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Criteria for assessing action undertaken by border municipalities towards a “green smart city”

Introduction

Climate change on Earth means that most cities throughout the world need to adapt in order to protect their residents from its detrimental effects. Following the notion of the Anthropocene and a holistic understanding of the relationship between man and the environment, a multifaceted transformation is required, in the same spirit as described in “The Great Transformation” by Karl Polany (Bendyk, 2015). This is why Pope Francis sees an answer to the challenges of the modern world in the cultural richness of nations, the restoration of solidarity and the co-creation of a green order in which people, animals and plants are linked by threads of interdependency (Franciszek, 2015).

Urban municipalities [Pol: “gmina”] are faced with a multitude of challenges: modernising flood protection and developing early warning systems, managing waste in accordance with the requirements of the circular economy, reducing thermal risk, and factoring green areas into the urban infrastructure during town planning. Bearing in mind the effects of climate change, ecological solutions are required to execute the transformation not only into smart cities but also “green smart cities”. Due to the magnitude of the ecological challenges, both terms should be permanently inscribed in the construction of sustainable city development. The evaluation criteria will depend on their size, geographic location and population. The scope and detail of the analysis must therefore be wider.

An attempt to determine the state of play in terms of how municipalities are acting in order to implement ecological solutions was made thanks to the “Climate (t) 2.0 – online solutions for future” project run by the Foundation for Polish-German Cooperation, under whose auspices researchers from the Poznań University of Economics and Business, in cooperation with the Viadrina University, Humboldt University and the Ebert Foundation, proposed a program entitled *Cross-border initiative for green smart cities/Grenzüberschreitende Initiative für grüne Smart Cities (GIGS)*, registered on the list of research under the number 00095/2020/AJ.

The aim of this article is to present the criteria by which the research instruments may analyse the ecological actions of municipalities, and thus define the most important directions of survey research. The proposed evaluation criteria should help municipalities obtain a full picture of the effectiveness of their action, the level of their advancement and social perception. The evaluation may additionally pinpoint deficits and errors in the understanding of sustainable development, as well as innovative solutions introduced by them and mentioned in the survey.

In accordance with Art. 7 sec. 1 of the Local Government Act, the municipality, within the scope of its own duties, has an inherent concern for spatial order, real estate management, environmental and nature protection and water management (*Act of 8 March 1990 on local government...*). “The most important role is assigned to planning instruments that ensure the rational organisation of action taken within the municipality in the field of environmental protection. This concerns both municipal environmental protection programs and municipal waste management plans” (Ciechanowicz-McLean, 2015). The environmental action plan implemented by the municipality constitutes the municipality’s eco-development program. Although limitations of jurisdiction in terms of water and air protection against pollution do exist, nevertheless local spatial planning, protection of the green-belt and some agricultural and forest species are all possible (Wyrębek, 2010).

The majority of municipalities, out of concern that their residents should enjoy a decent standard of living, take a variety of action whose results directly affect people’s lives and health, as well as the business appeal and economic development of the municipality. Pro-environmental activities require long-term planning and large financial outlays, which in the long run will add value to the municipality. Technological changes towards a low-emission, circular economy require high financial and personal expenditure as well as know-how support. For this reason, it is worth looking into urban and rural municipalities with populations of up to 100,000 that adopt innovative ideas and inventions to modernise and facilitate the lives of their residents with limited means, and thus become “green smart cities”. An important indication for research in this direction are municipalities in the Polish-German borderland area because of their ability to share experiences, the similarity of their environmental problems and huge areas of green infrastructure. Due to their diverse social potential and know-how, border regions can build new models of pro-ecological activities via cooptation (Decoville, Durand, Feltgen, 2015), boosting the effect of synergy, competitiveness and scale.

The ecological challenges faced by municipalities in connection with the ongoing climate change was the starting point for this article. The problems they have to deal with are similar in most cases, depending only on the scale of their financial and technical requirements and capabilities, as well as the substantive knowledge of the decision makers. Another aspect of the considerations is how to adapt this model to the specificity of border municipalities, which are subject to analysis in this research project. Their “green” potential, ability to take action and natural resources available were taken into account. Considering the varied nature of these regions, research criteria were then proposed for assessing their ecological maturity, which led to the formulation of the concept of a “cross-border green smart city”. At this stage, numerous research dilemmas emerged, which are an inherent feature of this type of analysis. The

added value of the article comes with the final subsection that focuses on identifying weaknesses and possible difficulties while striving for municipalities' attainment of ecological maturity, with particular emphasis on those lying on national boundaries. Hopefully the recommendations and guidelines may help in this process.

Ecological challenges facing municipalities – a universal overview

The climate changes taking place on Earth necessitate a new approach to the natural environment, which is the primary, non-renewable resource for human life. The creation of the European Green Deal (*Proposal for a Regulation of the European Parliament...*) is the EU's response to the people's needs to preserve environmental values and maintain their quality of life. Civilisational development has transformed the structure of housing, the result being that over 50% of the world's population lives in cities, and according to UN estimates, this number will exceed 80% by 2050. How to transform these huge urban clusters from a *cure city* to a *care city* is a challenge to be faced over the coming years.

It is universalism (Latin: *universalis*) which, although not a scientific concept, may provide the key to systemic solutions because, according to the dictionary definition, it aims to embrace "a certain whole, including people's activities, with universality".¹ Despite the varying levels of urban development around the world, citizens' needs and expectations regarding the quality of life in cities are similar. Taking into account regional specifics, it is possible to establish the elements of a constant that will, to a basic extent, guarantee the fulfilment of these requirements. A similar approach was used in the CITYkeys research project for the European Commission (Bosch et al., 2017). When selecting the key evaluation indicators for projects included within the smart city strategy and the smart cities themselves, the expectations of cities and the needs of the people were taken into account via the decades-old concept of ecological balance based on the so-called 3P Triple Bottomline (people, planet, prosperity) (Kolk, 2004).

The main indicators for assessing the ecological maturity of a municipality should be the implementation of environmental protection tasks in four areas: water management, clean air, waste management, protection of forest resources. This division results in four strategic elements from the point of view of the residents' life and health: smog-free air, the availability of clean water, soil without pollution and maintained ecological balance, which guarantees the survival of all species of fauna and flora for a safe and healthy human existence.

Improper waste management has a decisive influence on the quality of soil, water and air. Effective monitoring and cleaning of the soil and water environment, and preventing illegal hazardous waste dumping in the municipality area directly affect the health of the local residents. There may be over 3,200 post-industrial facilities in Poland, covering 5% of the country's area and affecting 75% of its cities. Remediation is required by 20–30% of their area.² The protection of the Earth's non-renewable re-

¹ Entry: universalism, <https://www.merriam-webster.com/dictionary/universalism>.

² Ground is remediation. A few words about the quality of land in Poland, <https://www.teraz-srodowisko.pl/aktualnosci/Grunt-to-remediacja-jakosc-gruntow-w-Polsce-8829.html>.

sources needs the cooperation, as it is broadly understood, of neighbouring municipalities, including ones located along national borders, in accordance with the principle that nature does not know state boundaries, which “change in time and space” anyway (Więckowski, 2019). Action taken by local governments based on cross-border cooperation includes: the elimination of ecological bombs, monitoring of pollution in rivers and reservoirs, creation of small retention points, restoration of wetland habitats, and the restoration of valleys and small watercourses. “Paradiplomacy” (Modzelewski, 2013) also involves preventive and biosecurity activities in relation to wild animals. It should take into account livestock corridors, the precise localisation of disease outbreaks, the registration of fallen game and joint sanitary inspections of farms by veterinary services.

Global warming affects the health of the Earth’s residents. Higher temperatures and extreme weather events are conducive to an increase in disease and even epidemics of infectious diseases. Allergy sufferers are exposed to an increase in seasonal allergen production. Additionally, heat-related mortality is increasing. Poor air quality is caused by the burning of fossil fuels, excess exhaust gases and secondary emissions. With regard to clean air, the ecological maturity of a municipality is determined by: the popularisation of clean energy, multidimensional competitiveness of public transport, including and protecting green areas in spatial planning, biophilic design in architecture, effective planting policy (Mihajlović, Mihajlović, 2017). The development of cross-border pollution distribution maps, including areas affected by smog from low-emissions and transportation, may contribute to the reduction of incoming smog.

The fourth element of the assessment is ecological balance, defined as the state of balance between the elements of a natural community consisting in their constant abundance and ecosystem stability.³ At the outset, the municipality may integrate ecological aspects with spatial planning by introducing location procedures that protect valuable natural areas against overdevelopment. Anthropogenic climate and environmental changes require swift responses from policymakers as well as understanding from citizens. Only synchronised action and rapid reaction to changing environmental conditions can contain the catastrophic effects of environmental degradation, or even reduce them. The best example of such an approach is the common practice of mowing grass in cities. However, uncut grass in fact is better at retaining moisture and does not require intensive watering, which burdens the municipal budget. Tall grass prevents soil erosion, reduces evaporation by lowering air temperature (a lawn can be 30 degrees cooler than asphalt and 20 degrees cooler than bare ground), while weed-infested grass captures dust and suppresses noise better. Even weeds contribute to the preservation of biodiversity, as the British organisation Livingroofs found out. When they were laying green roofs in London, they also counted on having to sow some native plant species.

A key role in the 21st century is played by transparent communication and dissemination of information, which results in a better functioning economy, state and, in turn, life of the residents. The importance of coherent communication that meets the growing needs of people has been emphasised many times by the Bank of Sweden,

³ GEMET, ecological balance <https://www.eionet.europa.eu/gemet/pl/concept/2441>.

awarding half of the Nobel Prizes to economists dealing with what may be broadly referred to as communication and information asymmetry (Mirrlees, Stiglitz, Akerlof, Spence). The economy, technology and knowledge form a kind of triad responsible, in the civilisational development of the world, for globalisation and the rapid dynamics of digital technologies (Deszczyński, 2020). The analogy between the determinants of decisions taken from the meso- and macro level and the municipality level are easily observed. Very often, the resolution of municipal problems is hindered by the human factor, which is related to selfishness, nonchalance and ignorance. The study should take into account the efforts of the authorities to constantly improve the qualifications of their officials.

To summarise, it is worth focusing on the most salient issues that the majority of municipalities will have to deal with as a result of climate change:

- Spatial planning that takes into account “ecological corridors” and airways while introducing buffer zones for human activity (Szulczewska, 2004);
- Severe and long-lasting rainfall, causing local inundation and flooding;
- Drinking water shortage;
- Air pollution;
- Increase in morbidity and epidemic outbreaks;
- Extinction of native fauna and flora;
- Growing quantities of municipal waste;
- The need to introduce smart second and third generation technological solutions (Tai-hoon, Ramos, Sabah, 2017);
- Introducing a grass-roots Internet of Things to monitor noise levels, air pollution, light pollution, etc.

The salient features of a border municipality in ecological development

Border areas *per se* are a separate analytical unit where two interacting elements must be taken into account. The first is the locational specificity, and the second is the geographical position at a cultural and political interface, related to the variability of historical borders (Barwiński, 2014). Western Poland, as a macroregion, fits within the global phenomena of globalisation and European integration processes of territorial entities (Tutaj, 2017). It is also an area which draws on the ecological heritage of its western neighbour, which is not without significance for its economic development. It is also worth underlining the long-standing German tradition of caring for the natural environment that differs from the Polish one. Identified with the environmental movement, the Green Party was founded in Germany in the 1970s. Its genesis was constituted by regional civic initiatives, after the Club of Rome warned, in a 1972 report entitled “Limits to Growth”, about the consequences of extensive exploitation of natural resources by highly industrialised countries (Decker, 2007).

The smart city strategy with its consideration for sustainable development is not a new phenomenon for the German side, as evidenced by the final report of the Ministry of the Environment from 2020 that commissioned the study of 18 smart solutions and their impact on natural environmental resources. It indicates institutional deficiencies and

the need for organisational changes, while presenting the applicable standards and legal rules for the proper shaping of smart and sustainable infrastructural solutions (*Smarte Umweltrelevante Infrastrukturen*, 2020). In the German public space, complementary to the concepts of a smart city or green city, emerges the notion of a smart village, rendered in German as *smart Dorf*. Politicians, scientists and entrepreneurs are increasingly interested in action that might improve the lives of smaller communities (Renker, 2018). Some examples are the municipalities of Raunheim, Rüssleheim and Kelsterbach, where all new and existing car parks are fitted with sensors. They provide data for a collective transportation concept to enable residents to commute quickly by car, bike or rail.

The specificity of border areas is their geographical location on the periphery of the country, which determines their economic development as well as the well-being of the residents, and therefore affects their involvement in the local life of small communities. However, a parallel can be drawn with borderline personality in that it may be assumed, as psychologist Jolanta Miluska rightly noted, that “the borderland hides a certain potential for destruction and development” (Miluska, 2018). The long presence of the Soviet troops stationed here and the People’s Army of the GDR, the uncertainty of the political future and the permanence of the borders contributed to the feeling of alienation or rejection. Poland’s accession to the EU structures in 2004 shifted the significance of these “forgotten” territories to the role of the main player in the EU integration policy (Jakubowski, 2015).

One major advantage of the border regions in their current development are their ecologically clean areas, huge forest areas and biosphere reserves, as well as proximity to their western neighbour. Natural values are treated as the main economic developmental opportunities for local municipalities. In studies related to the assessment of the development potential of the Polish-German border area as a result of the ongoing process of European integration, commissioned by the Federal Office for Construction and Spatial Management to the Hamburg Institute of International Economics, two aspects were noted that are critical from the point of view of ecological transformation. The first was tourism and the use of natural and landscape areas, while the second involved cultural and natural diversity (*Polish-German Border Area in 2020 – Developmental Scenario and Recommendations for its Implementation [Polsko-niemiecki obszar przygraniczny w roku 2020 – Scenariusze rozwoju i zalecenia odnośnie jego realizacji]*, 2020). The significant landscape values combined with the cross-border cooperation in the field of nature protection, initiated by the “Black Triangle” program or joint wastewater treatment plants in the border towns of Gubin and Świnoujście, should be continued in the “green smart city” strategy. The creation of tourist infrastructure contributes to alleviating psychological barriers while at the same time enhancing the image of the border area.

The condition for the success of these projects is the nature of the cross-border operations. They should be immediate, reactive (action-oriented and repeatable), prophylactic and coordinated. The international nature of cooperation brings immeasurable benefits in building a “green smart city” strategy. Establishing, for example, a network of cross-border bicycle freeways constitutes the creation of green infrastructure (Zaręba, Krzemiński, Dzikowska, 2019), which connects nature centres in urbanised cities in the form of green corridors (Benedict, 2006), thus contributing to the process

of de-bordering, accompanied by the intensification of relationship and partnership building (Nelles, 2011).

In research on the ecological maturity of municipalities in the Polish-German borderland, differences arising from the extent to which smart solutions have been implemented should be taken into account. Creating identical content in one universal research apparatus would appear to be impossible for several reasons. The work of the municipalities on either side of the border is different, as is the understanding of environmental challenges. The basic EU requirements regarding, for example, waste segregation, have been comprehensively resolved on the German side, also taking into account electronic and difficult-to-process waste. In connection with the deposit system existing in Germany since 2003, the problem of properly recycling rubbish does not exist. Environmental education for children and teenagers is included in the curricula created by individual federal states of Germany, which has significantly bolstered the environmental awareness of the younger generation. Generation gaps pose no observable obstacle to methods of combating climate change, as confirmed by a study conducted by the German Statistical Office in 2019. People over 55 years old seem to be better at following recommendations in the interests of sustainability. Young people are much better at ditching plastic, consuming less meat, using energy economically, eliminating excess paper packaging, and favouring the consumption of local products (Nier, 2019).

The higher stage of ecological transformation in Germany cannot be compared to the development of municipalities on the eastern side of the Oder. Incidental cases can merely create a precedent that does not set standards and is not evaluated.

Defining the most important criteria in the study of ecological maturity of border municipalities

A research tool that is universal in nature and available online should include the categories that are the most important from the point of view of environmental challenges, i.e.:

1. **Smart management** encompasses the use of information and communication technologies in public services and takes into account the important role of public participation in decisions made by the municipality. An important aspect of this area is the introduction of “green” solutions and their promotion in the broadly understood realm of business, which might make a municipality attractive from an economic point of view.
2. **Smart living** is about modern urban designs that place people and their needs in the centre of planners’ concerns, without disturbing the ecological balance.
3. **Smart environment** is the ability of a municipality to introduce solutions that will match the needs of its residents to the environmental challenges. This concept includes the human right to live in clean air, have access to green areas with preserved biodiversity and the guarantee of clean water supplies.
4. **Smart people** Smart people are socially active and environmentally conscious citizens with access to education and training opportunities that guarantee the effectiveness of the innovations introduced by the municipality (Korenik, 2019).

Three of the above categories guarantee sustainable development, based on harmony between 3 pillars: economic, social and environmental (Castanho, 2019). When combined, they form the basis of smart living while also embracing unconventional solutions and attractive facilities for residents. In architectural projects, environmentally friendly, modern solutions are increasingly applied, such as high-quality window joinery or LED lighting, and covering building facades with titanium paint that neutralises smog. In addition, as part of the development of green areas, vegetation is chosen that absorbs all kinds of pollutants. Furthermore, the existence of charging stations for electric cars, the availability of public transport, and bicycle paths are an additional advantage offered by the authorities in consolidating their image as a green municipality.

While studying the ecological maturity of the municipality, research apparatus should be implemented to assess the municipality's activity in the above 4 areas. The level and commitment to sustainable development in the spirit of climate change is the most important evaluation criterion, not the effect achieved, which is relative and depends on factors for which the municipality is not responsible. The levels of activity achieved are influenced by:

- the economic character of the municipality,
- its physical area,
- geographic location (including protected areas),
- number of residents and social structure.

For a municipality with large tracts of agricultural land, it will be important to maintain the continuity of cultivation in soil free from pesticides and chemical compounds hazardous to human health, to support organic farming and avoid monoculture. For municipalities that have large forest areas on their territory, it will be worth preserving and maintaining them as well as preventing fire. Such municipalities are most often attractive for tourists, which means handling the tourist traffic in terms of municipal waste disposal, more rubbish left in forests and a seasonal increase in the consumption of natural resources, such as water, and, as a result, higher sewage production. If the majority of the municipality's residents are elderly people, the main focal points in local politics will be facilitating public transport, substantive support in implementing ecological solutions and promoting home gardens.

In order to take into account this ecological multidimensionality of municipalities, the research should include the following aspects of smart management:

- 1) economic waste management, including difficult-to-process, hazardous and large-size waste, in the spirit of the circular economy;
- 2) acquiring external funding for ecological projects that will improve air, soil and water quality;
- 3) education and training of municipal administration officials in maintaining sustainable development;
- 4) cooperation with environmental organisations and specialists in niche areas for sustainable development;
- 5) development of new information technologies and the evolution of the Internet of Things.

A smart environment should include:

- 1) action undertaken by municipalities for the protection of endangered species;
- 2) reintroduction of native species of animals and plants;
- 3) restoration of watercourses and protection of water resources;
- 4) steps taken by the municipality to reduce air pollution sources (linear emission);
- 5) creating as many green zones as possible (Łukasiewicz, 2006) protecting against noise pollution or secondary smog.

The concept of smart living encompasses a number of areas of life in terms of the use of tools that offer new technological solutions to optimise life and the realisation of professional aspirations and life goals, as well as improving the quality of functioning in urbanised areas. From this point of view, the municipality should take into account:

- 1) taking action to maintain sustainable transport, including alternative forms of public transport such as bicycles, car sharing;
- 2) obtaining energy from renewable sources and using it economically;
- 3) incorporating biophilic design in the architectural arrangements of the urban structure;
- 4) developing green areas and using modern construction solutions that improve thermal comfort in the face of climate change (Fig. 1)

In the process of achieving ecological maturity, the main actors are the municipality and its residents. The municipality, as the initiator of the implementation of green technologies and their practical implementation within its area, becomes the main link in horizontal relations with the residents. Smart people are the end result of the nascent process of building a green municipality. Without their environmental awareness, it is not possible to transform the paradigm of a smart city into a green smart city.

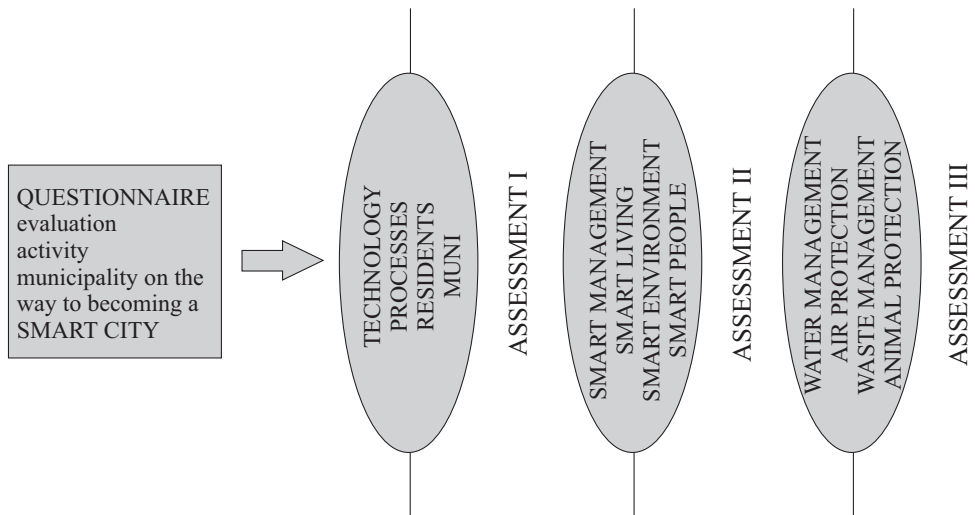


Figure 1. Formulating the concept of a “cross-border green smart city”

Source: Own study.

The growing interest in the smart city topic (Anthopoulos, Series, 2018) has not translated into the formulation of a universal definition of smart cities, let alone green

smart cities. The selection of appropriate ecological action at various levels of the economy, including on the mesoeconomic scale, i.e. regional (Konecka-Szydłowska et al., 2019) and local (Orłowski, 2019) is necessitated by deteriorating environmental conditions and the need to limit or avoid harmful changes. Following a diverse approach in defining a smart city, the suggestion of certain developmental trends may be observed. Terms such as “city of knowledge”, “digital city” and “ecological city” are used interchangeably in literature. However, attention is drawn to the multidisciplinary nature of the smart city concept, which covers areas of key importance for urban development, such as smart infrastructure, the economy, mobility, smart management as well as environmental issues (Yigitcanlar, 2018).

When formulating the concept of a cross-border smart city, the above aspects should be taken into account and the specificity of the border region should be emphasised. In addition to the aforementioned features, such as the region’s greenery, peripheral location on the country’s map, substantial years of economic neglect, political instability and insecurity, social problems also exist: social exclusion, emigration of young people, structural unemployment after 1990 and educational barriers. The borderland character of these regions also has some upsides, as shown in Fig. 2. The close presence of our western neighbour creates opportunities for spatial planning regardless of where the borders run. The Muskau Park is a perfect example of this. Cross-border projects in the form of a green network of cycle paths, joint analysis of environmental threats, water protection, prevention of natural disasters and epidemiological threats are all proposals that only confirm the unique locational flavour of border municipalities.

In the adopted model, the analysis of the ecological maturity of border municipalities will revolve around the following four spheres: the municipality as an organisation, relations with residents, the residents of a given municipality, technology and creativity as well as processes connected with the municipality’s ecological activity. It should be highlighted that both the technologies used by the municipality and the “silent knowledge” characteristic of the local community are of great relevance for the model. On the one hand, it can be a barrier against innovative initiatives, yet on the other hand, it may stimulate new projects.

The second figure illustrates the elements of the model. Of course, this is not a closed model and may be developed with new components that arise from the current state of knowledge, technology or other socio-economic factors. The first element of this model is the municipality as an organisation. It differs significantly from an enterprise in terms of its structure, types of relationships, leadership traits, method of financing, speed of changes, technologies used in solving problems, and above all, a mission and strategy focused on the residents (Pytko, 2012). What connects the municipality and the enterprise is their pursuit of transformation by allocating employees’ competences, improving their qualifications, skills and creativity. All these features, in conjunction with problem solving via the design method, are essential when using digital tools.

Another element of the model are the processes that the municipality should manage in the scope of improving the state of the natural environment, thus implementing the principle of sustainable development. From the point of view of effectiveness, what is relevant is the degree to which process management is integrated, which may be dispersed when it comes to larger units. An additional important element of these processes is stand-

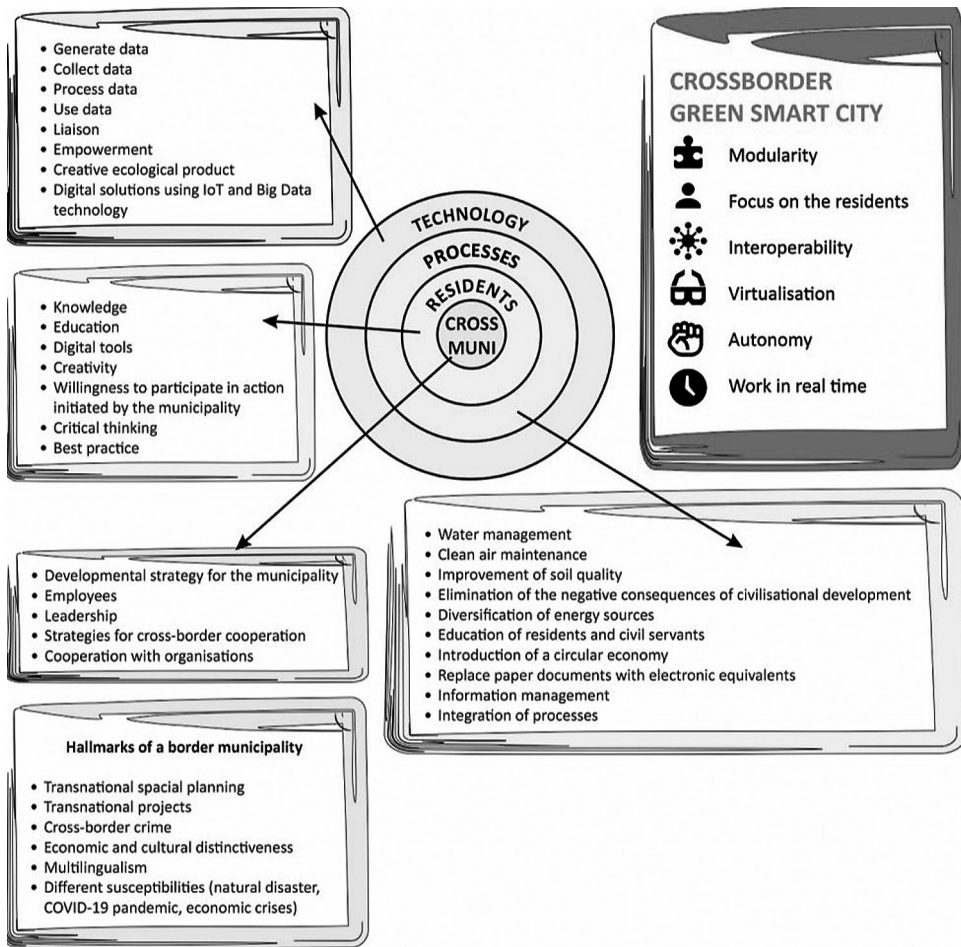


Figure 2. Model of action undertaken by a border municipality in order to achieve ecological maturity

Source: Own study.

ardisation. It is very important for residents, because it creates a new quality in relations with them and promotes the introduction of digital solutions, information exchange, etc. Process management encompasses areas such as water management, maintaining air purity, improving soil quality, eliminating the negative consequences of civilisational development, diversification of energy sources, education of residents and office workers, introduction of a circular economy, replacing paper documents with e-documents as well as the very important process of information management. However, without the participation of the municipality residents, especially in the construction of business models, the chances of standardising the processes are slim. At later more advanced stages of development, cross-border integration would also be necessary to achieve economies of scale.

The residents are a critical component of the model. The role of the municipality's residents focuses on their knowledge resources, creativity, sense of connection and

identification with the municipality, ecological awareness, and willingness to achieve a certain standard of living. They expect the municipality to initiate various solutions that will help to combat ecological problems, e.g. bicycle paths, recycling of rubbish, access to the Internet, available cheap and convenient public transport (Fig. 3). According to most researchers, the smart city concept is closely related to “the participation of residents in the city management process, in particular making choices and implementing projects” (Pięta-Kanurska, 2019). Achieving a higher level of social inclusion requires the self-generation of wealth. A long-term solution proposed by the idea of inclusive growth is the redistribution of wealth and directing economic activity towards employees and the local community. When more people participate in production, and thus in its results, they are more likely to use the resources obtained for the local good. This parallel shows a simple economic mechanism that translates into the activity of local municipalities (*Wealth for All...*, 2018).

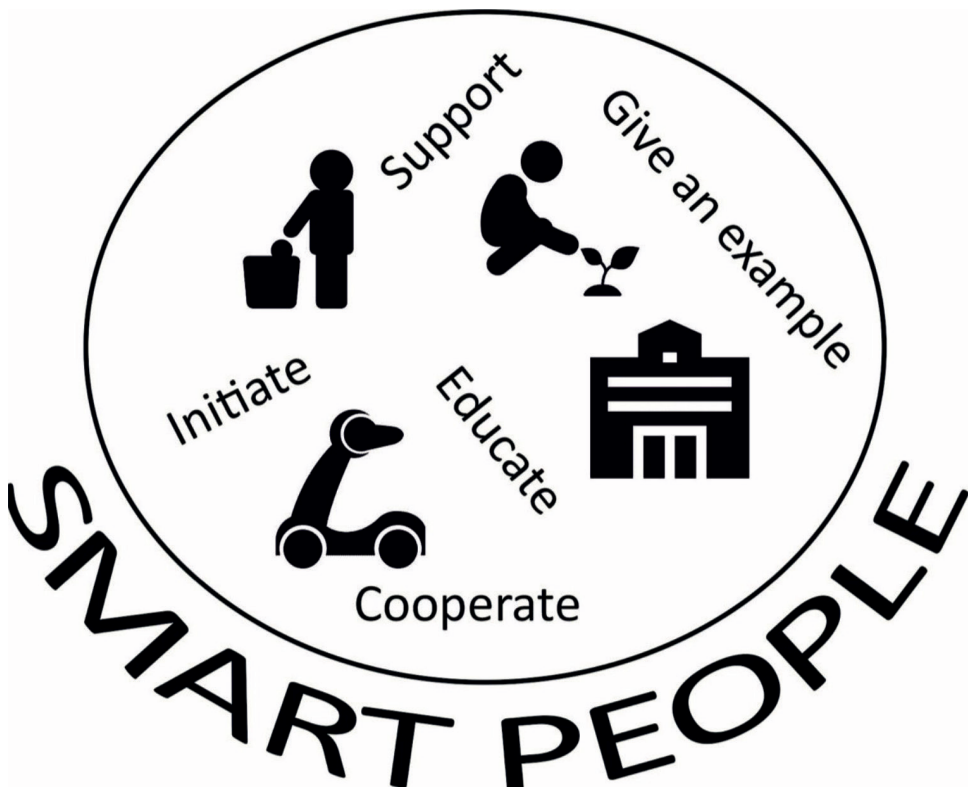


Figure 3. Municipality action in support of smart people

Source: Own study.

Technological development is a crucial element of the described model. Big Data and the evolution of the Internet of Things (IoT) have played an important role in the implementation of the smart cities initiative. Large data sets enable cities to obtain valuable information from a variety of sources, and the Internet of Things facilitates the

integration of sensors, and the identification of radio frequencies and bluetooth in the actual environment. There are many applications for the IoT in smart cities. Examples include smart parking lots, traffic control, lighting, waste management, park hosing, flood warning systems, monitoring systems for buildings and infrastructure, as well as smart air quality monitoring systems.

The analysis of data generated by devices operating in the IoT is a great challenge that both Big Data researchers and businesses themselves will have to face. Regarding data generated by smart devices, according to the Cisco report (*Cisco Annual Internet Report (2018–2023)*, 2020) it is estimated that by 2023 more than 29 billion devices will be connected to the IoT network, which in fact are an example of Big Data of a different type than those that we produce today on the “traditional” Internet. Due to their size and the vastness of the information gathered, they require enterprises to use different tools and adopt a different strategy. This will force businesses to turn towards integrated Big Data platforms operating in the cloud, capable of processing this data, thus enabling entrepreneurs to monetise data from the IoT. Currently, most of the largest companies (IBM, Microsoft, Google) use software that they have developed. However, you do not have to be a financial giant to be able to use Big Data and IoT solutions. Solutions in free R or Python programming languages have already been developed, enabling calculations to be performed on large data sets and using Big Data technologies (e. g., Hadoop, Spark).

The application of statistical and analytical methods will be essential to understanding such large data sets. It might seem that when using Big Data, we already know everything and we can abandon traditional statistical methods, in which a major role is played by care for data quality, sample selection or uncertainty, among others. Meanwhile, if we want to draw conclusions about the entire population – for example, on the basis of data from Facebook – we should take into account that young people are far more likely to be users. It turns out that statistical methods such as time series analysis, cluster analysis, dimension reduction methods, classification or regression are necessary for Big Data analysis. On the other hand, such large amounts of data give some machine learning methods a chance to shine, since they only really reveal their true capability when they have huge learning sets at their disposal. Such techniques include, for example, deep neural networks (Bengio, Courville, Goodfellow, 2018), which have become extremely popular in recent years.

The concept of a cross-border “green smart city” should take into account not only elements related to generally accepted smart solutions, but the entire gamut of natural values that these regions embody. The implementation of ecological solutions, thanks to cooperation and cross-border projects, can contribute to educating smart people. Thus, they will become an example of a successful eco-transformation while maintaining coherence with the natural environment.

Research dilemmas while analysing the ecological maturity of municipalities

The main research dilemma is also the measurability of the term “green smart city”, the number of categories, the breadth of the research scope and the standardisation of

qualitative research. The variety and heterogeneity of municipalities' action in favour of the needs of their residents makes it difficult to maintain the principle of universality, while personal influences and the relativism of answers remain unavoidable in closed questions. The departure from the statutory obligations of the municipality strengthens the discretion and often misinterpretation of the phenomena under evaluation. Due to the utilitarian nature of the study, it is worth assessing two participants: the municipality and the residents.

The former is subject to a qualitative assessment. The answers that the respondent can choose from should include the latest achievements and smart solutions that have been tried and tested in various parts of the world and have a chance of being implemented in border municipalities. Apart from human factors, the most important research elements include geographical and financial differences, which, although not subject to quantitative analysis, should be included in the final assessment:

- What is the percentage of green space in the total municipality area?
- How many projects from the civic budget involve green areas?
- What is the budget at the municipality's disposal?
- How many people in municipal offices have been delegated to work on smart city or environmental strategies?

When studying German municipalities, it is worth factoring in cultural differences, the level of economic development and the importance of ecological solutions in regional policy. The federal character of the state means an unequal and non-universal distribution of needs and work to be carried out. What binds the studied municipalities may be their borderland character, the GDR legacy and the adoption of West German ecological trends and European directives implemented by the central government. What should also be taken into account is that a large share of the operations is also undertaken in the form of voluntary work or by numerous NGOs in Germany (616,254 in Germany, 123,975 in Poland) (Gumkowska, 2017). They also lobby for green solutions and often take the initiative in promoting them. Despite the fact that Germany has been present in EU structures for a long time, the German border areas, like their Polish counterparts, have the same experience in using EU funds. This fact can level off financial differences, and the joint acquisition and distribution of funding can significantly contribute to the smart development of Polish and German towns and cities.

When studying the residents, solutions similar to the evaluation of the United Nations' carbon footprint survey may be adopted, i.e. by dividing it into three groups: economy, transport, and lifestyle, with three categories each. The first one should take into account the handling of municipal waste and discover any methods of saving water and electricity introduced by the residents of cross-border municipalities. The second group concerns mobility, as it is broadly understood, and choices made regarding means of transport. The final one concerns information on shopping behaviour, food preferences and the ability to dose thermal energy for the benefit of the environment as well as a healthy lifestyle for the owners of heated apartments.

Data obtained in this way illustrate the level of commitment to, and acceptance of, smart solutions. If someone rides a bicycle or uses public transport, they may expect changes in this direction. As a prosumer, we expect distributed energy sources. Smart people force through more substantial changes and accelerate green transformation.

In both research tools, what comes to the fore is the need to transform an individual into an active participant in green and sustainable solutions that build the attractiveness of the municipality in the long run. Conscious users opting for ecological housing and living solutions ensure the high quality and quantity of public spaces and their recreational appeal (Bosch et al., 2017). The municipality's acceptance and openness to bottom-up solutions proposed by the residents creates a coherent system of mutually interacting needs and expectations.

Another model of researching residents can be adopted, in which the other party performs a subjective evaluation of the provider of new green services, which serves to confirm the validity of their application or otherwise. A similar analytical mechanism was developed by researchers from the Massachusetts Institute of Technology during a study on urban greenery in 27 capitals of the world within the open Source Treepedia project. The Green View Index was established on a scale from 0 to 100, and satellite images of green urban areas, and above all the visual feelings of passersby, were not taken into account as the source base. Only the photos from Google street view analysed via the MIT algorithm showed to what extent the spread of tree crowns and plant vegetation affect the city panorama (Jerzy, 2019). It seems, however, that impressions alone are not enough for a transformation towards green smart cities and it is necessary to assess systemic solutions.

Regional policy recommendations for border municipalities, business and spatial management

On the basis of a bibliographic analysis within the scope of smart cities and sustainable development, a picture emerges of the range of challenges that municipalities have to face. However, by narrowing the research to border areas where global ecological problems can be scrutinised on a micro scale as if through a lens, one can name the problems that arise there and indicate solutions. National differences and those resulting from the stage of economic development may outline not only the scale of the new challenges, but also facilitate or even avoid the difficulties faced by city authorities. From the perspective of EU policy, the cooperation of border municipalities is a perfect model of how to work together and how state borders can blend into green infrastructure, which showcase the best solutions in building common regions within the EU.

What is most important thing when devising a cross-border green smart city strategy is environmental knowledge (Mickiewicz, Mickiewicz, 2005), along with training municipal officials who can learn from the business environment and from international contacts on global smart solutions in the field of sustainable development. This group of people forms educational chain of transmission to the residents of the municipality, who not only imitate pro-ecological attitudes, but also implement them in their everyday lives, whereby ecologically aware smart people become a *sine qua non* condition for a successful green transformation. To achieve the desired effect, it is worth building a culture of mutual relations, based on an understanding of mutual inspiration, support and encouragement. This will create the foundation for a deeper psychological transformation, which a German neurobiologist called "communal intelligence" (Hüther, 2013).

It is also important to provide substantive support and even permanent consultations with specialists from various fields of science as well as practitioners in order to avoid misguided and costly investments. One example of such are the waste incineration plants built in Poland, which, when placed alongside the implementation of circular economy principles, should not exist in their current preferred form.

An extremely important factor driving the economic development of the municipality is its greenness in terms of mobility, proper waste management, efficient water management, while the new mobile technologies introduced to improve the quality of life of the residents also facilitate the movement of tourists. A green municipality is an easier magnet for small and large investments, which will contribute to the prosperity of the region.

Further indications for the development of a cross-border green smart city strategy will appear in another empirical publication devoted to the results of a survey conducted in border municipalities on both the Polish and German side.

Summary

Evaluation criteria for studying the “ecological maturity” of border municipalities should include the four most important environmental markers that determine the quality of life of the residents, i.e. measures to improve the condition of air, soil and water, and care for the preservation of biodiversity, which guarantees ecological balance, without which people have no chance to live a healthy life. All solutions introduced by the municipality can also be categorised into appropriate action groups: smart management, smart environment and smart living. A special role in the concept of a cross-border green smart city should be assigned to city authorities and the residents, who are responsible for the success of eco-transformation in building ecological maturity through cooperation, participation in cross-border initiatives and constant consultation. Due to the multifaceted differences between border municipalities, every effort and every action undertaken in the field of green transformation is worthy of appreciation. Even the smallest successes motivate and ennoble the residents. Undoubtedly, it is difficult to build a universal research tool to assess ecological maturity, which will be homogeneous for the border area. The main obstacles are: the physical size of a given municipality, the population structure, decision-makers with different levels of knowledge, and different social expectations.

The proposed evaluation criteria provide an experimental framework on which to build levels of ecological maturity for border municipalities. They indicate the main directions and trends in eco-transformation. Over the course of technological progress and civilisational development together with a growing ecological awareness, the range of criteria is also evolving. The concept of a cross-border green smart city *per se* adds value to the rich literature devoted to the development of green smart cities. Regardless of the selected aspects in the pursuit of attaining the level of a green smart city, discontinuation of evaluation would deepen the already existing disproportions in the development of border municipalities, and thus withdraw them from the only and inevitable “green path of prosperity” in harmony with nature and its laws.

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Summary

The article presents a proposal for a research tool that might assess the ecological activity of municipalities, with particular emphasis on those that lie on national boundaries. With climate change, it has become necessary to take into account the principles of sustainable growth while maintaining high living standards in the long term. Systematic research on the action undertak-

en by municipalities in this area is a necessary requirement in the coming years. For this reason, the main directions and areas of research in the process of approaching the concept of a “green smart city” have been outlined. The available literature is limited to research in the field of smart cities and examines solutions for large urban agglomerations. The evaluation criteria of “ecological maturity” proposed in this paper are designed for small border municipalities. One may accept the thesis that due to their specificity, location, natural diversity and the opportunities for cooperation with a foreign partner that they offer, border municipalities can create a model of ecological behaviour in terms of a “green smart city”. This evolution requires support and monitoring for policymakers, and the proposed online research tool may reveal “ecological immaturities”, decisional errors or just plain negligence. One might only hope that, as a result of these indications, the recommendations will prove valuable for all local government units. On the other hand, a number of doubts and dilemmas are raised that researchers are unable to eliminate at this stage.

Key words: sustainable development, smart city, ecology, cross-border green smart city

Kryteria oceny aktywności gmin przygranicznych w kierunku „green smart city”

Streszczenie

Artykuł prezentuje propozycję narzędzia badawczego do oceny aktywności ekologicznej gmin ze szczególnym uwzględnieniem gmin przygranicznych. Wraz ze zmianami klimatu pojawiła się konieczność uwzględniania w dłuższej perspektywie czasu zasad zrównoważonego wzrostu z zachowaniem wysokich standardów życia. Systematyczne badanie aktywności gmin w tym zakresie to konieczny wymóg najbliższych lat. Z tego względu nakreślono główne kierunki i obszary badań w procesie dochodzenia do koncepcji „green smart city”. Dostępna literatura ogranicza się do badań w zakresie smart city i dotyczy rozwiązań dla dużych aglomeracji miejskich. Zaproponowane w pracy kryteria ewaluacyjne „dojrzałości ekologicznej” skierowane są do niewielkich przygranicznych gmin miejskich. Można przyjąć tezę, że gminy przygraniczne ze względu na swoją specyfikę, położenie, różnorodność przyrodniczą i możliwości kooperacyjne z partnerem zagranicznym mogą tworzyć model zachowań ekologicznych w aspekcie green smart city. Ewolucja ta wymaga wsparcia i monitoringu dla decydentów, a proponowane narzędzie badawcze dostępne online może wykazać „niedojrzałości ekologiczne”, błędy decyzyjne oraz zwykłe zaniedbania. Można mieć jedynie nadzieję, że w efekcie tych wskazań cenne okażą się rekomendacje dla wszystkich jednostek samorządowych. Z drugiej strony wzbudzają one szereg wątpliwości i dylematów, których badacze na tym etapie nie mogą wyeliminować.

Słowa kluczowe: zrównoważony rozwój, smart city, ekologia, przygraniczne zielone smart city

