The model of development of single-family housing areas and its application in urban planning

The main topic of the study is the development of single-family housing areas. The dissertation is based on a correlation study using multiple regression and artificial neural networks based on 72 residential areas covered by local spatial plans in the Poznań agglomeration, in the years 1993–2007. Their development and its determinants are analyzed from a perspective of 5, 10 and (whenever possible) 15 years. Finally, three case studies of single-housing plans are presented, based on the established regression model and supported by the study of spatial planning theory and local context.

The development of housing areas in agglomerations, beyond their inner center, is a process that requires special attention, since uncontrolled or improperly managed development can cause many negative suburbanization phenomena, including „urban sprawl”. This conclusion is confirmed by the report of the Supreme Audit Office². According to this report, space management in municipalities is assessed negatively due to spatial chaos and disorder. As one of the main reasons for this state, the report states the excessive dispersion of settlements caused by overestimation of future development. Such incomplete usage of housing areas generates higher service costs and significantly reduces the quality of living. It can be therefore deduced that the statutory analyses lack proper evaluation and an aware decision process.

Moreover, there is a deep need for understanding the influence of multiple spatial factors on the development of housing areas. Determining the effectiveness of development while maintaining a proper balance between natural and civilizational factors is a great challenge for science. The above considerations outline the issues of spatial development analyses in urban design and spatial planning.

In this context, this dissertation has two main goals. The first one is to explain the impact of local and supralocal factors on the development of residential areas. The second one is the creation of methods, techniques and tools for evaluating and forecasting of planning-related decisions. Their implementation is based on combining regression analysis with a study of issues related to planning theory and development of residential areas. This approach requires a complex research methodology which is reflected in the dissertation structure. After some basic assumptions made in the introduction, a subject-related study of the theory of urban planning is follows. Next, case studies selected from the subject literature, illustrating methods, techniques and analytical tools related to the dissertation’s field of study are introduced. This initial study depicts the lack of housing development analyses based on local conditions. The crucial regression analysis included in the dissertation is preceded by the subject study: single-family housing in local and supra-local statistics. This stage is of particular importance for the interpretation of the analyses’ results, their range of interpretation, and possible

application in future design practice. The following chapters focus directly on the chosen concept of the research and its subsequent application, starting from the presentation of the methodical structure, through the description of the explanatory study, to the application in urban design.

The aim of the research strategy was to collect a comprehensive research material and measure it in a highly organized way. Correlation analysis assumes a division into dependent and independent variables. The first, also called explanatory, describes development as the appearance of new buildings according to the adopted local plan at an interval of 5, 10, and 15 years. The dissertation adopted the basic dependent variable called "relative development level" which is the ratio of the difference in the number of buildings with a given function in the selected point on the time axis, from the moment of adopting the local spatial plan (5, 10, and 15 years) to the number of new buildings of a given type, derived from the regulations of the local spatial plan. The independent variables can be divided into two groups. The first one, the simple variables, can be directly measured on a quotient scale and the second one, the complex variables, are measured based on many factors described in detail in the dissertation. Their formulas are based on radial and multi-layer perceptron artificial neural networks. Finally, the regression model includes simple variables, such as: the distance from the agglomeration center measured in kilometers along roads, the housing area up to 600 meters away, the percentage of attached buildings in the local plan, and the percentage of buildings developed by a single investor. It also contains complex variables, such as the balance of natural resources, balance of nuisances, technical infrastructure, and access to strategic services and facilities.

In total, in the selected areas, the measurement concerned 958.3 hectares dedicated to residential plots with 3588 housing buildings already built. The areas are located in 9 municipalities: Czerwonak, Komorniki, MurowanaGoślinia, Oborniki, Rokietnica, Suchy Las, Szamotuły, and TarnowoPodgórne. The largest residential area included in the study has 89.2 ha, while the minimum size for consideration in the study was 2 ha. The average size was 12.8 ha. The basic source of information about building construction dates was the EGIB database and archival orthophotomaps, obtained both from CODGIK and available in the Google Earth Pro software. Additional data sources used for measuring dependent and independent variables were BDOT 10K databases, PODGIK Poznań service, obtained GESUT resources and a personal inventory. The data was processed with Esri ArcMap.

Regression analyses of the collected material allowed to establish a regression model. It allows to evaluate the development for 10 and 15 year samples to a significant degree. The model adjustment can be estimated at about 80%, according to the adjustment test. At the same time, the result for the 5 year sample can be considered a weak match, with a 55% adjustment. All models are statistically significant and meet the general assumptions of the multiple regression model. The phenomena closely related to spatial analyzes that could negatively affect the quality of the evaluation were examined as well. Both spatial heterogeneity and autocorrelation, and heterogeneity of time periods were verified. Moreover, a comparative test using artificial neural networks was performed.

The obtained results were discussed in the context of spatial situations and descriptive interpretation of processes, especially in cases with the largest disparity between the prediction and the real value. After the conclusions from regression analyses, the dissertation presents the concept of
using the regression model in spatial planning and urban design. This description contains a proposal for the entire procedure. It starts from collecting materials and measuring variables, and goes on to designing project solutions, their ongoing evaluation, and preparing a complete project with a detailed data summary and forecast. In local terms, the evaluation of design decisions using this model may lead, inter alia, to: the reconfiguration of functions, adaptation of designed elements of technical and communication infrastructure, public investment decisions regarding development, introduction of facilities and functions that increase attractiveness, remove nuisance, apply buffers separating the housing area from the nuisance, and reducing the housing area in a given location. At the same time, the obtained data is significant at a more general level of spatial planning, and on a supra-local level, since it may lead to: decisions concerning the suitability of an area for housing, reconfiguration of functional links between the analyzed area and dependent areas, coordinating designed elements of technical and communication infrastructure, decisions about conducting public investments outside the development area, decisions on revitalization of existing facilities and functions that increase attractiveness or introduce new ones outside the plan area, necessity to remove nuisances outside the plan area, introduce buffering elements operating in the analyzed area and its surroundings, and finally to take into account the actual demand for the housing function and its possible limitation.

The paper also introduces three case studies presenting the procedure of supported urban design with the original regression model. The first one is the area already covered by the local spatial plan in Szamotuly municipality. As part of the case study, an alternative project presenting three variants of development was proposed. The other two are areas not yet covered by local plans which are located in the municipalities of Oborniki and Rokietnica. In these cases, three variants were proposed. The first of them is automatically generated and it allocates the whole area for residential development. The second one is formed intuitively and only verified by the model. The last one was strictly driven by the regression model. These proposals were compared using the regression model and a detailed qualitative description. In the analyzed cases, compared to the option of dedicating the whole area to apartment plots, which appeared often among the 72 analyzed areas, the relative development level in variants supported by the model is up to two times higher. In all three projects presented in this paper, using the regression model, the estimated result parameters indicate that such solutions would be beneficial to landlords, potential residents, and the municipality alike. In those situations, the owners of the site were interested in selling plots for investments, and the number of completed investments, due to the 10 and 15 year forecast, would increase despite the reduction of the total area dedicated to single-family housing development. The proposed projects have improved living conditions, and reduced or eliminated nuisance. The profit for the municipality, with exception of the urban fee, is primarily a reduction of the number of scattered buildings, which, among other things, reduces the cost of implementing infrastructure obligations. In addition to these groups of interests, the benefits of the proposed solutions for the general public should be mentioned. Counteracting the negative processes of suburbanization described in the dissertation, including urban sprawl, can reduce pollution and the degradation of valuable natural areas. These examples indicate that the proposed concept of the regression model implementation supporting the design process.
directs the project towards the preservation of sustainable development principles and moreover, proves that all users of the space benefit from this solution. Therefore, this original regression model has a supportive, evaluative, informative, explanatory, and argumentative role.