quality of life in a smart city. This analysis is based on data concerning hospital operations in Poland spanning the years 2012 to 2021. It explores a range of indicators, including the number of hospitals per province, the ratio of hospitals per 1,000 square kilometers within a province's geographical area, and the relationship between the availability of hospitals and the GDP per capita. One noteworthy aspect of this paper is its utilization of cluster analysis to identify groups of provinces that exhibit similarities with respect to these indicators. Surprisingly, the research findings challenge the conventional division of regions into "Poland A" and "Poland B" based on wealth. Instead, the study reveals an unexpected outcome: a positive correlation of 0.81 between the number of hospitals and GDP per capita. This suggests that more prosperous provinces tend to have a greater number of hospitals available.

JEL Classification: I11, I15, I18

Keywords: smart city, smart living, quality of life, hospitals, cluster analysis

Introduction

Smart cities are conceived with the purpose of leveraging technology and data to enhance the quality of life for their inhabitants (Wolniak & Jonek-Kowalska, 2022). Quality of life serves as a metric for gauging the well-being and contentment of individuals and communities, and smart cities are dedicated to elevating this metric through various means, such as efficient infrastructure, innovative services, and sustainable practices. In this paper, we delve into the quality of life within smart cities and explore how they are reshaping the urban landscape.

A smart city can be defined as one that optimally employs the wealth of interconnected information available today to gain a better grasp of its operations, exert control, and optimize the utilization of limited resources. Smart cities strive to furnish their residents with a high quality of life by fine-tuning resource allocation and bolstering service efficiency (Jonnek-

Kowalska, 2022). Hospitals form a crucial part of the urban infrastructure in smart cities and their placement within a city can significantly impact the overall well-being of the community (Wolniak & Jonek-Kowalska, 2021). Ideally, in a smart city, hospitals are located in areas that offer easy accessibility to residents. This entails positioning hospitals in well-connected locales with access to public transportation networks and other essential infrastructure like roads and highways (Shmelev & Shmeleva, 2018). Central hospital placement improves access to medical services for a larger populace and reduces the time and resources required for commuting to and from healthcare facilities.

Smart cities also prioritize employing technology to enhance hospital services. For instance, smart hospitals may employ advanced medical equipment and digital technologies to elevate patient care standards and reduce hospital stays. They might also integrate sustainable technologies, such as energy-efficient lighting and renewable energy sources, to mitigate their environmental impact and promote sustainability (Visvizi & Lytras, 2019; Yun & Lee, 2019). In sum, the location and design of hospitals within a smart city are vital factors in promoting the health and well-being of the community. By seamlessly integrating healthcare facilities into the urban infrastructure and harnessing technology to enhance medical services, smart cities can create a more sustainable and resilient healthcare system for their residents (Dameri, 2016; Herdiansyah, 2023). Hospitals play a pivotal role in determining the quality of life, a concept intricately linked to Smart Living, one of the key facets of the Smart City concept (Lara et al., 2016; Albino et al., 2015).

From the aforementioned points, it becomes evident that there are research gaps concerning the relationship between population wealth and the number of hospitals. Additionally, there is a research gap in the context of categorizing Polish provinces into clusters based on hospital distribution.

The primary research questions addressed in this paper are:

- Identifying clusters of Polish provinces based on hospital distribution
- Exploring the relationship between provincial wealth and hospital numbers
- Examining the correlation between provincial population density and hospital availability

Based on the identified research gap, the following research objectives were set:

- C1: Exploring hospital distribution patterns among Polish provinces
- C2: Analyzing changes in hospital distribution trends in Poland over the past decade
- C3: Investigating the relationship between hospital numbers and population wealth

To realize those goals we formulated the following scientific hypothesis:

- H1. There is a correlation between the number of hospitals in a province and its GDP per capita.
- H2. There is a correlation between the number of hospitals in a province and its population density.

1. Literature review

Hospitals hold a pivotal position in enhancing the quality of life within smart cities. The overarching objective of smart cities is to enrich the well-being of their inhabitants, and hospitals stand as an indispensable pillar in achieving this objective. The impact of hospitals on the quality of life in smart cities is multifaceted, encompassing aspects such as improved healthcare access, the fostering of innovation, and bolstering sustainability efforts (Turhan et al., 2019; Tripathy et al., 2023; Prasad et al., 2023).

One of the primary avenues through which hospitals contribute to the quality of life in smart cities is by facilitating enhanced access to healthcare. Within smart cities, hospitals harness technology to offer more accessible and efficient healthcare services to residents (Bhat

et al., 2022). For instance, the integration of telemedicine services allows patients to consult healthcare providers remotely, thus reducing the necessity for in-person visits. This breakthrough can significantly improve healthcare access, especially for residents with limited mobility or those residing in areas with a scarcity of healthcare facilities (Xu et al., 2022).

Furthermore, hospitals in smart cities serve as incubators for innovation. Through the integration of cutting-edge technology, hospitals can pioneer novel healthcare practices, including the adoption of electronic health records, advanced imaging techniques, and robotic surgeries (Shakah, 2022; Ahmad et al., 2022). These innovative strides have the potential to enhance patient outcomes, curtail healthcare expenditures, and attract top-tier talent to the healthcare sector, all of which collectively contribute to an elevated quality of life for residents (Ogunmola et al., 2022).

Furthermore, hospitals within smart cities can actively contribute to sustainability endeavors. Hospitals, due to their extensive energy consumption and substantial waste production, can exert adverse effects on the environment (Alzawarmi et al., 2022; Kong, 2021). However, in the context of smart cities, hospitals have the opportunity to adopt eco-friendly practices. These may include harnessing renewable energy sources, implementing environmentally conscious building designs, and minimizing waste generation (Mei & Zhang, 2021). Such initiatives play a crucial role in diminishing the carbon footprint of hospitals and, in turn, bolstering the overall sustainability of the city.

Another vital facet of hospitals in smart cities pertains to their role in emergency preparedness. Smart cities are engineered to exhibit resilience and readiness in the face of emergencies, ranging from natural disasters to disease outbreaks (Wang & Zhou, 2023). Hospitals play an indispensable role in this preparedness paradigm by delivering essential healthcare services to residents during crises. Leveraging technology, hospitals can enhance their emergency response capabilities, with innovations such as predictive analytics enabling them to anticipate and address patient needs proactively during emergencies (Hartley, 2023).

Nevertheless, an analysis of the literature underscores that the integration of smart city technologies can yield both favorable and unfavorable outcomes for hospitals. Smart city technologies frequently gather and disseminate data from various sources. The utilization of such data can engender privacy concerns, particularly when it pertains to sensitive medical information (Ghosh et al., 2023). Hospitals bear the responsibility of safeguarding patient data, ensuring its security and confidentiality. Additionally, the adoption of smart city technologies can heighten the vulnerability of hospital systems to cyberattacks. Malicious actors may exploit vulnerabilities in connected devices or infiltrate compromised networks to access confidential hospital information (Hassan et al., 2023; Badr, 2023).

Furthermore, hospitals may become reliant on the infrastructure provided by smart cities, encompassing elements like electricity and communication networks. Any disruption in these systems could exert severe repercussions on patient care (Prasad et al., 2023). Additionally, the implementation of smart city technologies often necessitates substantial financial resources, potentially diverting funds from other crucial healthcare initiatives (Bhat et al., 2022). Moreover, these technologies require specialized knowledge and training, necessitating comprehensive training programs for hospital staff. This could prove to be a time-consuming and costly endeavor, possibly impacting staff productivity during the training period (Xu et al., 2022).

2. Methodological approach

One of the six primary dimensions within the context of a smart city is "Smart Living." Numerous experts discussing the concept of a smart city believe that healthcare is a pivotal

component that can be employed to assess Smart Living. For instance, in a study conducted by Jonek-Kowalska in 2022, it is emphasized that access to hospitals plays a critical role in determining the overall quality of life in a smart city. Furthermore, Reza Shami and his team (Reza Shami et al., 2022) argue that Smart Living within a smart city closely aligns with the notion of quality of life, and one of its dimensions is intricately linked with healthcare provision and accessibility by the city's residents. Given that healthcare and the availability of hospitals are acknowledged as fundamental aspects of quality of life, it becomes imperative to investigate the challenges associated with hospital accessibility as an illustrative example of the quality of life concerning healthcare access within a smart city.

To conduct this analysis, hospital operational data for Poland spanning the years 2012 to 2021 was sourced from the Polish Central Statistical Office. The data was acquired from databases accessible at https://bdl.stat.gov.pl/bdls/start. The rationale behind choosing this specific timeframe was to encompass the most recent ten years of available data. Notably, the most current data pertaining to the number of hospitals and related metrics in Poland is from the year 2021, which consequently serves as the endpoint for this analysis.

The analysis encompasses all 16 provinces in Poland: Masovia, Lower Silesia, Opole Province, Kuyavia-Pomerania, Lubusz Province, Lublin Province, Lodz Province, Podlasie Province, Lesser Poland, Silesia, Subcarpathia, Pomerania, West Pomerania, Holy Cross, Warmia-Masuria, and Greater Poland.

Key variables under scrutiny in this analysis include the number of hospitals within each province, GDP per capita, provincial area, and population. Recognizing that the establishment and maintenance of hospitals typically incur substantial costs, it is essential to explore the correlation between the quantity of hospitals in a given province and its economic prosperity, a metric effectively measured by GDP. The suitability of GDP as an economic well-being indicator has been previously established by Dyman and Sheiner (2018) and Bizkova et al. (2021). These indicators were developed using the Gillespie concept for indicator development (2007).

Based on the data collected, metrics reflecting the saturation of provinces with hospitals were calculated using the following formulas:

$$I_h = \frac{I}{Hn} \tag{1}$$

Where:

I_h – number of inhabitants per hospital

Hn – number of hospitals

I – number of inhabitans

$$Hn_a = \frac{Hn}{A}1000$$

Where:

Hn_a– number of hospitals per 1000km^2 of area

Hn – number of hospitals

A - area in km^2

To analyze the data, we employed cluster analysis. Specifically, we employed a hierarchical clustering technique known as the cluster analysis tree method, which presents the clustering results in the form of a dendrogram or a tree-like structure. This method entails the grouping of objects into nested clusters, with each cluster containing the objects that exhibit the highest degree of similarity to one another. Furthermore, the clusters at higher levels of the hierarchy encompass clusters from lower levels. In the agglomerative approach, the clustering process commences with individual objects and progressively merges the closest pairs of

objects into larger clusters until all objects are consolidated into a single cluster (Meijer et al., 2022; Saar & Topcu, 2022).

For the analysis of the collected data, we utilized STATISCICA-13.3 software. Additionally, all correlation coefficients were calculated at the significance level of α=0.05.

3. Results

The collected data reveals that, in 2021, the largest number of hospitals was located in Silesia Province, with 141 hospitals, and Masovia Province, with 118 hospitals. Both provinces significantly surpassed other Polish regions in terms of hospital count. Following closely behind were Lower Silesia with 84 hospitals, Lesser Poland with 73 hospitals, and Lodz Province with 61 hospitals. Conversely, provinces with the fewest hospitals included Lubusz Province with 24, Holy Cross Province with 23, Opole Province with 30, and Podlasie Province with 34 hospitals. It is noteworthy that some provinces experienced a decline in the number of hospitals during the analyzed years. This trend can be attributed, in part, to declining populations in these regions, leading to reduced demand for healthcare services. Consequently, some hospitals may have been compelled to close or merge with others to optimize resource allocation.

A key factor contributing to the decrease in the number of hospitals in certain Polish provinces is the government's promotion of healthcare service centralization to enhance their quality and efficiency. This policy has resulted in the closure of smaller hospitals and the consolidation of services into larger, specialized hospitals. Additionally, many hospitals in Poland operate on tight budgets, making it challenging to maintain their facilities and equipment. Financial difficulties can also lead to hospital closures.

Analysis of data from 2020 to 2021 indicates that the number of hospitals in Poland experienced an initial increase from 913 to 979 between 2012 and 2014. However, since 2014, the number has stabilized at around 950 hospitals, with only a slight increase observed between 2020 and 2021. The most significant decrease in the number of hospitals occurred between 2018 and 2019. Subsequently, the number of hospitals began stabilizing at around 900. Unprofitable hospitals were closed, and hospital consolidation became a notable trend, with multiple hospitals merging into larger medical units. This consolidation contributed to the decline in the number of hospitals in Poland and its provinces.

In Silesian Province, the number of hospitals increased from 134 to 145 between 2012 and 2013, reaching its highest point at 157 in 2018 before declining to 136 in 2019 and stabilizing at 141 in subsequent years. Masovia Province experienced smaller fluctuations, with a peak of 120 hospitals in 2013, a drop to 108 in 2014-2016, and stabilization at 118 thereafter.

When assessing the number of hospitals as an element of quality of life in a smart city, it is essential to consider the population-to-hospital ratio. Over the study period from 2012 to 2021, this ratio hovered around 42,000 people per hospital, with minor fluctuations between 39,391 (in 2014) and 43,113 (in 2019). However, significant disparities in hospital accessibility exist among provinces. In 2021, the average number of residents per hospital was 42,159.

Provinces with the highest accessibility had more than twice as many residents per hospital compared to provinces with the lowest accessibility. Provinces with the lowest number of residents per hospital included Silesia (31,062 inhabitants per hospital), Opole Province (31,653 inhabitants per hospital), Warmia-Masuria (32,137 inhabitants per hospital), and Podlasie Province (33,863 inhabitants per hospital). Conversely, provinces with the highest number of inhabitants per hospital were Greater Poland (63,690 inhabitants per hospital), Pomerania (60,441 inhabitants per hospital), and Holy Cross (51,690 inhabitants per hospital).

Another indicator affecting hospital accessibility is the ratio of hospitals per 1,000 square kilometers of a province's area. This indicator reflects geographic proximity, crucial for

the elderly and seriously ill who benefit from easier access to nearby hospitals. Despite a slight decrease over the years due to the reduction in hospital numbers, the variation is minimal. Silesian Province has the highest indicator value, standing at 11.43 hospitals per 1,000 km², more than twice the value of the next province, Lesser Poland (4.81 hospitals per 1,000 km²). It is followed by Lower Silesia (4.21 hospitals per 1,000 km²).

Provinces with the lowest values of this indicator include Lubusz Province (1.72 hospitals per 1,000 km²), Warmia-Masuria (1.74 hospitals per 1,000 km²), Greater Poland (1.84 hospitals per 1,000 km²), Lublin Province (1.87 hospitals per 1,000 km²), and West Pomerania (1.92 hospitals per 1,000 km²).

4. Discussion

The reduction in the number of hospitals in Poland, as observed in this study, is closely linked to the ongoing restructuring of the healthcare sector within the country. This restructuring involves the closure of financially unsustainable hospitals and the consolidation of multiple hospitals into larger medical facilities, often situated in the same vicinity or nearby cities. These activities have contributed to a noticeable decline in the total number of hospitals across Poland and its various provinces (Wielicka-Gańczarczyk, 2017; Fijałkowska, 2013).

This trend of hospital consolidation in Poland has significant implications for healthcare delivery. The amalgamation of hospitals has facilitated the implementation of advanced medical technologies and increased the availability of specialized medical practitioners, thereby enhancing the effectiveness and efficiency of healthcare services. The consolidation of hospitals in Poland has generated varying opinions among stakeholders. Advocates of these changes argue that they have led to improved healthcare efficiency, enhanced service quality, and optimized utilization of medical resources. Conversely, critics contend that hospital consolidation has diminished access to healthcare services for residents of smaller towns and villages, resulting in escalated healthcare costs (Fijałkowska, 2013; Suliantoro et al., 2021; Zwoliński, 2014).

Nevertheless, it's important to note that a reduction in the number of hospitals does not automatically translate to a decline in overall quality of life. The quantity of hospitals in a nation represents just one factor influencing the well-being of its citizens. The consolidation of hospitals can bring about positive changes, such as a more efficient healthcare system and the adoption of advanced medical technologies (Nikki Han & Kim, 2021).

Nonetheless, it is crucial to acknowledge that a reduction in the number of hospitals may have implications for healthcare accessibility in smart cities, particularly in smaller towns where hospitals may be shuttered or converted into specialized departments of larger institutions. This could lead to further centralization of healthcare services, potentially making it more challenging for residents in remote regions to access necessary medical care. Furthermore, as a consequence of hospital consolidation, working conditions for medical staff may deteriorate, particularly when larger medical units are compelled to carry out more procedures and treatments with fewer personnel (Zwoliński, 2014).

Hospitals serve as pivotal components of a country's social infrastructure, providing essential healthcare services to its populace. In a smart city where technological advancements and innovation play a central role, the healthcare system must be capable of efficiently and sustainably meeting the needs of the population (Grata, 2018; Zygmunt, 2014). A higher number of hospitals in a smart city can positively impact residents' quality of life, as it increases the likelihood of prompt and effective medical attention in cases of sudden illness or accidents, which is especially crucial for elderly or medically vulnerable individuals requiring regular medical care (Chatterjee et al., 2021). Furthermore, a greater concentration of hospitals can

attract investments to the healthcare sector, fostering its development and creating job opportunities. In this way, the growth of medical infrastructure can influence the economic development of the city (Matos et al., 2021; Ferreira & Marques, 2021).

It's also worth emphasizing that investment in healthcare infrastructure in a smart city aligns with the health and quality of life goals of its residents (Weinberg et al., 2023). A smart city encompasses not only advanced technology but also a welcoming environment and favorable living conditions, which include access to quality medical care (Seljan et al., 2022; Kisiała et al., 2022; Ge et al., 2021).

An analysis of the geographic distribution of hospitals per 1,000 square kilometers in Poland reveals that residents of southern Poland outside Subcarpatia Province have the closest proximity to hospitals. In contrast, northwestern and eastern Poland exhibit lower values of this indicator compared to the national average, indicating a lower concentration of hospitals in these regions.

To further explore the relationship between hospital saturation and population size and area, scatter plots were created for each of the individual Polish voivodeships under study. Figure 1 presents the graph depicting the correlation between the number of residents per hospital and the number of hospitals per square kilometer for these provinces.

Based on the analysis of this data, the following groups of provinces can be identified:

- Silesia: This province boasts an exceptionally high ratio of hospitals per 1,000 square kilometers and the most favorable ratio of residents per hospital. An analysis of the data indicates that Silesian Province offers the highest quality of life in Poland when measured by the availability of hospital services. It not only has the greatest abundance of hospital facilities but also the shortest average distance to a hospital for patients. This combination significantly enhances the quality of life in smart cities within this province.
- Opole Province, Podlasie Province, Warmia-Masuria Province: These provinces exhibit a notable abundance of hospitals when assessed in terms of the number of patients per hospital (indicating a low number of patients per hospital). However, they are characterized by considerable distances to hospitals due to the relatively low number of hospitals compared to the province's area. This configuration results in a trade-off between hospital availability and accessibility.
- Lower Silesia, Lesser Poland, Lodz Province, Masovia: These provinces demonstrate a relatively high level of hospital saturation concerning the province's area, along with an average number of people per hospital. The quality of life in relation to the availability of hospital services can be considered moderate in these provinces, with a balanced distribution of healthcare resources.
- Pomerania, Greater Poland: These provinces exhibit the lowest quality of life in terms of accessibility to hospital services. In these voivodeships, both the saturation of the province with hospitals per 1,000 square kilometers of the area and the number of residents per hospital are unfavorable. Consequently, these regions face challenges in providing accessible healthcare services to their populations.

In the subsequent phase of this study, the aim was to examine the extent to which the number of hospitals in a province correlates with the wealth of the population, as quantified by the GDP per capita index. The study employed the Guilford scales for the interpretation of correlation coefficients, following the methodology outlined by Putri et al. in 2019. A statistical significance coefficient of $\alpha=0.05$ was applied to evaluate the significance of all correlations under investigation.

Based on the findings from the study, conducted over the years spanning from 2012 to 2021, a consistently positive correlation was identified between the number of hospitals within a province and the economic prosperity of its residents, as indicated by the GDP per capita

index. It is noteworthy that all correlation coefficients reached statistical significance at the α=0.05 level. In the case of the year 2021, the correlation coefficient was notably high at 0.81, aligning with the very high category on the Guilford scale. This implies that there exists a strong positive relationship between a province's affluence and the presence of hospitals within its boundaries.

The outcomes of this study lend substantial support to hypothesis H1, which posits that the number of hospitals in a province correlates with the GDP per capita in that same province.

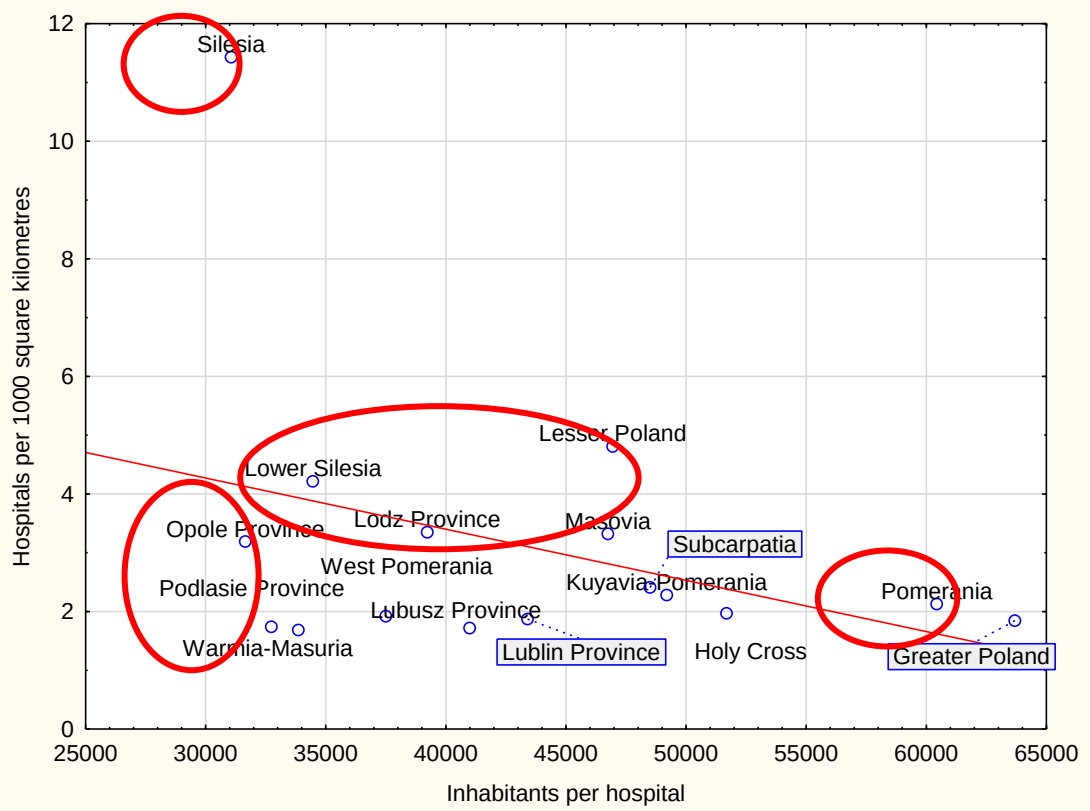

Figure 1. Relationship between the number of inhabitants per hospital and number of hospitals per 1000 square kilometers.
Source: Author own analysis.

The construction of hospitals is a costly endeavor, a fact substantiated by data collected in a World Health Organization report (Global, 2021). Various studies highlight the escalating expenses associated with the establishment of new healthcare facilities. For instance, Mishra and Koju (2020) conducted an analysis on this topic, while Wackers (2022) underscored the upward trajectory in hospital construction costs, particularly for those aligned with high quality and smart city concepts.

When contemplating the accessibility of healthcare services within smart cities, it is imperative to acknowledge that this sector's significance is on the rise in tandem with societal advancement and technological progress (Andreou & Manika, 2021; Olanrewaju et al., 2022). Consequently, an increased number of hospitals in a city can draw the attention of potential investors seeking opportunities in the healthcare industry, thereby bolstering the city's revenue streams (Persaud et al., 2020). Ultimately, the growth of the healthcare sector can make a substantial contribution to the city's GDP (Prasetyadi & Koonsrisuk, 2020; Rupani & Abu Bakr, 2017; Hassanain et al., 2013).

It is also noteworthy that enhanced healthcare services can lead to reduced healthcare costs for city residents, thereby enhancing their quality of life and stimulating economic activity (Bulajic et al., 2020; Andrade et al., 2020). A healthier and more motivated workforce can drive higher productivity and efficiency, ultimately contributing to GDP growth (Huerta, 2021; Bogataj et al., 2021).

Smart cities are typically designed to offer a comfortable and secure lifestyle, and this extends to healthcare infrastructure. They often invest in cutting-edge technology and medical equipment, enabling them to provide advanced healthcare and early disease detection. In 2021, the relationship between the number of hospitals in a province and its wealth, as measured by GDP per capita, can be expressed using the following equation: Number of hospitals = -38.39 + 0.0017 * GDP per capita.

Figure 2 illustrates a scatter plot of the agile test subjects, with confidence intervals clearly indicated. The study reveals that most of the examined provinces fall within the confidence interval. Notably, there are two distinct groups of provinces to consider:

- In the case of Silesia and Lesser Poland, the number of hospitals surpasses what their economic wealth would typically imply. These provinces are making substantial investments in healthcare infrastructure, particularly in the establishment of hospitals within their respective regions.
- Conversely, Greater Poland, Pomerania, and Lubusz Province exhibit a contrasting scenario. In these provinces, the number of hospitals is noticeably lower than expected based on their GDP per capita. This indicates a deficiency in healthcare development investment, particularly in terms of hospital facilities within these regions.

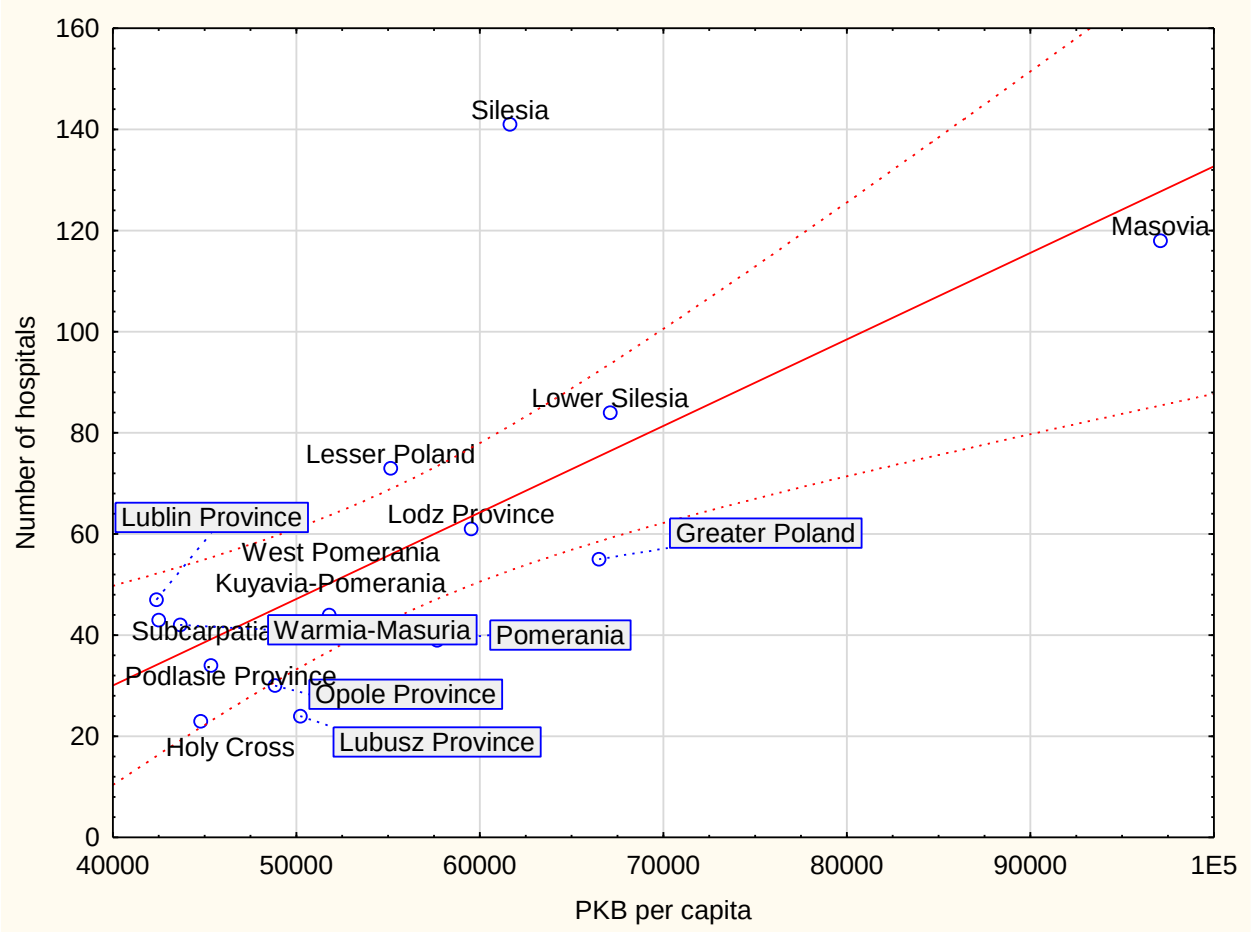

Figure 2. Relationship between the number of hospitals and PKB per capita in the province.
Source: Author own analysis.

The next intriguing factor to examine in relation to hospital-related data is the population density within a specific province. Data analysis has revealed a strong correlation, as per Guilford's scale, between the number of hospitals in a given province and its population density. In 2021, the correlation coefficient between these variables was 0.82, signifying statistical significance at the α=0.05 level. These findings lend support to hypothesis H2, which posits that the number of hospitals in a province is correlated with its population density.

This positive correlation between the number of hospitals and population density indicates that as the population of a particular area increases, so does the imperative to establish a greater number of hospitals to ensure adequate healthcare access for the residents. Augmenting the number of hospitals in densely populated regions is typically a justified approach since it enhances the likelihood of individuals receiving essential medical care when the hospital count aligns with the population size. Moreover, larger population centers often contend with a higher incidence of infectious diseases and other health challenges, amplifying the need for an increased hospital presence (Chao et al., 2017; Carnegie et al., 2022).

For the year 2021, the relationship between the number of hospitals in each Polish province and their respective population densities can be expressed by the following formula: Number of hospitals = 9.76 + 0.36 * population density.

Figure 3 depicts a scatter plot illustrating the correlation between population density and the number of hospitals in Polish provinces. The majority of the provinces examined fall within the confines of the confidence interval. In this figure, two distinct groups of provinces can be discerned:

- Provinces with a lower number of hospitals than expected given their population density. This group comprises provinces such as Holy Cross, Kuyavia-Pomerania, and Pomerania.
- Provinces with a higher number of hospitals than expected given their population density. This category encompasses provinces like Masovia and Lower Silesia.

The analysis reveals that a lower-than-expected number of hospitals relative to population density is notably pronounced in the central provinces of Poland, while a higher-than-expected number of hospitals relative to population density is most prominent in the capital province. The heightened concentration of hospitals in Masovia Province can be attributed to the presence of Warsaw, Poland's capital city, within its borders.

Warsaw serves as a significant healthcare hub, housing the largest and most advanced hospitals, clinics, and research centers. This concentration contributes to the elevated number of hospitals in Masovia Province compared to other regions in Poland. An influential factor driving this increased density of hospitals in the capital province is the demand for medical services, not only from its own residents but also from individuals residing in other parts of Poland who travel to the capital to access healthcare services (Zdęba-Mozoła, 2023).

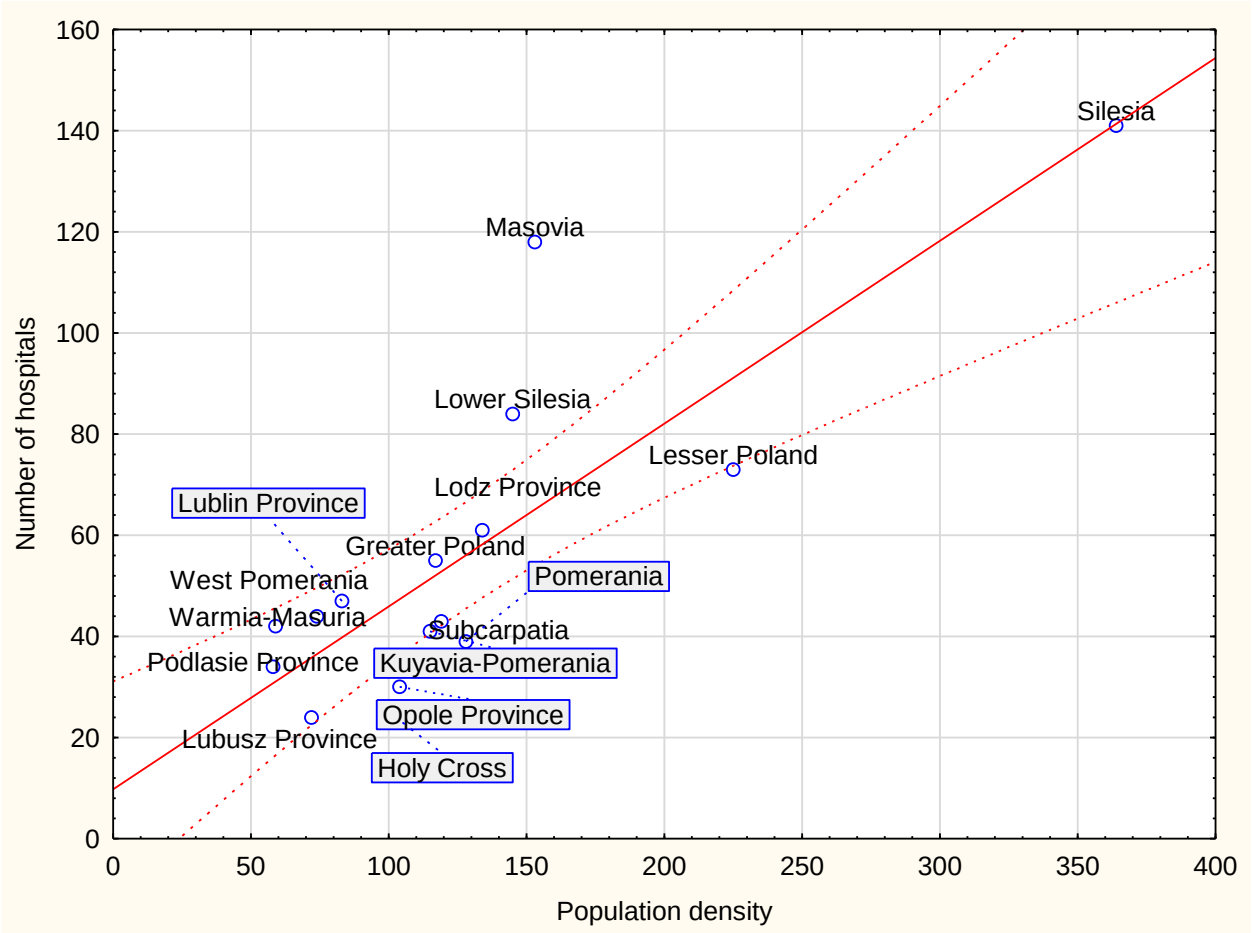

Figure 3. Relationship between the number of hospitals and population density in the province.
Source: Author own analysis.

To identify distinct groupings among the provinces under study, taking into account the analysis of three variables: the number of hospitals in a province, the number of residents per hospital, and the number of hospitals per 1,000 km2 of area, cluster analysis methods were employed. Specifically, the method of cluster analysis was applied, and the results of this analysis are illustrated in Figure 4.

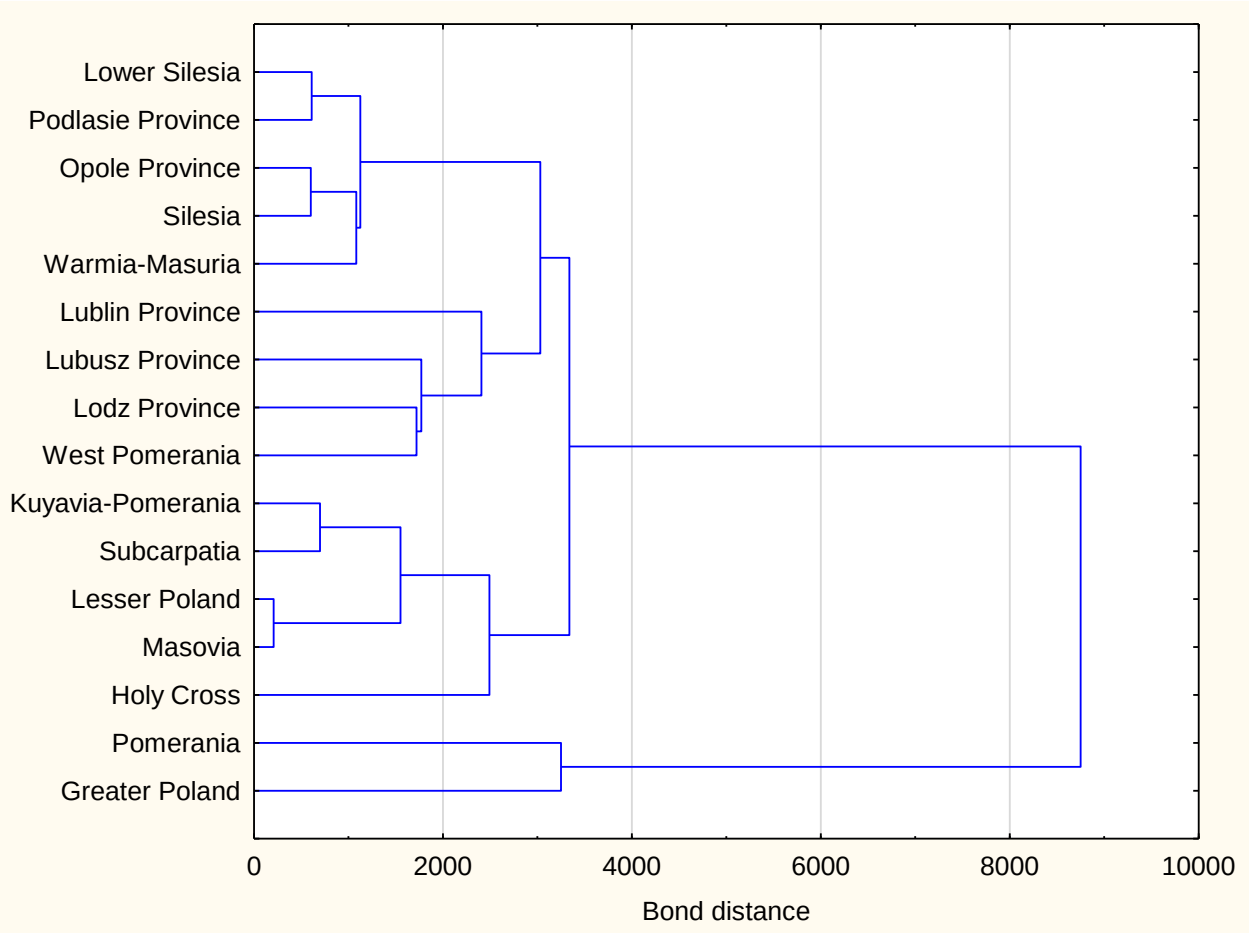

Figure 4. Cluster analysis for the studied provinces.
Source: Author own analysis.

Upon scrutinizing the outcomes of the cluster analysis, we find that they align with the findings presented earlier from the correlation and relationship analyses among the variables. When considering a maximum distance threshold of 3000, we can discern five distinct groups:

- Greater Poland - This province exhibits the lowest level of hospital accessibility, with a notably low number of hospitals per 1,000 square kilometers and one of the highest figures for residents per hospital. The hospital count in this province is significantly lower than expected given its economic wealth.
- Pomerania - This province is characterized by a relatively lower quality of healthcare accessibility. It features a small number of hospitals, a high number of residents per hospital, and a substantial distance to the nearest hospital due to a low ratio of hospitals per 1,000 km2 of area. Although the indicators are somewhat better compared to Greater Poland, the number of hospitals in this province remains lower than expected based on its economic wealth.
- Holy Cross, Masovia, Lesser Poland, Subcarpatia, Kuyavia-Pomerania - These provinces demonstrate an average level of hospital availability, both in terms of population and geographic area. The number of hospitals in these provinces falls within the confidence interval when correlated with GDP per capita.
- Lublin Province, Lubusz Province, Lodz Province, West-Pomerania - These provinces also exhibit average hospital accessibility, albeit slightly lower than the previous group, especially regarding the number of hospitals per 1,000 km2 of area. The number of hospitals

in these provinces aligns with the confidence interval for correlation with GDP per capita, with the exception of Lubusz Province.

- Warmia-Masuria, Silesia, Opole Province, Podlasie Province, and Lower Silesia - These provinces enjoy the highest level of healthcare accessibility, boasting a superior quality of life in terms of hospital availability. Silesia and Lower Silesia, in particular, have more hospitals than one might expect based on their economic wealth.

Taking into account the geographic distribution of provinces within each group, it becomes evident that the highest level of healthcare accessibility in Poland, as assessed by the availability of hospital services, is concentrated in the southwestern and northeastern regions. Conversely, the lowest level of healthcare accessibility is observed in northwestern Poland.

Conclusion

The data reveals that Silesia and Masovia provinces boast the highest number of hospitals, with 141 and 118 respectively. They are closely followed by Lower Silesia, Lesser Poland, and Lodz province. Conversely, the provinces with the fewest hospitals are Lubusz, Holy Cross, Opole, and Podlasie provinces. The number of hospitals in Poland experienced growth from 913 in 2012 to 979 in 2014 but eventually stabilized around 950. The most significant decrease occurred between 2018 and 2019. The ratio of population to hospitals fluctuates around 42,000, demonstrating substantial disparities among provinces concerning hospital accessibility. This publication underscores the importance of considering population size and accessibility when evaluating the number of hospitals as a determinant of quality of life in a smart city.

This paper also scrutinizes the indicator of the ratio of hospitals per 1,000 square kilometers of a province's area and its implications for smart city residents' access to healthcare and quality of life. In 2021, Poland's indicator stood at 2.87 [hospitals/1000km2], signaling a declining trend attributed to a decrease in the number of hospitals. The Silesian Province boasted the highest indicator value at 11.43 [hospitals/1000km2], while the lowest values were observed in Lubusz Province, Warmia-Masuria, Greater Poland, Lublin Province, and West Pomerania. This indicator carries particular significance for the elderly and seriously ill populations, serving as a gauge of their potential access to healthcare facilities.

The analysis of hospital distribution per 1,000km2 area in Poland illustrates that residents in southern Poland, excluding Subcarpatia Province, enjoy closer proximity to hospitals, while northwestern and eastern Poland exhibit lower indicator values. The study also delves into the correlations between hospital saturation in individual provinces, considering both population size and area.

This paper further explores the relationship between hospital availability and GDP per capita in Polish provinces. The results demonstrate that Silesia enjoys the highest level of hospital availability and quality of life in terms of hospital services, while Greater Poland and Pomerania lag behind. A positive correlation of 0.81 is observed between the number of hospitals and GDP per capita, indicating that wealthier provinces tend to have more hospitals. This relationship can be expressed using the formula: Number of hospitals = -38.39 + 0.0017*per capita GDP.

These findings support the hypothesis that hospital numbers correlate with GDP per capita. The study suggests that investing in healthcare infrastructure can enhance residents' quality of life, stimulate economic activity, and attract investment in the healthcare sector. It also highlights the rising costs of hospital construction and emphasizes the importance of prioritizing healthcare infrastructure in smart cities to provide better healthcare services to

residents. The study provides insights into the interplay between healthcare and economic development in Polish provinces.

The research further uncovers a strong correlation of 0.82 between the number of hospitals and population density, affirming the hypothesis that hospital counts in a province relate positively to population density. The article presents a formula for calculating this relationship for the year 2021: Number of hospitals = 9.76 + 0.36*population density.

The article observes that central provinces in Poland have fewer hospitals than expected based on their population density, while the capital province, Masovia, boasts more hospitals due to the presence of Warsaw, a prominent medical center with modern hospitals and research facilities. Lastly, the article underscores the demand for medical services from residents and patients from other parts of Poland who seek medical services in the capital as a significant factor influencing the higher concentration of hospitals in the capital province.

The paper's main innovation lies in its application of cluster analysis to identify groups of provinces with similar hospital-related indicators in Poland. Particularly intriguing is the finding that these clusters do not align with the traditional division of Poland into Polish A and Polish B, based on wealth.

However, this paper's primary limitation is its focus on a single country. Future research could explore multiple countries, such as those in the European Union, to facilitate comparative analysis. Additionally, examining aspects beyond hospitals, such as medical clinics and pharmacies, may offer a more comprehensive perspective on healthcare accessibility.

The primary theoretical implication of this paper is its identification of provincial clusters based on hospital distribution, statistical relationships between hospital numbers, GDP per capita, and population density, accompanied by formulae derived from these relationships.

From a managerial perspective, the paper's key insight is the divergence of provincial clusters from the conventional Polish A and Polish B divisions, offering potential for more sustainable policy development in Polish hospital management.

Future research could delve into other healthcare service providers, like medical clinics in Poland, their distribution, and influencing factors. Furthermore, comparing Poland's hospital system and hospital distribution with other European Union countries would provide valuable insights.

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