**DOCTORAL (PhD) THESIS**

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# Smart factors and spatial analysis of resilience in the Northern and Central Hungarian regions

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## 1. BACKGROUND AND OBJECTIVES

Currently, there are 8.222 billion people[1] living on our planet, and this number is increasing on a daily basis posing a number of challenges to society, the economy and the environment alike (Worldometer, 2025). A lot of cities and villages, serving as homes to this huge population, are constantly working to improve the living conditions and circumstances of the inhabitants in order to survive and thrive. Although the rate of global population growth has been slowing down, it is still one of the major challenges of our times, affecting mainly cities and also rural areas such as the agglomeration of Budapest in an increasing number of countries. The UN predicts that **the proportion of urban dwellers could reach 70% by 2050** (UN, 2018a). Cities are the engines of economic growth worldwide, competing at multiple levels for resources, investment, decision-making competences, institutional development, etc., necessary for their survival and development (Lechner Knowledge Centre, 2020). This raises a number of social, economic and environmental issues.

One such issue is climate change (Colding et al., 2024), which not only does negatively affect people's health, but also poses serious challenges for those working in agriculture, such as overcoming periods of drought or minimising frost and ice damage to orchards. Growing regional inequalities (Gyurkó et al., 2023) are also a cause for concern, as the gap between rich and poor is widening and peripheral settlements are becoming more and more disadvantaged. Another difficulty is the negative demographic trend affecting the whole of Europe and placing a heavy burden in Hungary on systems related to care for the elderly, but also on the labour market through the emigration of young and skilled workers (Obádovics – Tóth, 2023).

In order to comprehend and address issues, **an increasing number of concepts** are being developed by both researchers and practitioners. The emerging problems (e.g., globalisation, population growth, environmental challenges, etc.) have given rise to the idea of **smart settlements.** Currently, in addition to smart cities, we can also talk about smart villages or the 'smarting'[2] of villages - which can provide solutions to the challenges of the present and those of the future. The importance of this topic is also reflected in the growing number of experts working on it. For example, Giffinger et al. (2007) were among the first to create their smart efficiency assessment approach, which they used to an analysis of 70 medium-sized European cities. Their six smart dimensions form the basis of the dissertation. Cohen (2014) studied the efficiency of smart cities in Latin America with the aim of improving quality of life. Lados et al. (2011) studied

[1] Based on the data of 07 May 2025

[2] The use of the adjective 'smart' in the dissertation: the smart concept is already beginning to appear in urban development

nine Hungarian cities focusing on smart efficiency using seven sub-dimensions. Baji (2017) summarised the different interpretations of smart city concepts and sought to answer the question of what future smart cities will look like according to the experts of the topic. Egedy (2017) discussed the similarities and differences between the concepts of the creative city and the smart city, while Káposzta – Honvári (2019), based on the smart city concept, investigated the possibility of the emergence of smart villages and their impact on various aspects of rural development, thus helping to solve problems and identify new development directions. Such a new development direction has therefore led to the emergence of a ‘smart’ (more liveable) settlement, which is a long process and involves the capacity for constant change.

The rapid advancement of information technology has contributed to innovation in settlements to a great extent, thus helping them to become smart settlements, and, if properly applied, improving the quality of life of people living there. With the globalisation of the **internet** and the connection of computers and mobile phones to the internet, communication devices have spread rapidly around the world. This tendency is supported by the global spread of sensor technology, which makes it possible to monitor a variety of activities, such as different production processes, the weather, the identification of public service failure sources (such as burst pipes), or emerging traffic situations. But it is not enough just to implement the various 'causal' projects, it is also important to **measure and monitor** their **effectiveness** and efficiency improvements, not only to present our own results, but also to provide useful data for other settlements to help them implement them. Operations like energy efficiency or public transportation optimization can be swiftly influenced and adjusted by processing and analysing data from sensor observations. Apart from advancements in economic and environmental efficiency, innovations for society and its members are also gaining traction, however their efficacy is much more difficult to measure than that of sensors. The use of various **digital devices** is emerging in education (e.g., interactive whiteboards), health (e.g., smart blood pressure or blood glucose meters, smart rings, etc.) and eldercare (e.g., care watches) (Sallai, 2018; Szalai, 2023; Greutter-Gregus et al., 2024).

The redefinition of development and sustainability has brought resilience to the forefront, as it is evident that **globalization** and **urbanization** pose numerous challenges for various settlements. With its assistance, stakeholders are attempting to offer a solution for global issues like climate change or the preservation and expansion of the competitiveness of small towns and cities through the development of sustainable projects. All facets of the economy have been impacted by the sustainability approach since the Brundtland Commission defined **sustainable development** in 1987, the sustainability approach has permeated all dimensions of the economy. Sustainable towns and villages are characterised by their resilience to disasters, returning to a state of equilibrium after a shock (Seeliger – Turok, 2013). Resilience can also be mentioned as a factor in achieving sustainability. In the OECD Communication, **resilience** refers to the ability of any municipal system to withstand and recover quickly from multiple shocks and to maintain continuity of services after a crisis (OECD, 2018; Greutter-Gregus, 2023).

I first encountered smart cities during my Master's studies and was so interested that I started analysing smart cities from an environmental perspective in my thesis in 2020. This provided the basis for my doctoral dissertation to explore this increasingly important and dynamically developing smart city topic area, and extend the topic to include an analysis of the concept of smart cities and villages as well as their resilience.

I have pointed out in the literature review that, despite the fact that their indicator systems typically overlap, smart efficiency and resilience have only been measured independently in prior studies. Therefore, I have set the overall objective of creating an index system (Smart Settlement Efficiency and Resilience Index) based on publicly available statistical data to measure smart efficiency and resilience together. In my dissertation, I have summarised the literature and measurement options for smart cities and villages as well as resilience, and defined smart and resilient settlements as a new scientific achievement based on the research material processed. Finally, my index system allows for the joint measurement of smart efficiency and resilience. In doing so, I have extended the theoretical background and the practical applicability of this topic with my dissertation.

My dissertation consists of eight chapters. After explaining the rationale for selecting the topic, I have formulated my objectives, the scope of the research questions and drafted my hypotheses. In the next chapter, I have clarified the definitions related to smart settlements and resilience, presented their measurement possibilities, and explored the problems surrounding developments in smart settlements, and presented some good practice examples. After describing the database and methodology of the study, my results are presented. Finally, I have drawn my conclusions, made recommendations for further research and development, and introduced as well as summarised my recent scientific achievements and findings.

## 1.1 Objectives

The study area of my dissertation is the Northern Hungarian region and Pest county (including Budapest), which I considered necessary to include in the study due to its significant spatial structure shaping effects. The primary objective of the research is to measure the smart efficiency and resilience of the settlements in the study area together as a new scientific method, which has not been done in previous scientific work before. In addition, I will investigate whether there is a West- East spatial inequality effect from Budapest that determines the pace of development of settlements and the relationship between the subsidies and smart growth of the 2007-2013 and

2014-2020 programming periods. Finally, based on the results obtained, I will make recommendations to achieve smart urbanisation.

My doctoral research involves several objectives. Firstly, I have collected all available data for the study sample from the Lechner Knowledge Centre, the National Spatial Development and Planning Information System (TeIR) and the Central Statistical Office (KSH) databases and select the relevant indicators (**O1**) by correlation analysis. Based on this, I have created my own index system (Smart Settlement Efficiency and Resilience Index, OTHR index) to measure the efficiency and resilience of these 'smart' settlements together and examine them for the years 2012, 2017 and 2022 and rank the settlements based on the results (**O2**). I have then performed a cluster analysis on the OTHR index results and interpret the results (**O3**). Based on the cluster analysis groups, I have selected the settlements that have participated in the primary research and examined which ones have smart initiatives (**O4**). In the primary research I have involved the mayors of the settlements and the heads of their larger educational institutions (kindergartens, schools) and assessed their attitude towards smart initiatives, their opinion on the initiatives implemented so far and their impact, their future plans and the obstacles they have encountered in implementing the existing and future plans (**O5).** I have examined how the effectiveness of smart initiatives has been influenced by smart initiatives in settlements with a smart city concept and made recommendations for them and for settlements without a smart city concept on smart projects that could support their development and catching up in the future (**O6**). In this context, I have analysed the opportunities for project applications and funding for the 2007-2013 and 2014-2020 programming periods and how they relate to smart development (**O7**). Furthermore, I have used the OTHR database resulting from the studies to explore whether the West-East spatial inequality effect (spatial differentiation, with settlements closer to the western border of the country performing better economically than those closer to the eastern border) still prevails in the area under study (**O8**).

## 1.2 Research questions

After defining the objectives, I have answered the following research questions in the dissertation:

- **Q1:** How does the ranking of smart settlements evolve according to the OTHR index measuring efficiency and resilience in each study year?
- **Q2:** How does the location of the settlements affect their Smart Settlement Efficiency and Resilience index?
- **Q3:** Which projects related to which areas (e.g., digitalisation, environment, etc.) are most relevant for the settlements under study?

**Q4:** How has the aid requested and received in the programming periods covered by the study contributed to the development of the settlements?

### 1.3 Hypotheses

One of the most important parts of the doctoral dissertation is the formulation and testing of the research hypotheses. In my dissertation I have formulated the following eight hypotheses.

**H1.** The settlements in the Budapest agglomeration area are less resilient socially, economically and environmentally than settlements near other large cities because of the pull effect of the capital.

**H2.** The OTHR index of the settlements near the Hungarian-Slovak border shows a permanent decrease due to the peripheral character of the settlements.

**H3.** The cities of the study sample with a dominant regional role (with a population of at least 20,000) all form a cluster according to the OTHR index results, i.e., their smart city efficiency and resilience are almost equal.

**H4.** In the smart developments of the villages included in the online focus group survey, projects related to digitalisation are predominant (smart benches, deployment of camera systems, installation of wi-fi hotspot stations, e-government), while developments supporting mobility, environment, economic recovery, social well- being (such as electric bicycles, vehicle sharing, creation of smart communities), which could be a real solution for the catching-up of rural areas, are less important.

**H5.** Settlements in economically and socially underdeveloped areas are lagging behind in development support because the people living there are often low-skilled and therefore lack the skills to adapt to the use of new technologies, and because of the age structure of society.

**H6.** Among the settlements in Borsod-Abaúj-Zemplén county, the economically developed industrial towns/cities do not have a high OTHR index due to the negative impact of selected environmental indicators.

**H7.** The location of the settlements in the county strongly correlates with the OTHR index of the settlements. In this hypothesis, I assume that a West-East spatial inequality effect prevails, i.e., OTHR values show a continuous downward trend away from Budapest.

**H8.** In the settlements studied in the focus group survey, the efficiency of smart developments has shown an increasing trend over the programming periods up to the present day, which is also observed in the evolution of the OTHR indices.

**Table 1 Correlation between the research objectives, hypotheses, databases used and methods employed**

| Hypothesis | Data source | Testing methods | Objective | Implementing |
|---|---|---|---|---|
| H1 | OTHR index | correlation analysis, index formation, ranking, cluster analysis | C1, C2, C3 | March 2024 – December 2024 |
| H2 | OTHR index | correlation analysis, index formation, ranking | C1, C2, C8 | March 2024 – January 2025 |
| H3 | OTHR index | correlation analysis, index formation, cluster analysis, Spearman correlation | C1, C2, C3 | September 2024 – November 2024 |
| H4 | Integrated Settlement Development Strategy, online focus group survey | document analysis, focus group, empirical case study | C3, C4, C5, C6, C7 | September 2024 – December 2024 January 2025 – April 2025 |
| H5 | Integrated Settlement Development Strategy, online focus group survey, OTHR index | correlation analysis, index formation, ranking, cluster analysis, map visualization, focus group | C1, C2, C3, C4, C5, C6, C7, C8 | March 2024 – March 2025 |
| H6 | OTHR index | correlation analysis, index formation, ranking | C1, C2, C3, | March 2024 – September 2024 |
| H7 | OTHR index | correlation analysis, index formation, ranking, Local Moran I analysis | C1, C2, C3, C8 | March 2024 – October 2024 |
| H8 | Programming period documents, online focus group survey, OTHR index | document analysis, correlation analysis, index formation, ranking, focus group | C7 | March 2024 – March 2025 |

*Source: Author's own editing, 2025*

I have accepted or rejected the validity of my hypotheses based on secondary research data by examining the results of my Smart Settlement Efficiency and Resilience Index, cluster analysis and the analysis of the Integrated Settlement Development Strategy of each settlement, as well as by evaluating the questionnaire results of the primary research. I have summarised the relationships between the research objectives, hypotheses, sources of data and methods in a table (Table 1) for better clarity and interpretation, and added a column on implementation time to illustrate time management.

For the hypothesis testing, I have relied most heavily on the results of the OTHR index trained from secondary data, supplemented with data from the development documents and primary survey of the settlements under study. In total, ten methods of analysis have been used, and the analyses were carried out between March 2024 and April 2025.

## 2. MATERIAL AND METHODOLOGY

The **798 settlements of** the **Northern Hungarian region and Pest county** (Figure 1) have served as the database for the study primarily. In the research, I have first determined the Smart Efficiency and Resilience Index of the 798 settlements, then a cluster analysis has been performed on the sample, based on the results of which **twenty settlements** (Aszód, Budaörs, Budapest, Eger, Galgahévíz, Gödöllő, Gyöngyös, Hollókő, Hort, Karancsberény, Miskolc, Nagyréde, Rózsaszentmárton, Sajókeresztúr, Sáta, Szob, Szögliget, Tokaj, Vác, Visonta) have been identified and dealt with in my primary research and in the analysis of the Integrated Settlement Development Strategies.

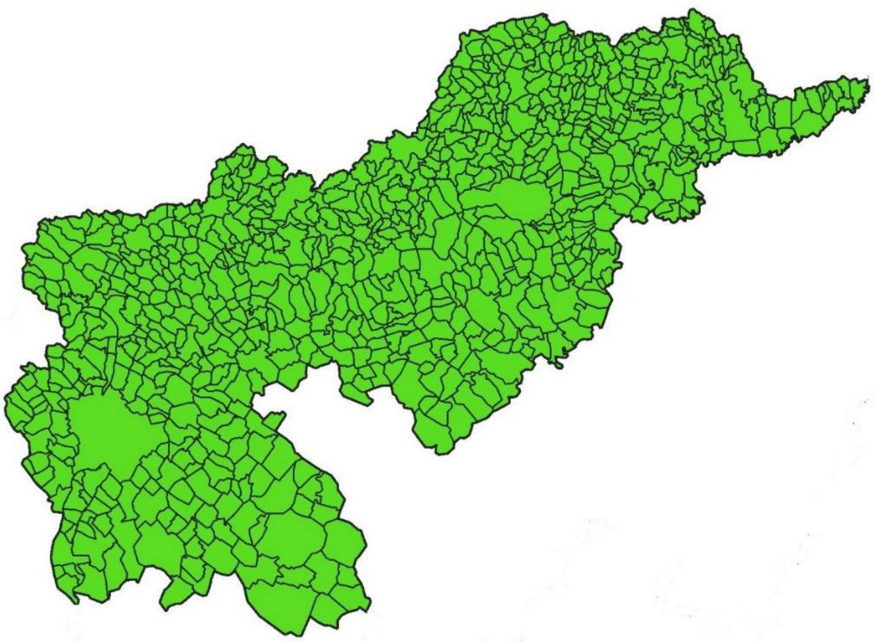

**Figure 1 Map of the study database**

*Source: Author's own editing, 2025*

This area was selected as the database for the study because, as a resident of Miskolc, I am close to the region and its settlements. Moreover, I know them well, so I hope to contribute to the development of the region through the results of my studies. The spatial structure of Hungary is highly differentiated, which is reflected in the spatial differences between the counties of the Northern Hungarian region and the Pest county of the Central-Hungary region. This spatial heterogeneity provides an opportunity for comparison, a more precise definition of development directions and the adoption of good practices and their adaptation to local conditions. For example, the settlement of Uppony in the Northern Hungarian region, which participated in the Smart Rural 21 project, is a model for other small villages in the region. The results of the cities and settlements and the recommendations made can also promote cooperation between settlements within the region and internationally (for example, in the form of cross-border cooperation or the creation of a smart area), which can be beneficial from a socio-economic point of view, as it can raise the living standards of the inhabitants and the economic role of the settlement. The analysis of the study area will support the definition of development policy guidelines to help the population of the counties under study to catch up, in particular the Roma minority, or to develop the digital literacy of the population. Furthermore, the spatial structural effects are external to the Northern Hungarian region, Budapest and Pest counties play a key role in the analysis of the West-East spatial disparity and the capital- capital effects, which is why I considered it essential to include them in the analysis, even if the classical pole theory is not fully valid.

### 2.1 Description of the research methods

The research methodology of my dissertation is structured in several parts:

In ***the documentary analysis,*** in addition to exploring and summarising the relevant literature the Integrated Urban Development Strategy of the settlements included in the cluster analysis has been examined as well as the development and funding applications for the 2007-2013 and 2014-2020 programming periods, to get an idea of which settlements have smart initiatives and what kind of support they have received and how this has affected their efficiency and resilience, and whether the results of these developments can be measured in the OTHR index.

In the ***secondary data*** analysis, first the indicators from the Lechner Knowledge Centre's Urban Assessment and Monitoring Methodological Proposal Annex 1 (Lechner Knowledge Centre, 2015) have been extracted, which are derived from statistical data sources, and then based on other smart city and resilience analysis methodologies such as Giffinger et al. (2007) (Figure 2), as well as Sebestyénné Szép et al. (2020), Hegedűs (2020), Suárez et al. (2016) and Banica – Muntele (2017) (Table 2), the set of smart city indicators using TeIR and KSH databases have been extended and modified.

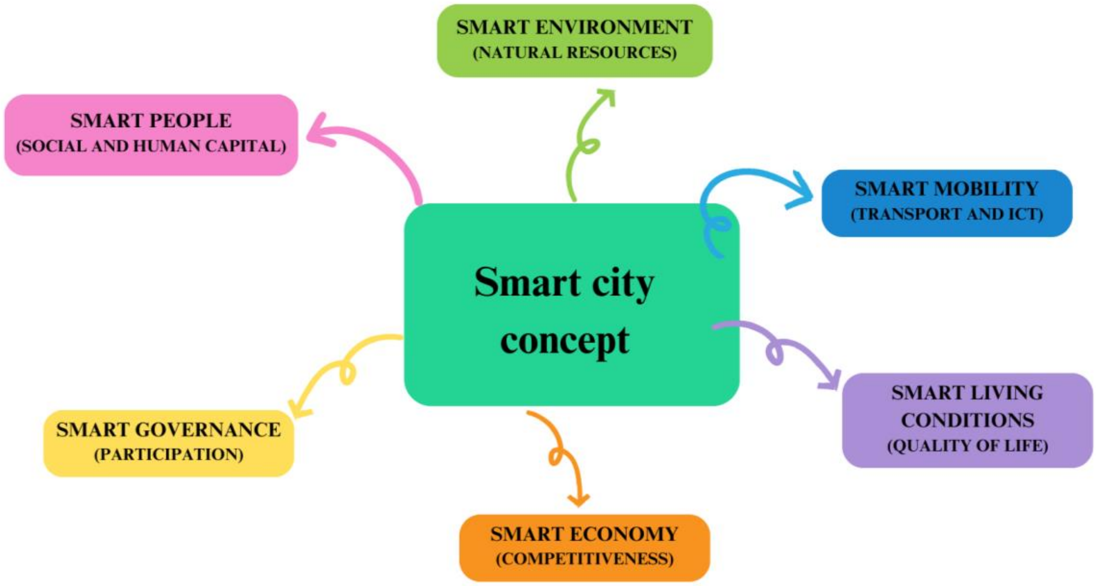


**Figure 2 Dimensions and factors of the Giffinger et al. (2007) smart city concept**

*Source: Author's own editing, 2024 based on Giffinger et al. (2007)*

To examine the factors of each dimension, indicators such as total number of registered jobseekers (number of persons), income per capita (HUF), electricity supplied to households (1000 kWh), number of NGOs (number of persons), number of registered businesses (number of persons), number of Internet subscriptions (number of persons), etc. have been collected from the databases mentioned above.

Table 2 shows the indicators used in my previous resilience studies, grouped by resilience component. I have included them in my analysis by aggregating them with the smart cities' efficiency indicators along the corresponding dimensions, as some of the resilience indicators (e.g., attendance and visits per 100 inhabitants (head count) in general practice and general paediatrics, electricity supplied to households (1000 kWh), etc.), thus avoiding double weighting of some indicators in the analysis. In the table, the impact of the indicators on resilience is given with a +/- sign, which, as in the efficiency measure, implies multiplying by -1 for indicators with a negative impact, the need for which is explained in more detail below.

**Table 2 Set of indicators for the resilience components used**

| Indicator | Impact on resilience (+/-) | Source |
|---|---|---|
| Social resilience component | | |
| Aging index [1] | - | KSH |
| Number of students participating in higher education by place of education compared to the total population, [persons/thousand people] | + | KSH |
| Number of people attending and visiting family doctor and family pediatrician services per thousand people, [people] | - | KSH |
| Proportion of recipients of settlement support, [%] | - | KSH |
| Economic resilience component | | |
| Per capita income subject to personal income tax, [thousand HUF] | + | TEIR/KSH |
| Estimated employment rate (proportion of taxpayers within the population), [%] | + | TEIR/KSH |
| Number of built apartments per thousand inhabitants, [thousandths] | + | KSH |
| Share of municipal taxes in municipal revenues, [%] | + | KSH |
| Environmental resilience component | | |
| Number of apartments connected to the public drinking water network, [pcs] | + | KSH |
| Number of apartments connected to the public wastewater collection network (public sewer network), [pcs] | + | KSH |
| Amount of electricity supplied to households, [kWh] | - | KSH |
| Municipal waste collected separately from the population, [kg] | + | KSH |
| Total green areas owned by municipalities, [$m^2$] | + | KSH |
| Number of passenger cars per capita, [pcs] | - | KSH |

*Sources:* Sebestyénné Szép et al. (2020); Hegedűs (2020); Suárez et al. (2016); Banica – Muntele (2017), KSH and TeIR, 2024

[1]The ageing index expresses the ratio of the elderly population (65 years old) to the child population (0-14 years old).

Abbreviations in the table: KSH - Central Statistical Office, TeIR - National Spatial Development and Planning Information System

Then all available data for the settlements included in the research (Northern Hungarian region and Pest county) for the study years 2012, 2017 and 2022 have been collected. The most recent data available for the research was from the year 2022, so I have used this as a basis for defining the other two study periods. I have chosen five-year periods because they are easy for anyone to interpret. In addition, data was also available for each programming period. ***A correlation analysis was*** then used to select and filter the relevant indicators. The idea behind the method was to explore the correlations between the indicators/variables, looking for groups of indicators that are more closely correlated with each other. The data were normalized using z-transform and correlation tables were constructed using the statistical programme RStudio. Calculation of the correlation coefficient from the sample:

$$r_{x,y} = \frac{\Sigma(x_i - \bar{x})(y_i - \bar{y})}{(\sqrt{\Sigma(x_i - \bar{x})^2 (\Sigma(y_i - \bar{y})^2}} \quad (1)$$

Where xiand yiare the variables of interest, $\bar{x}$ and $\bar{y}$ are the means of the variables.

In the correlation analysis, the criterion I have set is that I keep indicators whose value is greater than 0.3 and that there can be a maximum of three indicators within a set of indicators of a smart dimension whose correlation value does not reach this threshold when tested for correlation with another indicator. The value of 0.3 was selected because above this value at least a minimum correlation between indicators can be interpreted. I made exceptions for two indicators, which were Attendance and visits to GPs and GPs per 100 inhabitants (persons) and the Ageing index, which are essential indicators to reveal the true situation of the dimension.

As a result of the correlation study, ***I have created my own index system*** (Smart Settlement Efficiency and Resilience Index, ***OTHR***) (Annex M2 of the dissertation), which measures the efficiency and resilience of smart settlements together. The included indicators are equally weighted in the index construction.

I have then carried out ***an analysis of*** the sampled ***settlements based on the new index system.*** In the calculations, it was necessary to standardise the data, as the units of measurement and scaling were different, to ensure comparability of the data. To carry out this procedure, I have opted for the z-transformation, also used by Cohen (2014) and Szendi et al. (2020), where the initial values are standardised using their means and standard deviations. The normalisation is based on the formula of Cohen (2014):

$$y' = \left(\frac{y - \bar{y}}{dest_y}\right) \quad (2)$$

Where y' is the normalized value, y is the baseline data, $\bar{y}$ is the mean of the data series, and $dest_y$ is the standard deviation of the data series.

Due to the different scales of the indicators, I first projected them to 1 person using the constant population size and then calculated them on a common projection basis corrected for their means and variances. Then, a multiplication by -1 was applied to those indicators that are favourable for a settlement if they have a lower value (e.g., number of registered jobseekers, number of people attending medical care, etc.). The resulting data were aggregated by dimension to obtain their OTHR index values and ***ranked*** on this basis.

The calculation of the OTHR index is described by the formula below:

$$\text{OTHR index} = \sum_{k=m}^{n} \frac{y'_i}{a_i} \quad (3)$$

Where k is the number of smart dimensions from m=1 to n=6 (exception in 2012 where only five dimensions data were available), $y'_i$ is the i-th member of the normalized value, $a_i$ is the i-th member of the permanent population.

The results obtained were used to ***perform cluster analysis.*** In the cluster analysis, I created clusters of data that are similar according to some characteristic/dimension, thus forming relatively homogeneous groups. The purpose of the procedure is to show that there are groups within the study sample that are more similar to each other than to other group members.

SPSS was used to perform the cluster analysis. I have used **three methods to perform clustering** in the 798 settlements in the study sample, all of which are hierarchical clustering studies. These are the Ward procedure, which belongs to the group of variance methods, and the Nearest neighbour and Between-groups methods, which belong to the simple and average chain methods. In all cases, a quadratic Euclidean distance was used. For all three methods, I have examined how the clustering of settlements evolves when four, five or six clusters are formed. The Nearest neighbour and Between methods group most of the sample into a single cluster. These methods do not show any observable difference between settlements based on the OTHR index, so the **Ward method was selected** to form the clusters. In order to decide how many clusters to form, the results of each cluster ***were plotted on a map*** using QGIS 3.28 Florence. **The five clustering divisions of the Ward's method** best described the settlements studied. The first cluster was named 'developed', the second 'developing', the third 'stagnating', the fourth 'lagging' and the last one 'lagged behind', based on the performance and ranking in the OTHR index. The resulting clusters also form the basis for the primary research.

Besides the choice of the clustering method, I have also used ***map*** visualisation to visualise the spatial relationships.

For the primary research, I have conducted ***an online focus group query*** using an online questionnaire. According to the clusters of the secondary research, I have included the mayors of the settlements and the heads of the larger public institutions (municipal kindergarten and primary school, secondary school) in the study, contacting them by e-mail. In the survey, all four elements of the first cluster were selected, and on this basis four or four settlements from the other clusters were included in the study sample, which were determined using a random number generator. Finally, the focus group survey was conducted individually by self- completion of an online questionnaire, answering structured (pre-defined) questions, using the Google Form web interface. This solution was necessary because it was not possible to arrange a mutually convenient time with the heads of the settlements and institutions, even in the online space, due to their busy schedules. Thus, in order to better manage time and to ensure the completion of the survey, the focus group participants were able to answer the interview questions online in questionnaire form.

The questionnaire is a popular method of data collection, especially in the social sciences, but it requires careful preparation and attention. Before formulating the questions of the questionnaire, it is necessary to define the purpose of the questionnaire, i.e., what you want to measure, whether you want to use a quantitative or qualitative research method, and the size of the sample you intend to collect. The results for each settlement will be published on the basis of the anonymity of the respondents, who will be informed in detail before the survey. The questions and the method of response are presented in Table 14 of the dissertation. The introduction to the questionnaire did not include a conceptual briefing for respondents on the terms smart cities and smart developments, as I wanted to obtain individual responses free of external influences when answering the fifth question of the questionnaire (What are the 3 words that come to mind when you hear the term smart city?). In addition, the other questions of the questionnaire, which focused on smart developments, were answered by multiple choice, thus providing a reference point for the managers of settlements and public institutions, helping them to interpret the terms and to mark the appropriate answers.

In order to support the results of my third hypothesis, ***Spearman's correlation*** test has been used to analyse the relationship between the results of the OTHR index and the permanent population of the 798 settlements included in the study. The Spearman correlation is a type of rank correlation that shows the extent to which the magnitude of one variable determines the magnitude of another variable, as well as the direction and strength of the correlation. The procedure belongs to the group of non-parametric procedures and is more accurate the larger the sample size.

Also in the hypothesis testing, I applied Local Moran and ***Local Moran I spatial autocorrelation tests***, which help to explore spatial correlations.

$$I = \frac{n}{2A} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} \delta_{ij}(y_i - \bar{y})(y_j - \bar{y})}{\sum_{i=1}^{n} (y_i - \bar{y})^2} \quad (4)$$

Where n is the number of elements in the area units under study, $y_i$ and $y_j$ are the values of the variable under study in each area unit, $\bar{y}$ is the arithmetic mean of the indicator under study, A is the number of adjacency relations, and the coefficient $\delta_{ij}$ is 1 if i and j are adjacent and 0 otherwise (Tóth, 2014). If $I > \frac{-1}{n-1}$, then the autocorrelation relationship has a positive sign, and if $I < \frac{-1}{n-1}$, then the autocorrelation relationship has a negative sign. If $I = \frac{-1}{n-1}$, there is no autocorrelation relationship between the territorial units (Egri, 2017).

To explore and demonstrate spatial patterns, the local test function of spatial autocorrelation, the univariate Local Moran I method has been used published by Anselin in 1995. This method can be used to highlight areas that are similar or dissimilar to their neighbours (Tóth, 2014). Formula of the Local Moran I equation:

$$I_{i,t} = z_{i,t} \sum_i W_{ij} z_{j,t} \quad (5)$$

Where $z_{i,t}$ and $z_{j,t}$ are the standardized values of the observation units at time t. For the univariate Local Moran method, $z_{i,t}$ and $z_{j,t}$ refer to the same dataset. $W_{ij}$ is the spatial weight matrix (Anselin, 1995). The significance level of Local Moran is set at 0.05 and the number of permutations at 999. Based on the result obtained, the settlements can be classified into four groups:

1. high-high (HH): land units with a high value, for which the neighbourhood also has a high value,
2. high-low (HL): land units with a high value, where the neighbourhood has a low value,
3. low-low (LL): land units with a low value where the neighbourhood also has a low value,
4. low-high (LH): units of land with a low value where the neighbourhood has a high value.
5. non-significant category: these are areas with no significant local statistics (Tóth, 2014; Egri, 2017).

As a last method of investigation, for three of the settlements included in the primary research (Gödöllő, Miskolc, Szögliget), I have prepared an empirical case study to support the theoretical research from a practical point of view. In the case study, I have explored and demonstrated the practical benefits of the smart developments that have been implemented.

Finally, I have summarised the results based on the methodology and made recommendations for the development of less efficient/rational settlements.

## 3. RESULTS OF THE RESEARCH

The third chapter presents the results of the research. Firstly, the correlation values and the ranking of the settlements related to the Smart Settlement Efficiency and Resilience Measurement, followed by the cluster analysis, and finally the analysis and evaluation of the Urban Development Plans of the twenty settlements participating in the primary research, and the impact of the subsidies received during the programming periods.

### 3.1 Formation of the OTHR index

In order to obtain the set of relevant indicators for each dimension, a correlation analysis using the **Rstudio** programme was carried out. For the selection of the indicators, I relied on the statistical data available in the TeIR database, the statistical data in Annex 1 of the Lechner Knowledge Centre's Recommendation on the Methodology of Urban Assessment and Monitoring.

First, a set of possible indicators related to the ***smart mobility*** dimension were collected and then a correlation analysis was conducted for all three study years. The result was a **set of nine indicators.** Correlation relationships between 0.1 and 0.3 are considered weak, between 0.3 and 0.7 medium and above 0.7 strong. Weak relationships were only found between two to two indicators. Fifteen indicator pairs have a strong correlation relationship above 0.7.

In the next step, a possible set of smart efficiency and ***resilience*** indicators for smart ***and*** resilient ***environments*** were collected from the databases and then their analysis was performed resulting in **16 indicators.** Together, these indicators provide a comprehensive picture of the smart and resilient environment dimension.

Third, the set of indicators needed to analyse the ***smart governance*** dimension was identified. **Four indicators** met the criteria in the study. This was the only dimension for which no data at all was available for 2012 based on indicators.

A fourth correlation table was constructed to identify indicators of the ***smart and responsive economy.*** The result was a set of **eight indicators.** These indicators provide a picture of the economic situation of both the settlement and its residents. As before, I carried out correlation calculations for all three years of the study, and the results are approximately the same.

The one but last dimension of the correlation analysis was ***smart people***, where **nine indicators** make up the set of indicators for this dimension. There is a moderate correlation between most of the indicators.

The last dimension of analysis consists of the indicators analysing ***smart and resilient living conditions.*** To allow a good characterisation of living conditions/society in terms of resilience, two indicators (Attendance and visits to GP and GPs and Ageing index) were included in the indicator set with a correlation relationship of almost zero. As mentioned earlier in the description of the research methodology, these are essential to reveal the real situation of the dimension. The analysis of the settlements was thus carried out on the basis of the following **15 indicators.** Ten indicators were included in the calculation of the OTHR index of the dimension in 2012 and 2017, since at that time the different public education institutions (except primary schools) were still structured according to a different system, and no uniform data were available for them.

### 3.2 Smart Settlement Efficiency and Resilience Index indicator set, ranking of settlements and map visualisation of the index values

By creating the index system, a **complex** indicator (OTHR) has been created to measure the efficiency and resilience of smart settlements together. This was used to calculate the OTHR index scores of the 798 settlements included in the study and rank them.

The Smart Settlement Efficiency and Resilience Index (OTHR) analyses the settlements included in the study using a total of 62 indicators. In my opinion, this indicator allows for a comprehensive analysis, but in order to obtain more accurate results and statements, it would be necessary to expand and improve the data provision at the Hungarian municipal level, which would allow for the inclusion of additional indicators (e.g.: availability of air pollution data for small settlements as well).

On the basis of the OTHR index, a **ranking of settlements** was established for each of the three years of the study, and the top and bottom ten are presented in tabular form below (Table 3). For the year 2012, the ranking was based on five dimensions (data were not available for governance), with **Piliscsaba** (104.34) coming first. In 2017, the city was ranked fifth in the six-dimension study (75.75), and was pushed out of the top ten by 2022 (ranked 70th with a score of 14.70). The capital city ranked second in 2012 and first in 2017 and 2022. Its index has shown a steady increase from 97.40 to 146.53. In the starting year of the comparative analysis, Miskolc (84.36) was ranked third, then second in 2017 (101.29), but dropped back to fourth position in 2022 (106.35). Although its index values show an increasing trend, the rate of increase was not sufficient to achieve a higher ranking. One reason for this is that compared to 2017, its performance in four smart dimensions decreased by approximately 20%, with the exception of the smart people and living conditions dimensions, where the growth rate was between 25-50%. Eger was ranked fourth in the first two years of the study (76.01; 83.72), moving up two places to second in 2022 (125.27). Gödöllő improved its ranking from fifth in 2012 (64.11) to third (94.66) in 2017 and maintained it in 2022 (113.41).

If we look at the **last ten** settlements, we can see that **only settlements** are included in these positions. In 2012, the settlements ranked between 789 and 796 were in Borsod-Abaúj-Zemplén county, with the last two places occupied by a settlement in Nógrád (Felsőtold -31.76) and a settlement in Pest county (Csomád -34.47). In 2017, Szarvaskő in Heves county is ranked 789th, followed by Endrefalva in Nógrád county and the all-time improving Csomád.

**Table 3 The top and bottom ten settlements in the Smart Settlement Efficiency and Resilience Index ranking for each study year**

| Ranking | Settlement (2012) | Settlement (2017) | Settlement (2022) |
|---|---|---|---|
| 1 | Piliscsaba | Budapest | Budapest |
| 2 | Budapest | Miskolc | Eger |
| 3 | Miskolc | Gödöllő | Gödöllő |
| 4 | Eger | Eger | Miskolc |
| 5 | Gödöllő | Piliscsaba | Tokaj |
| 6 | Tornabarakony | Gyöngyös | Tiszaújváros |
| 7 | Visegrád | Tiszaújváros | Kazincbarcika |
| 8 | Gyöngyös | Visegrád | Sárospatak |
| 9 | Tiszaújváros | Kazincbarcika | Vác |
| 10 | Varbóc | Százhalombatta | Gyöngyös |
| … | | | |
| 789 | Pusztaradvány | Szarvaskő | Tiszacsermely |
| 790 | Vadna | Csenyéte | Parádsasvár |
| 791 | Felsőberecki | Domaháza | Felsőregmec |
| 792 | Gömörszőlős | Becskeháza | Nógrádmegyer |
| 793 | Beret | Endrefalva | Alsógagy |
| 794 | Domaháza | Csomád | Nagybárkány |
| 795 | Kánó | Gagybátor | Felsőgagy |
| 796 | Becskeháza | Bódvarákó | Endrefalva |
| 797 | Felsőtold | Felsőgagy | Sajógalgóc |
| 798 | Csomád | Vilyvitány | Kiscsécs |

*Source: Author's own editing, 2025*

Vilyvitány, located in the Sátoraljaújhely district of the Borsod-Abaúj-Zemplén county, is ranked last, with an OTHR index of -24.18. Among the 2022 list closers, one settlement from Heves county, Parádsasvár (-17.71), is at position 790, and three from Nógrád county, Nógrádmegyer (-18.63), Nagybárkány (-19.56) and Endrefalva (-22.43), are at positions 792, 794 and 796, respectively, the other settlements being in Borsod-Abaúj-Zemplén county. Kiscsécs, located in the Tiszaújváros district, is in last place with an index value of -32.91.

In the following figure (Figure 3) the evolution of the OTHR index value for the study year 2022 is presented, which is relevant for the thesis booklet, detailed data for the study years 2012 and 2017 are presented in subsection 5.2 of the dissertation. The settlements with the lowest index values are marked in yellow, the other settlements are marked in increasingly darker green according to their increasing values.

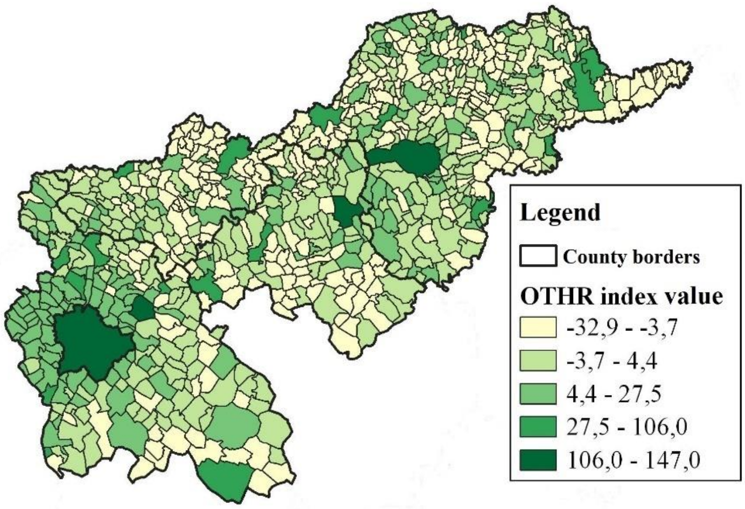


**Figure 3 Evolution of the Smart Settlement Efficiency and Resilience Index in the settlements studied in 2022**

*Source: Author's own editing, 2025*

Figure 3 shows the spatial distribution of the OTHR index values for 2022. The best performing settlement was **Budapest** with an index value of 146.5. Eger followed with a value of 125.3, while Gödöllő came third with a value of 113.4. Miskolc also had an index value above 100, followed by a more significant drop in the index value, with Tokaj in fifth place with a value of 65.9. A total of 293 settlements have a positive index value between 0 and 65. The first settlement with a negative index value is Sajóvámos, with an index value of - 0.04. After Sajóvámos, 499 settlements with a negative index value are ranked, with Kiscsécs being the worst performer with a value of -32.9. Compared to the 2012 and 2017 graphs, Budapest and its agglomeration area, as well as Eger and Miskolc, and the agglomeration of villages and small towns connecting the two settlements, appear **as a densification point.** Furthermore, it can also be observed that there are more settlements with a higher OTHR index along the route of the M3 motorway connecting Budapest and Miskolc than further north or south.

For the year 2022, I have also carried out a district-level analysis to see whether each district has only positive or only negative Smart Settlement Efficiency and Resilience index, thus supporting or rejecting the existence of a West-East slope.

The analysis shows that the only district with only **negative OTHR index is the district of Cigánd** in Borsod-Abaúj-Zemplén county. At the county level, I have also examined how many districts have only one or two settlements or towns with a positive index value, the other settlements having a negative value. The result was that for Pest county, two districts: Dabas and Nagykőrös, and for Nógrád county, four districts: Szécsény, Pásztó, Salgótarján and Bátonyterenye, in Heves county, two: the districts of Bélapátfalva and Heves, while within the administrative boundaries of Borsod-Abaúj-Zemplén county, two: the districts of Ózd and Mezőcsát. On this basis, no West-East slope effect is observed in the distribution of the OTHR indices of the settlements at the level of the study sample. In the case of Budapest, Eger and Miskolc and their agglomeration areas, their appearance as positive density points becomes even more visible.

Subsequently, I have also looked within the counties to see if there is any directional spatial inequality effect or shift based on the OTHR value (Figure 4).

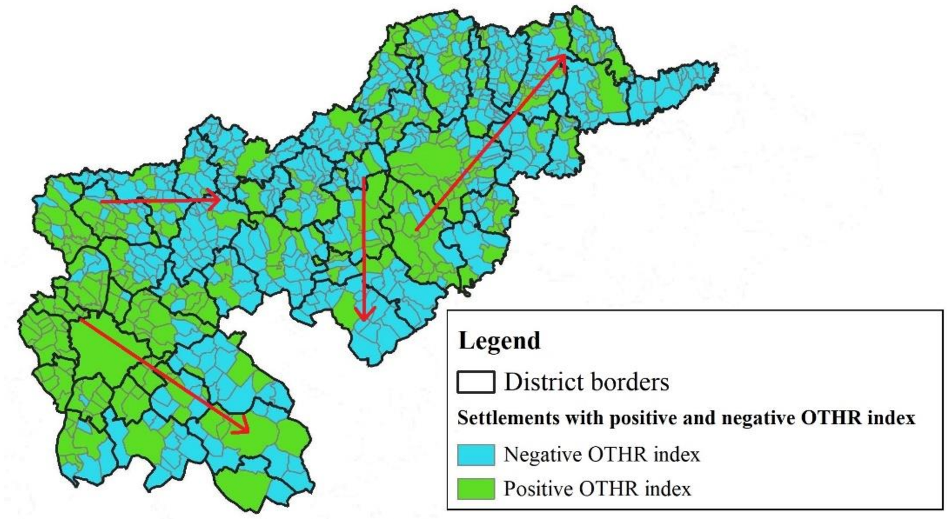


**Figure 4 Plots of spatial inequality effects by county**

*Source: Author's own editing, 2025*

In the analysis by **county**, a northwest-southeast spatial inequality effect can be identified for Pest county, a West-East spatial inequality effect for Nógrád, a north-south spatial inequality effect with a strong approximation for Heves, and a southwest-northeast spatial inequality effect for Borsod county, which are shown with a red arrow. I would like to emphasise that this does not mean, of course, that there are no settlements with a positive index value in the poorer performing areas, but only that their number and clustering is less than in the baseline area.

It can also be said that the majority of the poorly performing districts are located in the Great Plain (Pest, Heves and Borsod-Abaúj-Zemplén counties in the south and south-east), with the exception of Mezőkövesd district, which is one of the best performing districts in Borsod- Abaúj-Zemplén county.

Looking at the Hungarian-Slovak border settlements, there are four settlements in Nógrád county, namely Balassagyarmat, Szügy, Szécsény and Salgótarján, which have recorded positive OTHR values. In the Borsod-Abaúj-Zemplén county, only the town of Ózd in the Ózd district has a positive OTHR. Most of the settlements with a positive OTHR score have cross- border international **cooperation**, while for those with a negative score this is less frequent in the period under review, but there are nowadays some positive projects. The study clearly shows that the most disadvantaged settlements and their districts, often segregated, are the most deprived.

In order to support the findings of the county-by-county spatial inequalities and the H7 hypothesis, I have carried out a Local Moran I spatial autocorrelation test (Figure 5). The Moran I value is 0.151, which shows a weak positive autocorrelation.

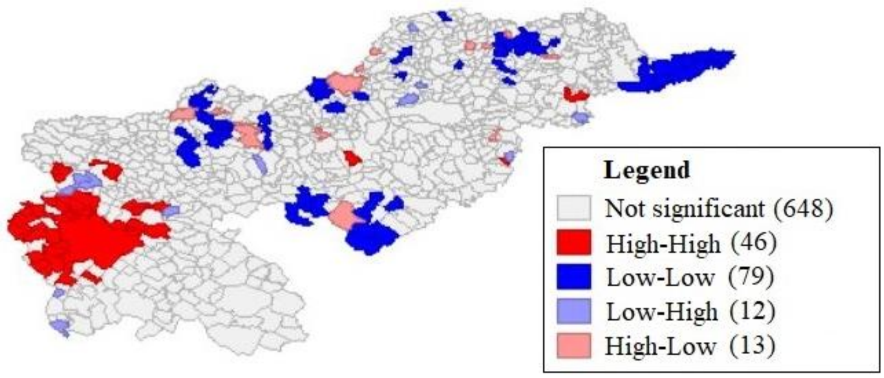


**Figure 5 Plot of the spatial autocorrelation values of the Local Moran I test**

*Source: Author's own editing, 2025*

The 798 settlements included in the study were predominantly in the low-low cluster, with 79 settlements in total. This includes the whole of the Cigánd district in Borsod-Abaúj- Zemplén county, which was already severely affected by both social and economic problems in the early 2010s (Kollár, 2012; Kovács et al., 2024), the southern and north-western part of the Heves district in Heves county, and the eastern part of the Bátonyterenye and Salgótarján districts in Nógrád county. All these settlement clusters are disadvantaged areas and confirm the results of the empirical analysis of the spatial disparities by county, which show that negative density points can be identified in the north-eastern direction in Borsod-Abaúj-Zemplén county, in the southern direction in Heves county, in the eastern direction in Nógrád county and in the south-eastern direction in Pest county, based on the OTHR index. In Pest county, the settlements of Budapest and the agglomeration to the west form a high-high cluster (46 settlements), with positive density points. A low-high cluster is formed by 12 settlements, six of which are part of the Budapest agglomeration (Makád, Szigetújfalu, Dunabogdány, Tahitótfalu, Pilisszentlászló), the remaining six settlements are in the Gyöngyös district (Maklár) and five in Borsod (Varbó, Alacska, Szin, Tiszaladány, Tiszapalkonya). Their OTHR index values are low, with only Maklár (5.51) and Szigetújfalu (0.16) having positive values. A high-low cluster is formed by 13 settlements located in the counties of Nógrád, Heves and Borsod-Abaúj-Zemplén. The settlements include district seats such as Ózd and Heves, and several villages such as Bánréve.

Overall, both the empirical and Local Moran I studies confirm that there is no West-East territorial inequality in the Northern Hungarian region and Pest county, with Budapest as the starting point, but that positive and negative points of density can be identified in each county, indicating the direction of territorial inequality.

### 3.3 Presentation of the cluster analysis

I have then performed the cluster analysis on each of the rankings obtained. In the thesis booklet I present the results for 2022.

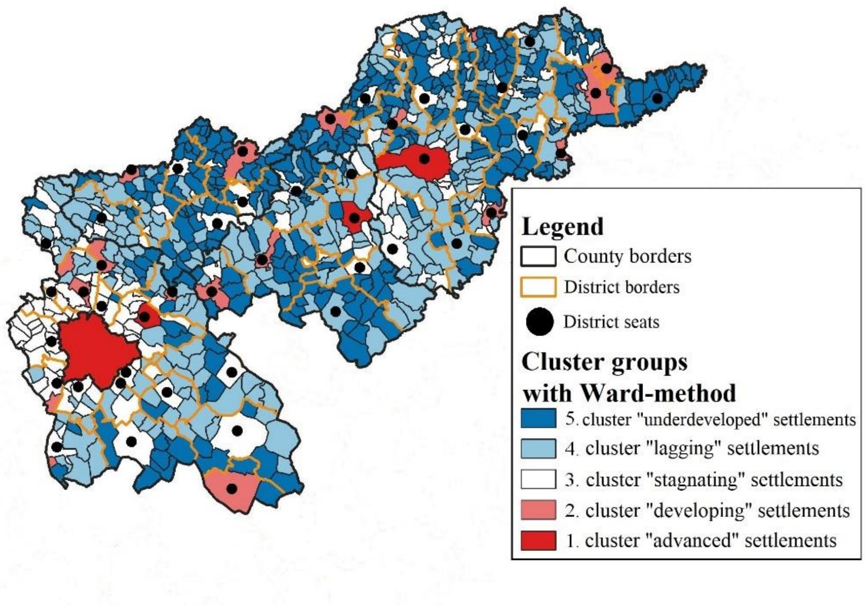


**Figure 6 The cluster groups formed based on the smart city efficiency and resilience analysis of the Northern Hungarian region and Pest county using Ward's method in the study year 2022**

*Source: Author's own editing, 2025*

In the year 2022 (Figure 6), the first cluster, shown in red on the map, included four settlements: **Budapest, Eger, Gödöllő** and **Miskolc.** It can be seen that Piliscsaba was excluded from the first cluster, and with an OTHR index value of 14.7, it could only be included in the third cluster. Compared to 2017, Budapest has maintained its top position, with Eger closing the gap to second place. Gödöllő maintained its bronze medal position, while Miskolc slipped two places. The second cluster is made up of 19 settlements, which are marked in purple. Tokaj, Tiszaújváros, Kazincbarcika, Sárospatak, Vác, Gyöngyös, Százhalombatta, Balassagyarmat, Salgótarján, Aszód, Visegrád, Szentendre, Perecse, Sátoraljaújhely, Tornakápolna, Lórév, Ózd, Hatvan and Nagykőrös were included. The third cluster is made up of 158 settlements, shown in green on the map. This cluster includes a large part of the Budapest agglomeration and some district centres such as Szikszó and Füzesabony. The fourth cluster, marked in blue, includes 293 settlements, both small towns and villages. The last, or fifth cluster, is made up of 324 settlements, mainly in border, peripheral and disadvantaged areas.

In the case of the Budapest agglomeration area, it can be observed that the classification of settlements in each cluster group has changed compared to 2017. The agglomeration ring has widened, several settlements that were classified in the fourth cluster in 2017 have caught up and joined the third cluster, but it can also be observed that settlements previously classified in the second cluster, such as Törökbálint or Budaörs, have slipped back and only joined the third cluster. The OTHR index of both settlements decreased from 28.6 and 28.1 in 2017 to 24.7 and 21.9 respectively.

For the 2022 results, I have also examined which settlements were the biggest advancers and the biggest decliners in the ranking of OTHR index values. From 2017 to 2022, the settlement of Tokaj improved the most positions, moving up from 50th to 5th, while the biggest decliner was Piliscsaba, which dropped from 5th in 2017 to 70th in the ranking. The average of the OTHR index values of the five clusters and the internal dispersion of the values were as follows: for the first ‘developed’ cluster, the average of the OTHR index values is 122.9, with an internal dispersion of 17.6; for the second ‘developing’ cluster, the average is 41.9, while the deviation of each value from the sub-averages in the clustered data is 12.1; for the third ‘stagnating’ cluster, the mean was 11.9, with an internal standard deviation of 6.0; for the fourth ‘lagging’ cluster, the mean of the OTHR index values was -0.38, with a deviation of 2.3 for each value from the sub-averages; for the last ‘lagging’ cluster, the mean and standard deviation were -8.9 and 4.0, respectively. The largest internal dispersion is observed for the values of the first cluster.

The Spearman correlation calculation was also performed for the 2022 data. The result is a correlation value of 0.36, i.e., the influence of population size is not dominant in this case, either.

### 3.4 Results of the documentary analyses

In this subsection, I present my findings based on the Municipal Development Plans and the documents of the programming period.

#### *3.4.1 Results of the analysis of the Municipal Development Plans*

In the analysis of the Municipal Development Plans, the study sample consists of **twenty settlements** selected from the cluster analysis using a random number generator (for details see subsection 4.2 of the dissertation). The document analysis shows that most of the developments are in the **smart environment** dimension, which mainly consist of solar energy upgrades on institutions and the installation of solar parks. In addition, their necessity and their positive impact on the environment are of course indisputable. Other popular dimensions are smart living, governance and mobility. These mainly include digitalisation-related developments such as the installation of smart benches and free wi-fi points, or the implementation of e-government or the use of devices to support elderly care. The 20 settlements included in the analysis all have some kind of smart initiative. Looking at the level of 'smartness', I have classified **six settlements as advanced**, namely Budaörs, Budapest, Eger, Gödöllő, Gyöngyös and Miskolc. In these settlements, in addition to basic energy modernisation, installation of wi-fi points, smart furniture, e-administration, there have been developments such as electric charging stations, geothermal heating, electric and environmentally friendly public transport, etc.

*3.4.2 2007-2013 programming period - New Széchenyi Plan*

During the 2007-2013 programming period, the objectives of the National Strategic Reference Framework (NSRF) under cohesion policy were implemented under six **thematic and territorial priorities**:

- economic development (research and technological development, SME development, business infrastructure, ICT support)
- transport development (support for TEN-T priority projects, road and rail investments)
- social regeneration (support for active labour market policies, human infrastructure development)
- environmental and energy development (compliance with Community environmental standards)
- territorial development (support for regional growth poles, rural development)
- state reform (modernising public administration, supporting civil society) (Nagy – Mohay, 2024).

To support the achievement of these objectives, eight sectoral and seven regional Operational Programmes have been adopted (Table 4).

**Table 4 Sectoral and regional Operational Programmes**

| Sectoral operational programmes | Regional operational programmes |
|---|---|
| 1. Economic development OP<br>2. Transportation OP<br>3. Social renewal OP<br>4. Social infrastructure OP<br>5. Environment and energy OP<br>6. State reform OP<br>7. Electronic government OP<br>8. Implementation OP | 1. Western Transdanubia OP<br>2. Southern Great Plain OP<br>3. Northern Great Plain OP<br>4. Central Hungary OP<br>5. Northern Hungary OP<br>6. Central Transdanubia OP<br>7. South Transdanubia OP |

*Source: Nagy – Mohay, 2024*

The applications in each Operational Programme were first examined for the six settlements at an advanced stage of smart growth. In general, among the sectoral Operational Programmes, the most applied programmes in the settlements analysed were **TAMOP, GOP** and **KEOP**.

Budapest, Miskolc and Eger received the most funding. This ranking is in line with the ranking of settlements in the OTHR index for 2012, suggesting that the support provided by the Operational Programmes has contributed to the increase in efficiency and resilience of these settlements. The OTHR index ranking of Gyöngyös, Gödöllő and Budaörs differs in that Gödöllő is ahead of Gyöngyös. The more favourable efficiency and resilience of Gödöllő is probably due to a more effective use of aid resources.

Next, I have examined the applications of the settlements classified in the initial level of smartness in the Operational Programmes. For these settlements, the sectoral Operational Programmes **TAMOP, KEOP** and **GOP** were the most popular. None of the cities and villages surveyed had submitted/won any grants under the EOP and VOP. Furthermore, the only settlement that did not receive any funding for any project in the 2007-2013 programming period was Visonta in Heves county.

**Vác** received the most funding in the programming period, followed by Tokaj and Aszód. Almost half of the towns and villages surveyed had between 6 and 13 successful applications. Galgahévíz received 3 grants, Karancsberény 2 and Sáta 1. The OTHR index ranks Vác, Hollókő, Aszód, Galgahévíz, Tokaj, Szob, Szögliget, Nagyréde, Hort, Rózsaszentmárton, Visonta, Sajókeresztúr, Sáta and finally Karancsberény. This order differs significantly from the order in which the Operational Programme applications were received. The settlements of Vác, Aszód and Hort are alone in the same position in both rankings. Tokaj, with 76 successful applications, is only fifth in the Smart Settlements Efficiency and Resilience Index ranking of settlements with initial smart developments, ahead of settlements such as Hollókő and Galgahévíz, which received funding in only eight and three applications respectively. This suggests that in the case of the settlements at the initial smart level, in many cases the support received in the 2007-2013 programming period did not contribute significantly to their catching-up. Therefore, I propose to carry out a detailed analysis of the winning applications and their implementation over time for these settlements in order to confirm or deny their impact on their ranking in 2012.

The individual projects can be linked to the Giffinger smart dimensions, i.e., the projects contribute to some extent to improving the efficiency of the settlements.

### *3.4.3 2014-2020 programming period - Széchenyi 2020*

The 2014-2020 programming period in Hungary is called Széchenyi 2020. It aims to make the European Union the most competitive economic and political community in the world. In line with this EU2020 strategy, the Government has developed **ten Operational Programmes**, which have been adopted by the European Commission:

- Human Resources Development Operational Programme (EFOP)
- Economic Development and Innovation Operational Programme (GINOP)
- Integrated Transport Operational Programme (IKOP)
- Environment and Energy Efficiency Operational Programme (KEHOP)
- Operational Programme for the Development of Public Administration and Public Services (KÖFOP)
- Hungarian Fish Farming Operational Programme (MAHOP)
- Operational Programme for Persons in Need (RSZTOP)
- Operational Programme for Spatial and Urban Development (TOP)
- Operational Programme for a Competitive Central Hungary (VEKOP)
- Rural Development Programme (VP) (palyazat.gov.hu, 2024).

All settlements and businesses were eligible to apply for the Operational Programmes.

The types of development to be supported included business infrastructure development, where funding was available for the creation of industrial parks, incubators, innovation and logistics centres and the modernisation of related services. Other areas of development included the creation of sustainable tourism and the development of transport to promote the economy and labour mobility, but there were also a number of options to choose from and overlaps between Operational Programmes (e.g., funding for the construction and extension of cycle paths could be found in both the IKOP and the VEKOP) (TOP 2014-2020, 2024).

In relation to my **O7** research objective, I have first analysed the relationship of the applications of the six settlements classified in the advanced smart level to smart development.

Budapest has the highest number of winning applications this time again, with a total of 1955 applications, and the highest number of successful applications in the Competitive Central Hungary Operational Programme. Looking further at this region, Budaörs and Gödöllő submitted 58 and 54 successful applications respectively. Miskolc received funding in 1 029 applications, Eger in 472 and Gyöngyös in 237. While Budaörs, Budapest and Gödöllő submitted the most applications under the VEKOP, GINOP proved to be the most popular Operational Programme for the settlements of the Northern Hungarian region at the advanced level of smart growth.

If we compare the results with the 2017 OTHR index, we can say that **Budapest** and **Miskolc** are in the lead in both cases, Gödöllő is third, Eger fourth, Gyöngyös sixth and Budaörs 19th, but the order changes when looking at the number of applications awarded, with Gödöllő in last place. It can therefore be concluded that although Gödöllő has received significantly fewer tenders than Eger, Gyöngyös or Budaörs, it has been able to use them more effectively to increase its smart efficiency and resilience. In terms of the number of applications, EFOP and KEHOP are behind VEKOP and GINOP with more than 300 applications, and 226 projects for regional and urban development. As in the 2007-2013 programming period, I have also examined applications from early 'smart' settlements for Széchenyi 2020.

Among the Operational Programmes MAHOP and RSZTOP, the cities and villages examined did not have any applications supported. In the IKOP, only Vác received funding in one case. The most popular Operational Programmes were GINOP and VEKOP for settlements with initial smart developments, based on their regional accessibility.

In terms of the number of successful applications, **Tokaj** was the first with 68 projects, followed by Vác with 55 and Rózsaszentmárton with 14. Karancsberény is in last place with 2 successful applications.

Vác, Aszód, Galgahévíz, Tokaj, Hollókő, Szob, Szögliget, Sajókeresztúr, Nagyréde, Rózsaszentmárton, Hort, Visonta, Karancsberény, Sáta. It can be seen that Tokaj, despite having received the most aid among the settlements surveyed, is only fourth in the ranking of the OTHR index in terms of efficiency. The same is true for Sáta, which with 7 applications is also last in the efficiency ranking among the settlements at the initial level of smartness. Looking at the winning applications, we find projects to improve the energy efficiency of buildings, to promote access to health and to strengthen local identity and cohesion. Galgahévíz, with four positive evaluations, is ranked third in the OTHR ranking of the present settlements. The projects supported were aimed at the extension of the municipal ASP system, building energy improvements and the development of small and medium-sized enterprises. On this basis, I believe that the settlement owes its advantageous position not so much to its winning applications, although it has undoubtedly contributed to the increase in its OTHR index, but to the effectiveness and efficiency of its existing or own resources.

The relationship between the ranking of the settlements on the basis of the OTHR index and the impact of the tenders won in the Operational Programmes is analysed in more depth in relation to my hypothesis **H8** using the table below (Table 5).

**Table 5 Changes in the ranking of the settlements studied according to the OTHR index in each study year and in the number of applications won in each programming period**

| Settlement | Ranking 2012 | Change | Ranking 2017 | Change | Ranking 2022 | Number of applications (2007-2013) | Number of applications (2014-2020) |
|---|---|---|---|---|---|---|---|
| Aszód | 32 | ↑ 11 | 21 | ↑ 7 | 14 | 32 | 11 |
| Budaörs | 23 | ↑ 4 | 19 | ↓ 11 | 30 | 168 | 58 |
| Budapest | 2 | ↑ 1 | 1 | — | 1 | 6628 | 1955 |
| Eger | 4 | — | 4 | ↑ 2 | 2 | 854 | 472 |
| Galgahévíz | 50 | ↑ 10 | 40 | ↓ 224 | 264 | 3 | 4 |
| Gödöllő | 5 | ↑ 2 | 3 | — | 3 | 197 | 54 |
| Gyöngyös | 8 | ↑ 2 | 6 | ↓ 4 | 10 | 320 | 237 |
| Hollókő | 25 | ↓ 79 | 104 | ↓ 52 | 156 | 8 | 10 |
| Hort | 247 | ↓ 168 | 415 | ↓ 86 | 501 | 6 | 7 |
| Karancsberény | 630 | ↑ 42 | 588 | ↓ 150 | 738 | 2 | 2 |
| Miskolc | 3 | ↑ 1 | 2 | ↓ 2 | 4 | 1655 | 1029 |
| Nagyréde | 153 | ↓ 249 | 402 | ↓ 67 | 469 | 20 | 7 |
| Rózsaszentmárton | 273 | ↓ 139 | 412 | ↓ 24 | 436 | 11 | 14 |
| Sajókeresztúr | 568 | ↑ 196 | 372 | ↑ 90 | 282 | 13 | 12 |
| Sáta | 602 | ↓ 162 | 764 | ↑ 116 | 648 | 1 | 7 |
| Szob | 57 | ↓ 57 | 114 | ↑ 66 | 48 | 11 | 3 |
| Szögliget | 122 | ↓ 32 | 154 | ↑ 75 | 79 | 6 | 4 |
| Tokaj | 53 | ↑ 3 | 50 | ↑ 45 | 5 | 76 | 68 |
| Vác | 11 | — | 11 | ↑ 2 | 9 | 117 | 55 |
| Visonta | 559 | ↑ 105 | 454 | ↓ 141 | 595 | 0 | 9 |

*Source: Author's own editing, 2025*

The table shows the ranking of the cities and villages surveyed, their progress (green arrow), stagnation (yellow line) and regression (red arrow) by year of survey and the number of applications won in each programming period. Eight of the 20 settlements analysed (Aszód, Budapest, Eger, Gödöllő, Sajókeresztúr, Sáta, Tokaj, Vác) show that the **applications won** in the programming periods **may have contributed to** the upward trend in their smart efficiency and resilience, as **reflected in** their **ranking** on the basis of their **OTHR** index. Three of these settlements show a steadily increasing trend: Aszód, Sajókeresztúr and Tokaj. Four settlements (Budapest, Eger, Gödöllő, Vác) show stagnation either from 2012 to 2017 or from 2017 to 2022, i.e., they have maintained their previous position. In the case of one settlement, Sáta, there has been 116 good improvements from 2017 to 2022, thanks in part to an increase in the number of projects supported from one to seven. I have identified seven settlements (Budaörs, Galgahévíz, Gyöngyös, Karancsberény, Miskolc, Szob and Szögliget) that showed a positive shift in their OTHR ranking in 2017 or 2022. Where there was an improvement in the ranking from 2012 to 2017 (Budaörs, Gyöngyös, Karancsberény, Miskolc), it appears that the settlements had more successful applications in the 2007-2013 programming period than in the Széchényi 2020 programme. In other words, the larger number of projects may have resulted in more projects that actually act as efficiency enhancers for the settlements. The only exception to this is Galgahévíz, but here I assume that the improvements implemented up to 2017 had a greater efficiency-enhancing effect. For Szob and Szögliget, there was a positive shift in the ranking from 2017 to 2022, but the number of applications won in the 2014-2020 period is lower than in the previous programming period. There are two possible explanations, either the winning applications were not implemented until 2012, so that the OTHR index score could not have been positively affected only in the 2017 studies, or the number of projects awarded and implemented in the 2014-2020 programming period is lower but the impact is more positive. **Five settlements** (Hollókő, Hort, Nagyréde, Rózsaszentmárton, Visonta) **have shown a worse performance in** the OTHR index ranking year after year, regardless of the number of projects awarded and their impact. One reason for this may be that the projects supported have contributed less to increasing the smart efficiency of the settlements. In addition, their own developments not supported by Operational Programmes are missing or do not contribute to the positive performance of the settlement in the smart dimensions, and the location, age composition of the population, education, other socio-economic factors of the settlement may also be behind the negative trend, which can be explored further.

Overall, it can be said that the applications won in the Operational Programmes of both the 2007-2013 and the 2014-2020 programming periods have contributed to increasing the smart efficiency and resilience of settlements, but to a different extent, depending on the impact of the applications implemented on the settlement as a whole. It can be observed that settlements at an advanced level of smartness tend to have more successful applications and a higher OTHR index ranking, while those at an early level of smartness tend to have fewer applications (also due to their size) and the successful applications do not contribute as significantly to increasing the efficiency and resilience of the settlement as in the case of advanced ones.

### 3.5 Results of the online focus group survey

For the primary research, an online focus group survey was conducted using an online questionnaire. From the five groups resulting from the cluster analysis, **four to four settlements** were selected using a random number generator, for a total of twenty (Table 6).

**Table 6 Number of enquiries and completions by cluster of the settlements surveyed**

| Clusters | Settlements | Number of requests | Number of fills | Number of fills per cluster |
|---|---|---|---|---|
| 1 | Budapest | 38 | 1 | **8** |
| | Eger | 6 | 1 | |
| | Gödöllő | 9 | 3 | |
| | Miskolc | 10 | 3 | |
| 2 | Aszód | 5 | 1 | **4** |
| | Gyöngyös | 6 | 1 | |
| | Tokaj | 5 | 1 | |
| | Vác | 8 | 1 | |
| 3 | Budaörs | 4 | 4 | **8** |
| | Hollókő | 2 | 1 | |
| | Szob | 1 | 1 | |
| | Szögliget | 2 | 2 | |
| 4 | Galgahévíz | 1 | 1 | **5** |
| | Nagyréde | 1 | 1 | |
| | Rózsaszentmárton | 1 | 1 | |
| | Sajókeresztúr | 3 | 2 | |
| 5 | Hort | 2 | 1 | **4** |
| | Karancsberény | 1 | 1 | |
| | Sáta | 2 | 1 | |
| | Visonta | 3 | 1 | |
| | | | | |
| | **Összesen:** | **110** | **29** | **29** |

*Source: Author's own editing, 2025*

The survey included the mayors of the settlements and the heads of their larger municipal institutions (nursery schools, schools). Out of a total of 110 requests, **29** were finally **completed.** The results are not representative. The survey sought to identify the most common smart developments in each cluster and their impact on the daily life and development of the settlement, as well as whether, as a result of these developments and their impact, the settlements are open to further developments and, if so, in which areas they intend to implement projects in the future and with what resources.

The survey was based on 20 questions, the results and context of which are set out below. Respondents most frequently gave the terms **safety**, liveable, nature, family, innovative in response to the question of what are the three words that first come to mind about their represented settlement. Most of the terms that emerged were related to some aspect of becoming a smart settlement. Some are elements of one of the smart dimensions (e.g., energy- efficient - smart environment, innovative - smart economy) or others are objectives of social well-being, of becoming a smart settlement (liveable, supportive, safe, dynamic development). This suggests that, in addition to the importance of local values and the link to the settlement (e.g., family, childhood), **there is a demand**, if not yet consciously, for the opportunities offered by smart settlements, and that the smart developments already implemented have **a positive impact on** perceptions of the settlement. I then asked them to compare the three words that first come to mind when they hear the term 'smart city'. **Development** was the most common, followed by future, sustainable, digitalisation, innovation and online in almost equal proportions. The terms **development-development** appear in the answers to both questions, which I believe could be a good starting point for looking at the future of settlements.

I also wanted to know respondents' views on smart growth. Of the 29 respondents, 14, or almost 50%, thought that smart developments are useful but need to be further promoted among the population. This was the response from all three respondents in Gödöllő, but also from Vác and Galgahévíz. Ten of them (e.g., Aszód, Szögliget, Tokaj) considered smart developments to be useful and that a well thought-out development plan can improve the situation of a settlement, while five were more sceptical about the usefulness of smart developments, considering them useful but not providing answers to the main problems of the settlement. However, it is a reassuring sign that none of the respondents thought that smart growth was not useful and a waste of money.

The next question in the survey asked for information on what smart developments have been implemented in settlements so far (Figure 7).

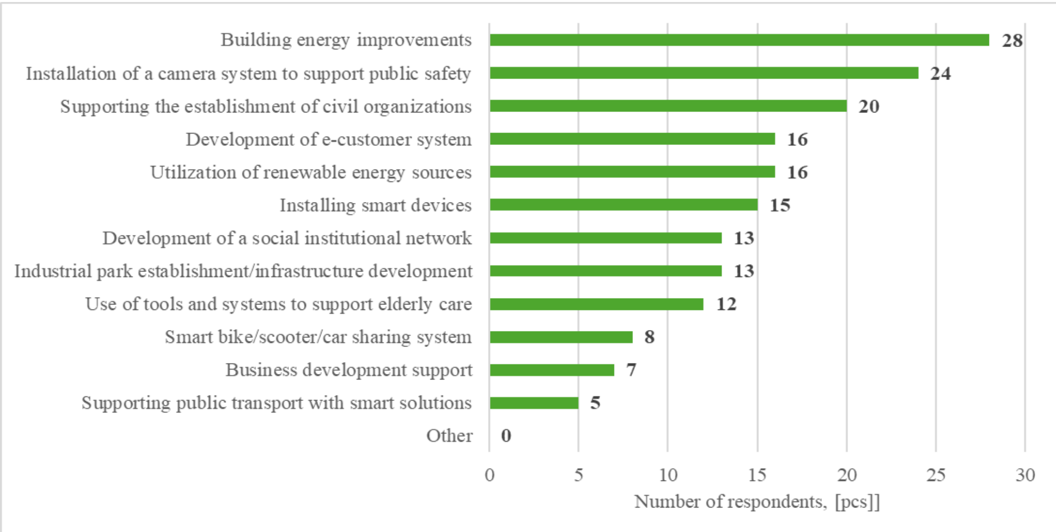


**Figure 7 Smart developments implemented according to respondents' answers**

*Source: Author's own editing, 2025*

Of the 29 respondents, 28 reported that energy efficiency improvements had already been made in their settlement. 24 said that a camera system had been installed to support public safety and 20 said that their settlement had supported the creation of civil society organisations. Around half of the respondents indicated that their settlement had implemented renewable energy or developed an online customer system or installed a smart device in public spaces.

Other smart developments that received more than ten votes include the development/creation of industrial parks, the development of a network of social institutions and the use of tools and systems to support elderly care. The three lowest scores were for the existence of systems to support smart mobility, the development of entrepreneurship and the support for public transport through smart developments. The responses are in line with my findings from the analysis of the Local Development Plans that the most popular smart dimensions are **living conditions, governance, environment** and **mobility**.

Related to the objectives of the focus group survey, I also examined which smart developments are most common for each cluster. For this analysis, I only considered each settlement once. Most of the settlements had a **building energy, public safety** or **NGO development**, and these are the most popular smart developments by cluster.

According to survey respondents, the resulting developments have contributed to the greening of the settlement, easier and faster administration of public affairs, an increase in the cultural programmes of the settlement, a higher population retention rate, improved public safety, the creation of jobs at home and economic recovery (Figure 8).

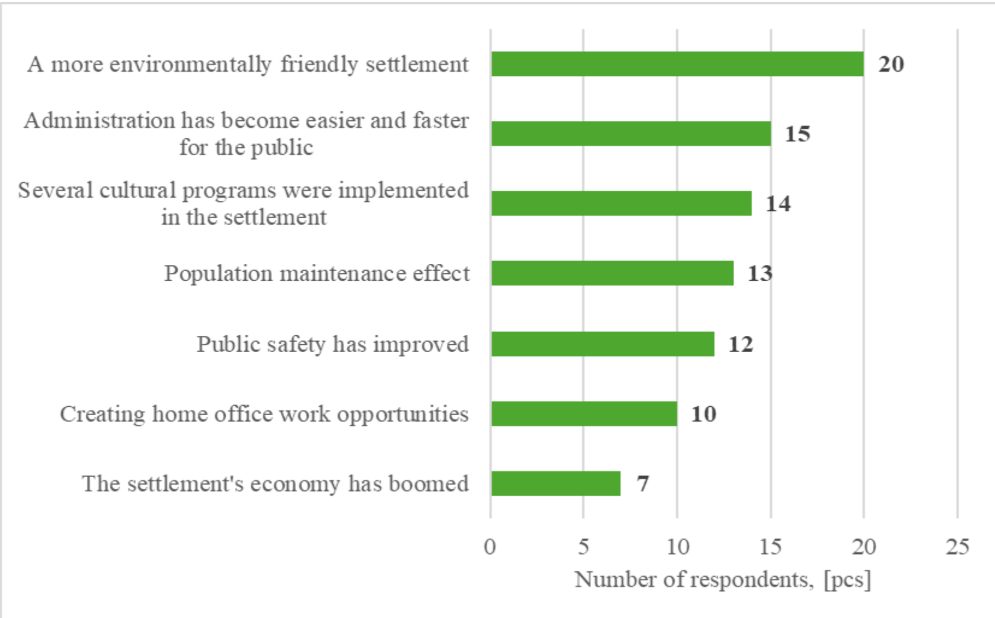


**Figure 8 Impact of implemented developments according to respondents**

*Source: Author's own editing, 2025*

Based on the responses to each of the options, I believe that the responses confirm that smart developments and thus the embodiment of **smart settlements** have a place in the concepts of settlement development and that their **positive impact should be an achievable goal** in the life of settlements.

It is not only the **scarcity** or lack of **financial resources** that can be a problem in implementing various types of development, but often also **the complexity** and bureaucracy of **the project application system** or the reluctance of the population to participate. I therefore asked the representatives of the settlements participating in the research about the obstacles they had encountered in the course of the development projects they had already carried out. The most frequently cited were problems with financing, the complexity of the application system and the high administrative burden. These were followed by the constraints of obtaining appropriate technology and tight implementation timeframes. The attitude of the public is only in one case identified as a barrier to smart upgrading. Vác also highlighted **the specific difficulties of public procurement procedures as** an individual response.

I also asked the representatives of the settlements about their smart development plans for the next 1-3 years. Eleven responses were received that related to energy improvements, including energy modernisation of buildings and modernisation of street lighting. The installation and further expansion of camera networks, smart meters, smart benches, hotspots and smart zebras were prominent among the responses. Several mainly large cities or small towns close to a large city would like to install charging points for electric cars, or electric or environmentally friendly public transport, but there are also some who would like to develop their town by creating an interactive visitor centre or a knowledge-intensive economy. In the environmental dimension, the **development of green spaces** and the **use of renewable energies** were also among the objectives. It is clear from the responses that in most cases, initiatives that are trendy and easily supported by grants continue to be the objective, with only one project that is also intended to strengthen the economy of the settlement in the long term.

My aim was also to investigate the resources that settlements are seeking to use to implement these improvements. Only **Hollókő** intends to implement its plans **using** only **its own resources**, while the other settlements would like to obtain funding through some kind of grant scheme. It can be said that the settlements wish to apply for funding primarily through the **TOP+** and **Hungarian Village Programmes**.

In the case of projects already implemented, funding problems were the main obstacle. As regards future plans, 31% (24%) of respondents again cited **the scarcity of funding** as the most critical implementation factor, 29% (23%) feared that grant applications would be rejected and 17% (13%) were concerned about the complexity and bureaucracy of the application system. 8 settlements are concerned about the lack of technological background, while 7 are worried about the inadequate level of training of workers.

In addition to providing several response options and leaving the possibility to respond individually, I asked the representatives of the settlements what further smart improvements they would suggest to implement (Figure 9).

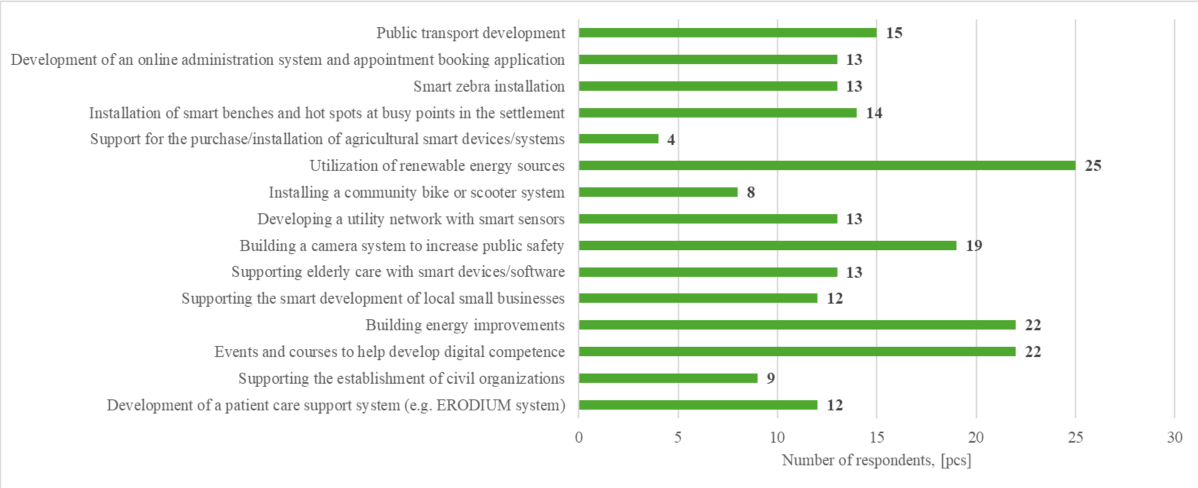


**Figure 9 Smart improvements proposed by respondents**

*Source: Author's own editing, 2025*

The most popular of the proposed smart developments were the **use of renewable energy sources**, events to promote digital literacy, building energy improvements and the installation of a camera system to improve public safety, with around two thirds of the municipal representatives (e.g., Tokaj or Gödöllő) wanting to see such investments in their settlement. For example, the improvement of patient care systems, the improvement of public transport, but also the promotion of smart local small business development to stimulate the economy, received between 12 and 15 votes. Eight settlements (e.g., Sajókeresztúr, Budaörs, Szob) felt that the installation of a community bike or scooter sharing system in their settlement would be necessary in the future, and nine settlements felt that support for civil society organisations was necessary. Due to the location and nature of the settlements, only **four settlements** (e.g., Gyöngyös or Nagyréde) intend to make smart developments to support and stimulate **agriculture in** the future.

Based on the answers to the previous question and this one, I believe that the settlements are open to smart developments, and that there is an increasing number of initiatives aimed at real development and 'smarting', such as the development of digital competence, smart development of the public utility network, the installation of bicycle or scooter sharing systems, which could even increase interoperability between settlements, reducing emissions.

The high proportion of elderly people, especially in rural, peripheral areas, raises the question of the extent to which this is a barrier to smart development. According to the mayors and managers interviewed, **the population**, particularly the over-50s, is more **open to innovation** than not, but there are always those who are completely closed to it. However, several of them stressed that, despite the initial reluctance and refusal, once the works are completed, the citizens of the settlement become interested, learn and get used to the new things. The importance of digital education for the older age groups also appears in several responses, and in connection with this, the previous figure shows that increasing the digital skills of the different age groups also appears as a future development goal.

Based on the online focus group survey, it can be said that the smart developments already implemented in the settlements participating in the research mainly concern the dimensions of smart environment, smart mobility, smart governance and smart living conditions. Most of them contribute to the creation of a **rudimentary** level of ‘smartness’. A high proportion of citizens in the settlements are open to innovations, initially reluctant to take part, but becoming interested as the projects come to an end. The main obstacles to the implementation of smart innovations are the issue of **funding**, the complexity and bureaucracy of the application system and the rejection of applications for funding. Most settlements are not able to achieve their smart growth objectives on their own, and mainly seek funding through the Széchényi Plan Plus Operational Programmes. It is therefore clear that the settlements participating in the research are keen to **pursue further smart developments** and that there is an increasing focus on real 'smart' developments.

### 3.6 Presentation of the empirical case studies

In the case of Gödöllő, Miskolc and Szögliget, the settlements participating in the primary research, I have prepared empirical case studies to support the theoretical research from a practical point of view. In the case study I explore and demonstrate the practical benefits of the smart developments that have been implemented. The settlements were selected on the basis of personal motivation, as I have family ties to Gödöllő and Miskolc and Szögliget, and I believe that all three settlements are good examples for their surroundings and for more distant settlements. The case study of Gödöllő is presented in detail in the thesis booklet, while the case studies of Miskolc and Szögliget are presented in subsection 5.6 of the dissertation.

**Gödöllő** is located in Pest county, part of the Budapest agglomeration, and is about 40 minutes by car from the capital's downtown area (Figure 10). However, the congestion caused by heavy road traffic and the need to upgrade the roads are negative factors in the life of the town. However, the electric scooter sharing system in Gödöllő offers an alternative to reduce road traffic and to choose a more environmentally friendly mode of transport, which is linked to both the smart mobility and the environment dimensions. The scooters can be rented and paid for via a mobile phone application in designated parking spaces. The service can be used on a per-minute basis or by renting a scooter. It has the advantage of reducing road traffic and emissions and is often faster than public transport. The disadvantage is that users often park their scooters in parking spaces other than those designated and, if not used with due care and respecting the rules, they can be dangerous. The e-roller system was launched about a year ago in Gödöllő, so its promotion is still ongoing.

The city also boasts another smart mobility development, the smart zebra, of which there are currently six in Gödöllő. The principle of the Safecross Smart Zebra system is as follows: posts are placed on the two sides of the road, sensors in them detect when a pedestrian passes and activate a sensor which sends a signal to the active LED lights in the pavement via a control unit, which flash to warn drivers to stop. This signal lasts only as long as the pedestrian is crossing the roadway. This means that the signal only comes into operation when it is really necessary. The purpose of the system is to ensure that drivers expect to see a pedestrian crossing when the LED is flashing and must stop.

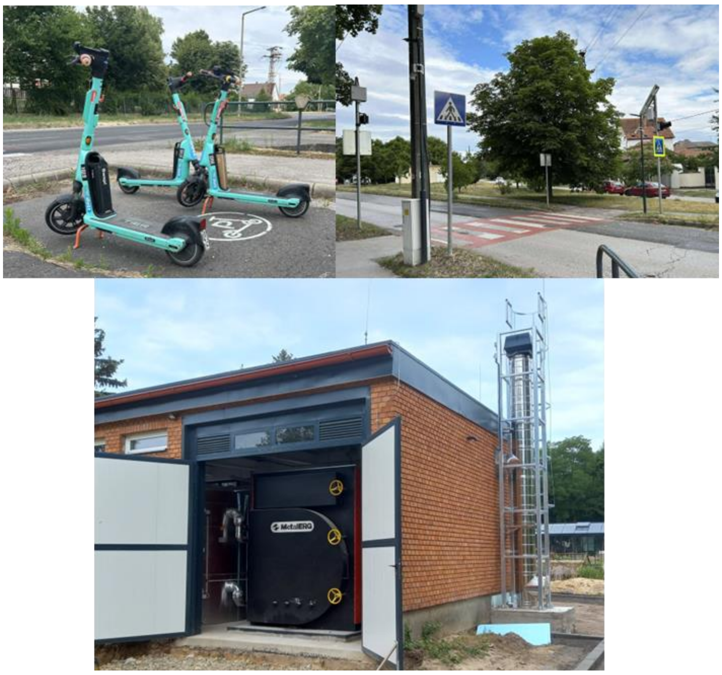

**Figure 10 Examples of smart developments in the city of Gödöllő**

*Source: Author's own photos, 2025*

One of the strengths of the city of Gödöllő is the high quality and unique training offer of the Hungarian University of Agricultural and Life Sciences, which contributes to the increase of the number of highly qualified professionals in the settlement. It is also involved in promoting smart solutions for the settlement, for example by carrying out projects such as the construction of a biomass heating plant to support the environmentally friendly heating of the institution. The heating plant uses local renewable energy sources thanks to the straw bales available in its training plant. The technology has been developed specifically for this raw material, which can be used under optimal conditions with a heat recovery efficiency of 85% thanks to automated control.

The city has further climate and energy-conscious developments and smart initiatives in the areas of smart dimensions, such as green space improvements, modernisation of education, development of digital competences. I believe that Gödöllő can serve as an example for smaller settlements to follow, even with these few examples, to take the first steps on the road to becoming smart.

Overall, I am convinced that the settlements and towns included in the research are well on the way to becoming smart settlements, but in many cases, especially in small settlements, this requires the development of an appropriate development strategy, and the state has a significant role to play in ensuring that the feasibility of these developments is not hampered by funding problems.

## 4. CONCLUSIONS AND RECOMMENDATIONS

**H1:** My research has refuted the idea that settlements in the Budapest agglomeration area are less resilient socially, economically and environmentally than settlements near other large cities, because the capital's pull effect is more powerful than its pull effect.

For the year 2012, the map representation (Figure 30 of the dissertation) shows that several settlements on the southern border of Budapest are part of the ‘backward’ cluster group, similar to other larger urban agglomerations. However, there are a higher number of ‘developing’ and ‘stagnating’ settlements in the Budapest agglomeration area than in the agglomeration of Eger or Miskolc, suggesting that the capital city does not attract a higher share of resources based on the values obtained in the study. Furthermore, the Budapest agglomeration has higher OTHR values in the study years 2017 and 2022 (Figures 31 and 32 of the dissertation) and thus higher resilience than other settlements in the agglomeration of larger cities such as Eger or Miskolc.

For the agglomerations, I have checked the change in their OTHR index by 2022 compared to 2012 by using a standard deviation calculation. I have taken as a basis the lists of agglomeration settlements currently in force. Out of 115 settlements in the Budapest agglomeration, only 24 settlements had no increase in their OTHR index, including Piliscsaba, Maglód, Szigethalom and Visegrád. The standard deviation of the OTHR index values was 16.97 in 2012, 17.83 in 2017 and 19.37 in 2022.

Out of 19 settlements in the Eger agglomeration, 6 settlements failed to improve their values, such as Szarvaskő, Noszvaj and Hevesaranyos. The standard deviation of the OTHR index values was 18.40 in 2012, 20.98 in 2017 and 29.10 in 2022. The standard deviation values show that the OTHR index values of the settlements increased significantly over the study years.

In the case of the Miskolc agglomeration, 14 out of 41 settlements stagnated or decreased in 2022 compared to 2012. These include Boldva, Hernádkak and Onga. Nevertheless, the standard deviation values show an increase, with 14.10 in 2012, 16.88 in 2017 and 17.78 in 2022.

I have also examined the evolution of the standard deviations in the case of the Salgótarján metropolitan agglomeration, where out of 13 settlements, only 2 settlements, namely Salgótarján and Vizslás, improved their OTHR index values, while 11 did not. The only exception is that the standard deviation decreased in 2017 compared to 2012: 12.41 in 2012, 10.30 in 2017 and 14.38 in 2022. The results further confirm the disadvantaged situation of the Salgótarján region.

It can therefore be concluded that the settlements in the Budapest agglomeration have developed over time, their OTHR index has increased, the capital does not attract the necessary resources to create resilience to a greater extent than other larger cities.

I propose targeted smart development support for the agglomeration areas of larger cities such as Eger, Miskolc or Salgótarján (e.g. by modernising public transport between the cities, supporting the creation and smart development of local businesses (e.g. digitalisation), modernising public schools in the agglomeration in terms of energy and digitalisation, housing subsidies to encourage people to move from the central settlement to the agglomeration, etc.), which would not only reduce the burden on the central settlement (e.g. congestion, difficulties in ensuring equal provision of services), but would also create a stronger agglomeration area in socio-economic and environmental terms. I also recommend that settlements with a lower OTHR index should examine the possibility of adapting the smart developments of settlements with a higher ranking in the settlements ranking and implementing them in a way that is adapted to local conditions, with the involvement of experts.

**H2:** My research did not confirm my hypothesis that the OTHR index of the settlements shows a permanent decrease as they approach the Hungarian-Slovak border due to the peripheral character of the settlements.

For all three survey years, there are several settlements with a high OTHR index along the border. Among the border settlements of Pest county, Perőcsény, Tésa, Balassagyarmat, Salgótarján or Szécsény in the case of Nógrád county, and Jósvafő, Mikóháza, Sátoraljaújhely, Sárospatak in the case of Borsod-Abaúj-Zemplén county. These settlements had higher values in 2012, 2017 and 2022 than the worst performing cluster of small and large towns and villages. The majority of settlements with a positive OTHR value have cross-border international cooperation, while for those with a negative value this is less frequent in the period under study. I therefore conclude that active international relations increase social and economic efficiency. Nowadays, there are already positive projects for settlements with a negative index value, for example, in the settlement of Cered in Nógrád county, a bus service will be launched from March 2025 between the settlements of Salgótarján, Rimaszombat and Losonc, which will provide an opportunity for the settlement to catch up.

I therefore propose that the border settlements establish international links and implement projects that will benefit both sides of the border in terms of interregional projects. Such an initiative could be the implementation of a multi-municipal public transport system, as in Cered , or the German Grieth ‘region taxi’ (see section 3.7.1), which could increase the mobility of the population, thus making it easier for them to find work or earn a higher income, or a jointly run post office or shop, which could contribute to an increase in living standards, efficiency and resilience. I would also recommend that development policy makers increase funding for these peripheral, disadvantaged settlements and set up a consultancy system whereby the leaders of the settlements, together with experts and the population, can identify the smart developments that are most beneficial to the development of the settlement/region.

**H3:** My third hypothesis was not confirmed, as the cities with a population of more than 20,000 inhabitants (Budaörs, Budapest, Cegléd, Dunaharaszti, Dunakeszi, Eger, Érd, Gödöllő, Gyál, Gyöngyös, Hatvan, Kazincbarcika, Miskolc, Nagykőrös, Ózd, Salgótarján, Szentendre, Szigetszentmiklós, Vác, Vecsés) are not in one cluster but in several clusters according to the results of the OTHR index.

It can therefore be concluded that the efficiency and resilience of smart cities are not at the same level. In 2012, the settlements are divided into five clusters (developed, developing, stagnating, lagging), in 2017 into four clusters (developed, developing and stagnating) and in 2022 into three clusters (developed, developing and stagnating). The results show an increasing trend in their index values.

The output of the Spearman test suggests that the evolution of the OTHR index value is not significantly influenced by the population size, but it is influenced by the differences in the values of the indicators in each dimension.

On the basis of the 2022 data, I suggest that the settlements in the third, 'stagnating' cluster (Budaörs, Cegléd, Dunaharaszti, Dunakeszi, Érd, Gyál, Szigetszentmiklós, Vecsés) should rethink their urban development plans, possibly restructuring them, in the direction of more smart development, even pilot projects (e.g., smart pilot district). The pilot projects that have been implemented could thus serve as a model for similar settlements in the country. Monitoring would provide researchers with a useful source of data on the effectiveness of smart cities, thus helping future strategic planning and decision-making, as well as the identification of further development directions.

**H4:** My fourth hypothesis is that in the smart developments of the villages included in the online focus group survey, projects related to digitalisation are the most prominent (smart benches, deployment of camera systems, installation of wi-fi hotspot stations, e- government), with less emphasis on developments that support mobility, environment, economic recovery, social well-being (such as electric bicycle or scooter rental, vehicle sharing or village taxi, smart communities such as shared governance, devices and applications for elderly and sick care or the installation of systems to support agriculture, energy modernisation and optimisation of energy use), which could be a real solution for catching up rural areas. I partially accept this hypothesis.

Looking at the smart developments already implemented in the surveyed villages (Figure 42 of the dissertation), I found that digitisation-related projects are present in almost all settlements, with the installation of smart benches and camera systems to improve public safety at the forefront, but with a nearly equal share of projects supporting the environment and social cohesion. These include energy efficiency improvements in buildings, the use of renewable energies, especially solar energy, the creation and development of various NGOs and the use of systems to support elderly care. In my opinion, the initiatives taken by the settlements are forward-looking and could have a positive impact in the long term, but in most cases they are still very rudimentary and less well thought through. As a result, the methodology of development is often based on what is available for funding or what is already being developed in neighbouring settlements, because it is needed by the settlement that does not yet have that development.

I therefore recommend that the settlements participating in the study that do not yet have a smart development concept should develop a real strategy to support openness to digitalisation, which would contribute to socio-economic and environmental development and catching up, thus providing targeted support for lagging regions.

**H5:** My fifth hypothesis, that the settlements in economically and socially backward regions are lagging behind in development support, was partially confirmed in my research, because the people living there are often low-skilled and thus lack the knowledge to adapt to the use of new technologies, and the age composition of society is also unfavourable.

I have examined the last ten settlements in the OTHR index ranking to verify this hypothesis. I found that most settlements have a low population, for example, Becskeháza has only 30 inhabitants. Education levels are also low, with a maximum of 8th grade primary education, with a high school graduation rate of 10% and a diploma rate of 2% in these settlements. Their digital literacy is also low, the older age group is not engaged in digital activities, and young people have only basic skills, limited to social media use and basic operations (e.g., creating a folder). The age composition of the society shows a positive change, i.e., a more favourable ageing index, where the settlement has a high proportion of Roma minority. In addition, all but four settlements in the 2007-2013 and 2014-2020 programming periods - Beret, Csenyéte, Gagybátor and Kiscsécs, where no funding was found in any of the years - have at least one winning application. On this basis, I can partially accept my fifth hypothesis, since the high proportion of the Roma minority means that the age composition is favourable, but the educational level and digital skills of the population are low, which are a barrier to development.

I propose to educate the population of these disadvantaged settlements in general and digital skills, for example by holding workshops where participants can improve their knowledge not only in theory but also in practice, and to launch a motivation programme to encourage young people to not only complete basic education but also to acquire at least one profession, with preference for manual labour-intensive sectors. This would provide the labour market with more skilled young people who, once in work, would reduce the burden on the social care system and contribute to the reduction of the disadvantaged population.

(Incentive scheme: if they are successful in their studies (above C average), learn a trade and pass an exam, they will be helped to find a job and housing, under strict conditions.)

**H6:** In my hypothesis, I argued that among the settlements in Borsod-Abaúj-Zemplén county, the economically developed industrial towns do not have a high OTHR index due to the negative impact of selected environmental indicators.

I can partially accept this hypothesis, because among the four industrial cities (Miskolc, Kazincbarcika, Ózd, Tiszaújváros), Miskolc is included in the cluster group of 'developed' settlements based on their OTHR indices, the other three industrial cities belong to the 'developing' cluster in all three study years. Miskolc is therefore in the cluster with the highest OTHR index. However, I have also found that the negative trend in the OTHR index is not due to the environmental indicator, as the settlements in the hypothesis test performed best in the environmental dimension out of the six smart and resilient dimensions. Presumably this is because they pay more attention to the elimination of environmental damage due to their industrial past. Miskolc, Kazincbarcika and Tiszaújváros had the weakest overall performance in the governance dimension, while Ózd had the weakest overall performance in the people dimension.

In the case of Miskolc, Kazincbarcika and Tiszaújváros, since the last year of the study in 2022, several developments have been made or started to be made to increase efficiency and resilience (e.g.: in Miskolc, the purchase of new electric BYD buses, from April 2025 Miskolc will be the sample city of artificial intelligence, in Kazincbarcika the tourist and smart development of Csónakázó lake, in Tiszaújváros the development of an energy efficient and green strategy, etc.), in the case of Ózd, I propose the creation of job-creating businesses linked to the people dimension, exploiting local assets such as the natural opportunities (Bükk Mountains, the 'city of seven valleys') or the industrial past, and the proximity of the Slovak-Hungarian border, in cooperation with the surrounding settlements (e.g., Uppony), which offers the possibility of creating a cross-border smart area.

**H7:** On the basis of my findings, I partially reject my seventh hypothesis that the location of settlements in the county is closely correlated with the OTHR index of the settlements, assuming that the West-East spatial inequality effect is also present in the study area, so that the values show a steady downward trend away from Budapest.

Based on the OTHR index values, the West-East spatial inequality effect cannot be clarified on the basis of their distance/location from Budapest, because the results of the individual settlements do not show a West-East decrease, but positive and negative density points are observed within the county, a kind of spatial inequality effect (Figures 28-29 of the dissertation), which is confirmed by the results of the Local Moran I autocorrelation test.

The negative density points always point in the direction of segregated settlements or settlements and districts classified as disadvantaged; therefore, I propose the complex development of these settlements, in which, in addition to economic stimulus investments, it is essential to increase the educational level of the population. The leaders of these settlements can use the smart development projects of neighbouring settlements with a higher OTHR index as a basis for studying and adapting them, and for defining and implementing common development goals. Development ideas: improving public transport with larger cities to support/ensure easier access to work or better education; creating schools where children's cognitive skills can be developed and digital skills of several generations can be developed; creating tourist areas based on local assets by bringing together three or four settlements (e.g., Szécsény-Nagylóc-Rimóc guided tour, with visits to the Forgách castle in Szécsény, the Doll Museum in Rimóc, the water reservoir in Nagylóc, and the possibility of paragliding on Szél Hill, in addition to the lookout).

**H8:** I reject my eighth hypothesis that, in the settlements surveyed in the focus group survey, the effectiveness of smart developments has been increasing over the programming period up to the present day, as can be seen in the development of the OTHR indices.

My analysis shows that, of the 20 settlements analysed, eight clearly show that the tenders awarded during the programming periods have contributed to the upward trend in their smart efficiency and resilience, as reflected in their ranking on the basis of their OTHR index. In addition, I have identified seven settlements that have shown a positive shift in their OTHR ranking in 2017 or 2022. Where there has been an improvement in the ranking from 2012 to 2017, it can be seen that the settlements had more successful applications in the 2007-2013 programming period than in the Széchenyi 2020 programme. In other words, the larger number of projects may have resulted in more projects that actually act as efficiency enhancers for the settlements. The only exception to this is Galgahévíz, but here I assume that the improvements implemented up to 2017 had a greater efficiency-enhancing effect. For Szob and Szögliget, there was a positive shift in the ranking from 2017 to 2022, but the number of applications won in the 2014-2020 period is lower than in the previous programming period. There are two possible explanations, either the winning applications were not implemented until 2012 and therefore could not have had a positive impact on the OTHR index score until the 2017 studies, or the number of projects awarded and implemented in the 2014-2020 programming period is lower but the impact is more positive. Five settlements in the OTHR index ranking, irrespective of the number of projects awarded, have performed worse year on year. As there were settlements that only moved up in the OTHR ranking in one of the years of the study and others that continued to show a downward trend despite having received grants, my claim that the effectiveness of smart growth has been increasing over the programming period up to the present day, as measured by the OTHR index, is not confirmed.

Here again, I can only conclude that a well thought-out and real smart development strategy is necessary for settlements, because without it, the smart developments implemented with the aid received cannot make a sufficient contribution to increasing efficiency and resilience.

I therefore propose that a smart development concept be drawn up, based on the smart development plans of settlements with a high OTHR index, and that existing strategies be rethought with the involvement of specialist companies and experts. After all, all digital development is futile if it does not include people. The focus of development policy should be on the implementation of smart developments adapted to local conditions, and the measurement of their effectiveness should also be carried out, using the data collected to support the future development of the local community and other communities, as well as the effective work of researchers.

The results of this dissertation provide an opportunity for future research. I therefore propose, among others, to study the Eger-Miskolc congestion point and the settlements along the M3 motorway route from recent data (2023-2024). I also believe that it would be worthwhile to examine the efficiency and resilience of the whole country using the Smart Efficiency and Resilience Index, establishing a ranking of the country's settlements, thus identifying future regional development priorities.

# 5. NEW SCIENTIFIC FINDINGS

**E1**: Based on and summarising previous concepts of researchers on the subject, I have developed **a definition of a smart and resilient settlement**: a smart and resilient settlement is a settlement that uses smart tools and technological advances, takes into account local assets and seeks to use them to the benefit of the settlement, participates in decision-making with its citizens, and aims to continuously improve knowledge and skills. Due to the tools used, the development of knowledge and cooperation, the settlement is able to prepare for global challenges and shocks, to withstand them without major economic, environmental or social damage, and to return to or even become more resilient once the shock has passed.

This scientific result contributes to the body of theoretical knowledge by summarising in a single definition the findings specific to smart and resilient settlements (cities and villages), rather than interpreting existing concepts (smart city, smart village, resilient city) separately.

**E2**: The six smart dimensions of Giffinger et al. (2007) and Sebestyénné Szép et al. (2020), Hegedűs (2020), Suárez et al. (2016) and Banica - Muntele (2017), I have created my own **Smart Settlement Efficiency and Resilience Index** using data and indicators from the Lechner Knowledge Centre, TeIR and the KSH, **to measure** the efficiency and resilience of smart settlements to shocks, the details of which are presented in the earlier chapters of this thesis. In previous research, they have been measured only separately by the researchers working on the topic, so based on the overlap of their indicator systems, I saw the need to create a statistically computable, aggregated index that would contribute to the extension of the methodology on the topic. Using the Smart Settlement Efficiency and Resilience Index, I have calculated the index values of the 798 settlements included in the study and, based on this, I have established **a ranking of settlements** for the study years 2012, 2017 and 2022, which results will help to identify development policy directions in the settlements of the studied counties. Moreover, the index is suitable for the construction of a national ranking, thus supporting the possibility of eliminating disadvantaged areas.

**E3**: Based on the results of several procedures, a cluster analysis using Ward's method was carried out, in which the settlements forming the study sample were divided into **five groups reflecting the levels of development.** The first cluster is named ‘developed’, the second ‘developing’, the third ‘stagnating’, the fourth ‘lagging’ and the last one ‘lagged behind’ according to the evolution of their OTHR index values. The ranking of settlements in clusters can serve as a reflection for municipal leaders on the improvements made so far and can help them to make decisions on future developments. The findings are empirically based.

**E4**: Using the ranking of settlements based on the OTHR index, I have found that there is no West-East spatial inequality effect in the study area as a whole, but that **spatial differentials in different directions can be observed across the counties**. In the case of Pest county, a north-west-south-east spatial inequality effect, in the case of Nógrád a West-East spatial inequality effect, in the case of Heves a north-south spatial inequality effect, while in the case of Borsod county a South-West-North-East spatial inequality effect can be identified.

The scientific result falls within the scope of empirical observations. The positive and negative density points detected provide information on the success or failure of development efforts to date, and help to identify effective regions as role models and to target development support for disadvantaged regions.

**E5**: Based on the results of the primary analysis, I have found that most smart initiatives mainly address the dimensions of **smart environment, smart mobility, smart governance** and **smart living conditions**, most of them contributing to the achievement of early smart growth. They are mainly related to energy and digitalisation areas (e.g., solar panels, smart devices).

This new empirical result gives experts an idea of the infancy of smart developments in Hungary and will help future smart concepts to include more initiatives that contribute not only to the initial smartness but also to the realisation of real smart settlements or areas.

**E6**: The grants awarded in the programming periods under review **have contributed to** increasing the smart efficiency and resilience of settlements. However, the improvements resulting from the applications awarded to settlements at the initial 'smart' level do not contribute as significantly to increasing the efficiency and resilience of the settlement as in the case of the more advanced ones.

The empirically based finding is a guideline for development policy, highlighting the need to strengthen the application possibilities for grants for the initial 'smart' settlements, which focus on real 'smarting'.

# 6. LIST OF PUBLICATIONS

6.1 Scientific articles – in a foreign journal in a foreign language

1. GREUTTER-GREGUS, É. - KONCZ, G. - NÉMEDI-KOLLÁR, K. (2024): Resource efficiency and the role of renewable energy in Miskolc: the city's journey towards becoming a smart city. Energies 17 : 21 Paper: 5498 (2024)

2. SZIRA, Z. - GREUTTER-GREGUS, É. - GREUTTER, Z. - VARGA, E. (2024): Regulation of precision farming in EU countries. EU Agrarian Law: The Journal Of Slovak University Of Agriculture In Nitra / Agrárne Právo Eú 13 : 2 pp. 10-16. , 7 p. (2024)

6.2 Scientific articles – in a national journal in a foreign language

3. GREUTTER-GREGUS, É. - GREUTTER, Z. (2024): The connection between the smart city concept and human resource management, with a special focus on the role of competences and corporate competitiveness. Studia Mundi - Economica, 11(1), 55–67.

4. GREUTTER, Z. - GREUTTER-GREGUS, É. - SZIRA, Z. - VARGA, E. (2024): The impact of the COVID-19 pandemic on the work-life balance of employees. Regional and Business Studies, 16(1), 5–13.

6.3 Scientific articles – in a national journal in Hungarian

5. GREUTTER-GREGUS, É. - KONCZ, G. - NÉMEDINÉ, K. K. (2024): Okos települések fogalmi áttekintése és hatékonyságuk mérésének lehetőségei (Conceptual overview of smart cities and ways to measure their effectiveness). A FALU, 39(1), 5–25.

6. GREUTTER-GREGUS, É. - KONCZ, G. - NÉMEDINÉ, K. K. (2023): A magyar vármegyeszékhelyek rezilienciájának vizsgálata a koronavírusjárvány tekintetében (Examining the resilience of Hungarian county seats in relation to the coronavirus pandemic). Studia Mundi - Economica, 10(3), 46–57.

7. GREUTTER-GREGUS, É. (2023): Környezeti index és Környezeti Városi Reziliencia Index értékeinek számítása négy Szabolcs-Szatmár-Bereg megyei és négy Győr-Moson-Sopron megyei település esetében (Calculation of environmental index and environmental urban resilience index values for four settlements in Szabolcs-Szatmár-Bereg county and four settlements in Győr-Moson-Sopron county). International Journal of Engineering and Management Sciences / Műszaki és Menedzsment Tudományi Közlemények, 7(4), 17–29.

8. GREUTTER, Z. G. - GREUTTER-GREGUS, É. - SZIRA, Z. - VARGA, E. (2023): Fókuszban az alkalmazotti jóllét: lisztérzékeny munkavállalók életminőségének vizsgálata (Focus on employee well-being: examining the quality of life of employees with celiac disease). Studia Mundi - Economica, 10(3), 58–67.

9. GREUTTER, Z. - GREUTTER-GREGUS, É. - HAJDÚ, D. (2022): Szakmai képzéseken résztvevő nappali tagozatos tanulók jövőbeni tervei Borsod-Abaúj-Zemplén megyében (Future plans of full-time students participating in vocational training in Borsod-Abaúj-Zemplén county). Észak-Magyarországi Stratégiai Füzetek, 19(1), 58–65.

6.4 Conference publications in a journal or proceedings in a foreign language

10. GREUTTER, Z. – VAFNÓCZKI, A. – GREUTTER-GREGUS, É. – SZIRA, Z. – VARGA, E. (2024): Sustainable labour market in a circular economy? Examining the migration motivation of welding students in Hungary. In European Policies and Efficient Public Administration - Current Issues and Challenges. Reviewed Proceedings of Scientific Papers and Abstracts from the 8th Annual International Scientific Conference (pp. 1–8).

11. HAJDÚ, D. - GREUTTER, Z. - GREUTTER-GREGUS, É. (2022): Future plans of students in Borsod-Abaúj-Zemplén county with the vocational qualification studied. In XVIII. Nemzetközi Tudományos Napok [18th International Scientific Days] : A „Zöld Megállapodás" – Kihívások és lehetőségek [The 'Green Deal' – Challenges and Opportunities] : Tanulmányok [Publikcations]. (pp. 286–291).

6.5 Conference publications in a journal or proceedings in Hungarian

12. GREUTTER-GREGUS, É. (2022a): A Város Rugalmassági Index (CRI) környezeti dimenziójának elemzése a Borsod-Abaúj-Zemplén megyei városok esetében (Analysis of the environmental dimension of the City Resilience Index (CRI) in the case of cities in Borsod-Abaúj-Zemplén county). Hantos Periodika, 3(2), 26–42.

13. GREUTTER-GREGUS, É. (2022b): Okos városok környezeti, gazdasági és életminőség dimenziójának vizsgálata Borsod-Abaúj-Zemplén megyében (Examining the environmental, economic and quality of life dimensions of smart cities in Borsod-Abaúj-Zemplén county). In Doktoranduszok Fóruma, Miskolc, 2020. november 19. (pp. 87–96).

6.6 Abstracts

14. KONCZ, G. – GREUTTER-GREGUS, É. – NÉMEDINÉ KOLLÁR, K. (2025): Examples of renewable energy developments in european and hungarian smart villages. In: Koponicsné Györke, Diána; Szabó, Rozália; Barna, Róbert (szerk.) Sustainability and Resilience International Scientific Conference (SRISC) : Book of Abstracts Gödöllő, Magyarország : Hungarian University of Agriculture and Life Sciences (2025) 212 p. p. 52

15. GREUTTER-GREGUS, É. - GREUTTER, Z. G. (2024a): Migrációs kihívások a magyar munkaerőpiacon = migration challenges on the hungarian labour market. In: Bujdosó, Zoltán (szerk.) Egységet – Cselekvést – Teljesítést = Unit. Act. Deliver: XIX. Nemzetközi Tudományos Napok = 19th International Scientific Days: Előadások és poszterek összefoglalói = Summaries of presentations and posters Gyöngyös, Magyarország: Magyar Agrár- és Élettudományi Egyetem Károly Róbert Campus (2024) 105 p. pp. 36-36., 1 p.

16. GREUTTER-GREGUS, É. - GREUTTER, Z. G. (2024b): Okos város, okos hr menedzsment – öt európai főváros okos emberek dimenziójának vizsgálata = smart city, smart hr management – investigation of smart people dimensions in five european capital cities. In: Bujdosó, Zoltán (szerk.) Egységet – Cselekvést – Teljesítést = Unit. Act. Deliver: XIX. Nemzetközi Tudományos Napok = 19th International Scientific Days: Előadások és poszterek összefoglalói = Summaries of presentations and posters Gyöngyös, Magyarorszá: Magyar Agrár- és Élettudományi Egyetem Károly Róbert Campus (2024) 105 p. pp. 37-37., 1 p.

17. GREUTTER-GREGUS, É. - NÉMEDINÉ, K. K. - KONCZ, G. (2023): Coronavirus epidemic – did the resilience of the Hungarian county seats change to the impact of the

epidemic? In: Bujdosó, Zoltán (szerk.) A tudomány világa: A MATE Károly Róbert Campusán megrendezett 2023. évi workshop előadásainak összefoglalói Gyöngyös, Magyarország: Magyar Agrár- és Élettudományi Egyetem Károly Róbert Campus (2023) 74 p. pp. 33-33., 1 p.

18. NÉMEDINÉ, K. K. - GREUTTER-GREGUS, É. - KONCZ, G. (2023): A fenntartható városfejlesztés és reziliencia alapvető összefüggéseinek vizsgálata 2020 után. In: Bujdosó, Zoltán (szerk.) A tudomány világa: A MATE Károly Róbert Campusán megrendezett 2023. évi workshop előadásainak összefoglalói Gyöngyös, Magyarország: Magyar Agrár- és Élettudományi Egyetem Károly Róbert Campus (2023) 74 p. p. 47

19. GREUTTER-GREGUS, É. (2021): Okos városok környezeti dimenziójának vizsgálata. In: Czeglédy, Tamás; Hoschek, Mónika; Koloszár, László (szerk.) 35. Országos Tudományos Diákköri Konferencia Közgazdaságtudományi Szekció 2021. április 22–24.: Rezümékötet Sopron, Magyarország: Soproni Egyetemi Kiadó (2021) 638 p. pp. 386-386., 1 p.

6.7 Further scientific publications

20. GREUTTER, Z. – VAFNÓCZKI, A. – GREUTTER-GREGUS, É. – SZIRA, Z. – VARGA, E. (2024): How to make current labour market conditions sustainable to prevent labour migration?

21. GREUTTER-GREGUS, É. (2021a). Okos városok környezeti, gazdasági és életminőség dimenziójának vizsgálata Borsod-Abaúj-Zemplén megyében. Diáktudomány: A Miskolci Egyetem Tudományos Diákköri Munkáiból (Examination of the environmental, economic and quality of life dimensions of smart cities in Borsod-Abaúj-Zemplén county. Student science: From the Scientific Student Conference Works of the University of Miskolc), 15, 161–167.

22. GREUTTER-GREGUS, É. (2021b). Okos városok környezeti, gazdasági és életminőség dimenziójának vizsgálata Borsod-Abaúj-Zemplén megyében (Examining the environmental, economic and quality of life dimensions of smart cities in Borsod-Abaúj-Zemplén county). Hantos Periodika, 1(1), 5–17.

23. GREUTTER-GREGUS, É. (2020). Okos városok környezeti dimenziójának vizsgálata (Examining the environmental dimension of smart cities). Hantos Periodika, 2020(1), 22–41.

Of the 29 scientific publications in the Hungarian Scientific Works Collection, 23 belong to the field of economics while 6 publications belong to the field of earth sciences. Only my scientific publications belonging to the field of economics are included in the publication list.

| Publication types | Count | | Citation[1] | |
|---|---|---|---|---|
| | All | Detailed | Independent | All |
| **I. Scientific journal articles** | 11 | | | |
| in international journal in foreign language | | 2 | 0 | 0 |
| in international journal in hungarian | | 0 | 0 | 0 |
| in hungarian journal in foreign language | | 3 | 1 | 1 |
| in hungarian journal in hungarian | | 6 | 1 | 2 |
| **II. Books** | 0 | | | |
| a) Book as author | 0 | | | |
| in foreign language | | 0 | 0 | 0 |
| in hungarian | | 0 | 0 | 0 |
| b) Book as editor[2] | 0 | | | |
| in foreign language | | 0 | | |
| in hungarian | | 0 | | |
| **III. Book chapter** | 0 | | | |
| in foreign language | | 0 | 0 | 0 |
| in hungarian | | 0 | 0 | 0 |
| **IV. Conference in journal or conference paper** | 5 | | | |
| in foreign language | | 3 | 1 | 3 |
| in hungarian | | 2 | 0 | 0 |
| **Publications (I-IV.)** | 16 | | 3 | 6 |
| **Abstract[3]** | 8 | | 0 | 0 |
| **Research data** | 0 | | 0 | 0 |
| **Other scientific works[4]** | 5 | | 0 | 0 |
| **All scientific publications** | 29 | | 3 | 6 |
| **Hirsch index[5]** | | | 1 | 1 |
| **Educational publications** | 0 | | | |
| Higher educational works | 0 | | | |
| Book in foreign language | | 0 | 0 | 0 |
| Book in hungarian | | 0 | 0 | 0 |
| Book chapter in foreign language | | 0 | 0 | 0 |
| Book chapter in hungarian | | 0 | 0 | 0 |
| Educational material | 0 | | 0 | 0 |
| **Titles of protection** | 0 | | 0 | 0 |
| **Achievements** | 0 | | 0 | 0 |
| **Popular science works** | 0 | | | |
| Journal articles | | 0 | 0 | 0 |
| Books | | 0 | 0 | 0 |
| Other popular science works | | 0 | 0 | 0 |
| **Of public interest or unclassified publications[6]** | 0 | | 0 | 0 |
| **More publications[7]** | 0 | | 0 | 0 |

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|---|---|---|---|---|
| **Other authorships[8]** | 0 | | 0 | 0 |
| **Citations of edited publications** | | | 0 | 0 |
| **Citations in dissertations and other types** | | | 0 | 0 |
| **All publications and citations** | 29 | | 3 | 6 |