Spatial Absorbency Concept as a Decision Support System for Sustainable Local Development

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Abstract. The practise of last decades of land use planning system in Poland allowed local authorities to design new land uses freely, without proper analyses. It resulted in designing in total over 10 times more area for new housing purposes than is developed as housing nowadays. To prevent this situation the amendment of the Act on planning and spatial development set, among others, the new obligation. Each municipality, before designing new land uses, needs to prepare an assessment of demand for each land use and the absorbency of existing real estate reserves for that land use but still not developed in that way. The demand analysis is defined by regulations in order to categories that have to be taken into account, while the absorbency evaluation is not. Therefore, each municipality includes different factors, uses another method and has a distinct accuracy of analysis. The purpose of this work is to present a concept of spatial absorbency calculations. The proposed method was tested in a pilot studies on a case of Jaworzyna Śląska (Poland) in order to verify the possibility of application of the framework in practise. The sources of this study were data from spatial planning documents, available public statistics and map services. Due to the lack of detailed regulations regarding the estimation of absorbency, the proposed method was based on the review of existing spatial policies developed under the new law as well as developed individually by authors. The results of the research are helpful in preventing excessive land use designing. In addition, they provide information on the development opportunities of municipalities and their potential to invest. These calculations support the rating of not only usable area of the development, but also the number of potential new residents. The method is fully applicable in ArcGIS and CommunityViz software and may constitute the framework of decision support system for local authorities in sustainable local land use planning.

1. Introduction.
Spatial planning in Poland at the local level allocates too much space for development. In the scale of the whole country, approx. 12% of the areas has been designated for settlement functions, while in fact only 1% of Poland's area is used in this way [1]. Such situation is one of the factors influencing the economic and financial standing of property developers and the real estate market situation [2][3]. In that matter real estate market is similar to other branches, which are constantly changing [4]. Therefore, in October 2015, an amendment to the act on spatial planning and development was introduced, which obliges municipalities to prepare the area's balance. The legal basis for estimating spatial absorbency is Article 10 para. 5 of the Act of March 27, 2003. on planning and spatial development [5]. The Act divides the absorbency calculation into: (1) already built-up areas with a developed functional and spatial structure and (2) other areas that are only designated for development in local plans outside the
compact structure of the settlement unit. This calculation aims to answer the question what the relationship between demand and supply for investment areas is. As a result, local authorities are to be equipped with tools to monitor the spatial development process, supporting them in the decision-making process regarding spatial development. Space decision support systems have been already used in energy issues [6] or transport [7]. This work is to complement this trend of research with future land use planning systems. However, the legislator has not specified a precise definition allowing delimitation of these two categories of sites, which opens the way to different interpretation of the regulations.

In addition to problems related to the delimitation of territories, the legislator has not clarified the concept of spatial absorbency. In scientific publications it is difficult to find a definition of the term "spatial absorbency”. It is much easier to find the term "natural absorption", referring to the issues of the natural environment, including such components as water-bearing capacity [8], environmental carrying capacity [9], land carrying capacity [10] or urban land population carrying [11]. It can be noticed, however, that such publications distinguish between the concept of absorbency and spatial capacity [12]. This document specifies that absorbency is estimated for still undeveloped areas or to areas with a negligible degree of anthropogenical transformation, which did not cause significant changes in the environment. On the other hand, the term "capacity" is used in the case of land that has been transformed by a human being, e.g. by determining the specific purpose of the area [12]. The above definitions and separation of the term of absorbency and capacity shows that the Act contains two different definitions under one term.

The proposal of the calculation model of spatial absorbency has been preceded by the analysis of source materials in order to check how in practice the municipalities in Poland calculate this value. The analysis covered four municipal spatial policies, which were adopted after the amendment to the Act introducing this obligation. At the beginning, it can be stated that the methods for estimating spatial absorbency are diverse. In most cases, the reserve of land has been designated for municipal spatial policies and master planes, and based on them, calculations have been made that took into account only the surface, ignoring the geometry of the areas. The estimation was based mainly on the quotient of the area reserve in a given category of destination and the relevant indices selected individually for the purpose of calculations. Many calculations referred to a small number of land use classes, which resulted in generalized results. The most popular land use classes have been agriculture/rural housing, single-family housing and multi-family housing. Most studies omit functions other than housing. In addition, there is a small number of studies with a detailed description of the method for determining areas with a compact functional and spatial structure. In some cases, the estimation of absorbency capacity in areas outside the compact form of development has been restricted to a reserve area of land intended for settlement functions in masterplans. In the majority of municipal spatial policies, the estimation of absorbency has met the general provisions of the Act concerning this indicator. Due to the lack of proper explanations and not very precise and sometimes simplified calculations, one cannot highly assess the methods of absorbing the analysed documents, nor directly model themselves on any of them.

The purpose of this work is to present a concept of spatial absorbency calculations divided into specific land use classes. Such studies are considered to indicate the maximum usable area of the new development, which is feasible with the existing forms of land development and the records of planning documents.

2. Study area and data sources
The proposed method has been tested in a pilot studies on a case of Jaworzyna Śląska (Poland) in order to verify the possibility of application of the framework in practice. Municipality of Jaworzyna Śląska is urban-rural community, which is located in Lower Silesia in the county Swidnica. This local government unit includes the city of Jaworzyna Śląska and 12 villages. Each town is located in a separate geodesic area. Almost 75% of the area of this territorial self-government unit has a valid local spatial development plan.
The planning documents for the commune were based on the municipal spatial policy and master plans. As the municipal spatial policy was adopted in 2015, most of the datasets were correct with current situation. In few cases the current land use was updated based on Open Street Map [13]

3. Method

The proposed method of estimating spatial absorbency is presented below in Figure 1. Basic input data used in the method are: future land use designed in municipal spatial policy (step 1.1), and existing buildings (step 1.2). The existing buildings have been the basis for determining the area of compact residential development (step 2). Analyses have been carried out with ArcGIS (version 10.4.1) and CommunityViz (version 5.1.2) tools. The area of the commune has been divided into basic reference units in the form of squares with dimensions 100 m × 100 m.

![Figure 1. Conceptual model of spatial absorbency calculations](image)

In accordance with the principle of preventing sprawling of buildings, distances of new investment areas from the center of a given town have been defined (step 3.1). As regards the assumptions used in the method, one factor has been adopted determining neighbourhood from existing buildings (step 3.2) and technical infrastructure taking into account roads and utility networks (step 3.3). The adopted
parameter is 60 m, which is an average doubled front of building plots in the community. Due to local conditions, it is necessary to assess the impact of a given neighbourhood on neighbouring areas [14], and therefore this parameter can be edited.

For the previously designated neighbouring areas, points have been assigned to valorize the areas according to the point bonititation method. The value for the distance from the center equal to the distance itself, the neighbourhood with each building has been assigned value 1, while the vicinity of the existing infrastructure has been assigned the following points:

- 1 point - existing unpaved road and without infrastructure;
- 2 points – paved or unpaved road along with one of the infrastructure network;
- 3 points – paved road and the presence of one of the infrastructure networks;
- 4 points – paved road and presence of water supply and energy networks;
- 5 points – paved road and presence of at least one additional infrastructure network above water and energy supply.

After assigning the points, each of the resulting vector maps has been cut with a grid of squares (step 4) and changed to raster after the value attribute of the particular analysis (step 5.1, 5.2, 5.3). Then the data in this format has been reclassified, i.e. each class was given the appropriate number of points to unify the data in the summary. For the analysis of building buffers and roads, a scale proportional to the value of the raster attribute has been applied. In contrast, for distance studies, a greater number of points for smaller distances in classes have been assigned. A spatial summation tool (step 6) has been used to create a result map. In preparing this analysis, twice as much weight has been given to the raster showing the neighbourhood from the buildings.

With the final determination of compact functional and spatial areas within each settlement unit, mainly the resulting result map has been taken into account. Areas located in the last two ranges have been qualified as areas potentially outside the compact building structure. Another factor has been the way of land development, if at the potential border of these areas there has been an area unconnected with the building location (forest, agricultural), this area has not been classified as a compact building structure. As a rule, areas that obtained 8 points and more have been classified as areas with an developed functional and spatial structure (step 7.1) and other areas (step 7.2).

For designated areas, spatial absorbency has been determined using the Build-Out Wizard tool as part of the CommunityViz package (step 8.1, 8.2). On the basis of the parameters of the currently implemented buildings, detailed parameters describing the average plot area, the average percentage of buildings on the plot, the number of storeys and the average distance of the building from the road or the border of the area have been specified. The effect of using the extension tool has been determining the number of buildings, which can be maximally created on the free surface area, in a delimitation in various ways of development. This analysis has been so much more detailed that it included the geometry of the resulting reserves of areas. No plots have been designated in the area where the plot could not actually be built, e.g. a rectangle with a large disproportion of sides, too sharp angle at one of the peaks, etc. These assumptions are closely related to geometrical conditions of plots, which in practice are recorded in the real estate cadastre [15].

4. Spatial absorbency – pilot study
As a result of the analytical steps described in the method, the result of the evaluation was obtained (step 6), areas with a developed functional and spatial structure (step 7.1), and other areas (step 7.2).
Figure 2. a) Urban structure assessment, b) selected built-up area, and c) non built-up area

Land use classes for different functions have been selected on the basis of the municipal spatial policies and master plans, which correspond to the actual or planned use of the area for a specific function see Figure 2 a, b, c. In general, 9 classes have been separated, which can be further divided into two main groups: 1. settlement functions related to the allocation of land for housing development (residential buildings, mixed: residential/ multi-family buildings, mixed: residential buildings/services, multi-family buildings, farm buildings, mixed: residential buildings/farm buildings), 2. post-deployment functions, not related to the settlement of people (services, mixed: industrial / services). Both the areas for compact as well as outside the compact building structure were divided into the same types of land use.

Table 1. Spatial absorbency calculations for Jaworzyna Śląska municipality

| Type of land use area                      | Built-up area [m²] | Non built-up area [m²] | Total [m²]   |
|-------------------------------------------|--------------------|------------------------|--------------|
| residential buildings                     | 1 059 840          | 527 616                | 1 587 456    |
| mixed: residential/ multi-family buildings| 1 482              | -                      | 1 482        |
| mixed: residential buildings/service      | 46 640             | -                      | 46 640       |
| multi-family buildings                    | 7 902              | -                      | 7 902        |
| mixed: multi-family buildings/services    | 1 632              | -                      | 1 632        |
| farm buildings                            | 170 601            | 58 140                 | 228 741      |
| mixed: residential buildings/farm buildings| 7 308            | 61 380                 | 68 688       |
| services                                  | 35 444             | 104 929                | 140 373      |
| mixed: industrial/services                | -                  | 708 478                | 708 478      |
| **SUM**                                   | **1 330 849**      | **1 460 543**          | **2 791 392**|
Total absorbency for land intended for residential development is almost 1.3 million m². A big difference between the absorption capacity between different types of land use can be noticed. It results from disproportions in the number of separated new buildings and the area designated for this function. There is also a significant share of farm buildings in absorbency capacity in the built-up area, about 160,000 m². The total absorption for areas in compact structure building not intended for residential functions is almost 64 thousand m². The smallest value of absorbency from designated destination classes was mixed: multi-family buildings/services over 1.6 thousand m². From the sum of the values of both types of calculated usable areas, the total absorption of areas with a fully developed functional and spatial structure is 1 330 849 m² for all types of land use.

In the area outside the compact building structure, there are only 5 out of 9 all land use categories. In this case, the highest absorptive value was recorded with the function Mixed: industrial/service over 700,000 m². Mainly due to the fact that the planned municipality is planning to open one of the subzones of the Wałbrzych Special Economic Zone. A large share of the estimates of absorbency is also noticed in the case of areas of residential buildings, more than 530 thousand m². The next result was obtained by farm buildings of about 57 thousand m², which shows the disproportion of the size of individual results. As it can be seen, the collective value of the absorbency analysis for non-detached buildings is 817 147 m². However, for the whole analysis of areas outside the compact functional and spatial structure, the described absorbency estimate equals 1 460 543 m².

On the basis of the table 1, there is a considerable disproportion in the scale of the entire municipality between the absorbency for areas with a single-family housing function and other types of areas. The planning documents of this local government unit are mainly designated for such purposes in areas transformed from agricultural functions. Also, farmland areas have quite a large share in the absorbency capacity. As far as the general absorption of new buildings is concerned, it can be noticed that in areas with settlement functions, it is almost twice as large as outside them. The total capacity of new residential buildings expressed in the usable area of buildings is over 191 ha. While the acreage of the land, which can be built up in the area with a post-employment function, is over 88 ha. Hence, the total absorbency capacity of the whole Jaworzyna Śląska community for all described areas, in accordance with the provisions of the Act, is over 279 ha. This number expresses the maximum variant of potentially new buildings in usable space.

5. Discussion and conclusions

Estimation of the area's spatial absorbency is a new issue in Polish conditions, and due to the lack of implementing regulations defining the rules for conducting this assessment, and a small practice in its calculation, there is a need to develop guidelines that may constitute good practices in this area. The presented research is a contribution to the discussion on the ways of accomplishing the task imposed on local governments, covering issues related to spatial planning at the local level.

Due to the scope and detail of the analyses performed in this study, it can be considered that the chosen method has been more accurate than the existing studies in other municipalities. In this study, tools from the ArcMap program and its CommunityViz extension have been used, which facilitated the entire process of estimating spatial absorbency. In addition, in the applied expansion analysis, those surfaces have been rejected, on which, due to unfavorable geometry, a new plot cannot be physically isolated. Therefore, the performed calculations can be considered as more reflecting the actual potential of the community to locate new buildings. In this study, a greater level of detail been applied, because the calculations have been limited to providing potential usable space of new buildings in square meters of each of the existing land functions.

On the basis of the above-described method, an estimation of spatial absorbency has been performed in the community of Jaworzyna Śląska. In the area of the commune, over 279 ha of usable area of new buildings could be built. Approx. 50% of the land would be intended for housing development. Absorbency in areas outside the compact functional and spatial structure in comparison to the total result is almost 60%, mainly through a larger area of free land for investment. Such a large building potential in the analysed community is possible due to the large areas of plots and a high rate of their development.
In addition, the number of potential plots for development (3141) has been determined, out of which 3017 households could be separated, as well as the number of population that could settle in this area (about 9,000). It should be noted that according to the amended regulations, the absorbency value determines the maximum variant.

Developing methods of estimating the spatial absorbency in the municipalities has an impact on the process of spatial management. The use of the proposed calculation may prevent uncontrolled spread of housing functions, supporting the decision-making process of locating new buildings, as well as uncontrolled urban sprawl in suburban areas [16-19]. It also verifies the investment potential of the community and influences the estimation of the potential number of inhabitants in new households. As a result, the community can rationally use the area based on the principle of sustainable development [20]. In addition, proper development of areas reduces the expenses related to bringing the necessary technical infrastructure to new buildings, which are the expenses of local government unit [21]. Estimating the spatial absorption of communal areas can indeed have a positive impact on the quality of spatial planning across the country and improvement of the quality of life of residents [22] among others, through providing better quality resources [23-24].

State the objectives of the work and provide an adequate background, avoiding a detailed literature survey or a summary of the results.

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