The 9th International Conference "ENVIRONMENTAL ENGINEERING"
22–23 May 2014, Vilnius, Lithuania
SELECTED PAPERS
eISSN 2029-7092 / eISBN 978-609-457-640-9
Available online at *http://enviro.vgtu.lt*

Section: Sustainable Urban Development

The use of geoinformation in the process of optymalizing the use of land

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Abstract

Spatial planning as a typical example of decision-making, resulting in the term land use is a complex and lengthy process, and thus high-risk. All activities that occur at the level of land use must be reasonable and due to the need for sustainable development, and address the needs of the social, economic and environmentally conditioned. The most often encountered definition of optimal land use is that which causes the highest land value from among the physically possible and legally permitted forms of use, while remaining consistent with its function. Optimization of urban functions is to verify the function of the area's most mismatched and the proposal to convert them to fit the functionality most common features of natural and anthropogenic. Adaptation of problem areas should be based on the opinion of the inhabitants of the city, reflecting their current needs as well as on. economic calculation which takes into account possible revenue and cost of land transformation in terms of the characteristics of natural and anthropogenic. This paper presents a procedure for determination of the optimal states of land use as a tool in the urban space management process. The developed algorithm combines the basic rules of the social, economic and ecological optimization. This algorithm will help to determine the optimal land use function with clearly-defined actions necessary to perform the planned task. The aim is also to collect, systematize and develop an optimal set of geo-information describing the status of land use as a criterion for the evaluation as the basis for the transformation of land use. The result is a clean and simple scheme allowing for the transformation of land use and selection of the optimal use of land. The spatial use optimization procedure aims to minimize uncertainty in the spatial planning process. The proposed system can be used on different scales and with diverse degrees of detail of spatial analyses and with the so-called "spatial monitoring" to analyze and verify individual land management forms with regard to minimizing the costs of transformation and maximizing income.

Keywords: geoinformation; land use; optimization.

1. Introduction

Spatial planning of a town as a typical decision process as a result of which the land use is determined is a complex and long process and hence it involves high risk. Continual striving for obtaining new areas for housing development, search for new solutions for location of new investment projects, the need to determine the appropriate direction of development cause the need for using new methods that would support taking the decision on transformation of the space function. Multitude of characteristics of that space influencing its use causes the need for applying new methods supporting rational space management and represents the base for spatial planning of the town. Legal regulations and methods of town management require continual improvement of the planning methods by combining new scientific disciplines aiming at regulating the town development processes and mitigating conflicts that develop during the progress of such processes. Hence, all actions undertaken at the level of spatial management must be rational and must result from the need for sustainable development. They must also consider the social and economic needs as well as the environmental conditions. The need for sustainable development is the consequence of the innate striving of the man to maintain the natural order of the world, a certain „optimum", which allows development of humanity and, first of all, secures its survival. Optimisation of the urban space function aims at verification of the worst ill-fitting functions of the area and presenting proposals for replacing them with functions fitting the best the natural and anthropogenous characteristics present. Adjustment of problem areas (with the so-called non-urban functions) should be based on the opinions of town residents reflecting their current needs and on the economic calculation that considers the possible revenues as well as the costs of area transformation as concerns the natural and anthropogenous characteristics.

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http://dx.doi.org/10.3846/enviro.2014.110

2. Urban space function optimisation

The functional-spatial system of the town presents the distribution of areas occupied for specific uses (functions of the town) and proportions of those areas in relation to the total area of the town. This shows presentation of the functional-spatial structure from the perspective of the land use in the town. Knowledge of the space use forms allows investigating the spatial development of the town. It permits evaluation of the existing development status and determination of human activity contribution to the image of the given area [1]. The functional structure of town is defined as the system of dependences occurring in correlation with the multitude and complexity of activities that occur within its area. Time and space relations that develop between individual elements of urban space development become important [2].

Distribution of urban space use functions is the resultant of activities of various entities although it is not accidental. There are general rules that govern the development of that structure. Appropriate choice and distribution of areas in town allocated to different use functions is of major significance for satisfying the economic and functional needs. Hence, the areas division concept has the decisive influence on the spatial structure of every town.

In spatial management, the notion of optimisation is used in verification of the best (optimal) ways of land use. That verification covers first of all the issue of optimal spatial location of business entities and very often covers the areas of towns and their surroundings [3]. According to the dictionary of foreign words, the word optimisation originates from the Latin term „optimus" and literally means "the best". Expanding the interpretation, optimisation means obtaining the best (optimal) results in a discipline or mathematical determination of the most favourable solutions for complex issues [4].

The core of optimisation is that each fragment of space at a given time has the possibility of obtaining optimal status of use. However, presence of appropriate characteristics in a given fragment of space does not "force" the space to assume the appropriate status of use. It should only be stated that the probability of transformation of the current use towards the optimal use is the highest (maximal). By accident that use status can actually be achieved [3–5].

Aiming at development of the principles necessary for studying urban space function optimisation the survey of spatial preferences covering residents of Olsztyn was conducted. This survey was to provide answers to the following questions:

1. How important the space functions are to the needs of the town and its residents – choice of 21 functions.
2. Which of the natural characteristics of land are important for appropriate functioning of the urban space – choice of 30 characteristics.
3. Which of the anthropogenous land characteristics are important for appropriate functioning of urban space – choice of 38 characteristics [6–7].

Development of the matrix of correlations between the urban space functions and land characteristics was the consecutive stage. The matrix of correlations consists of 11 space functions, 13 natural characteristics and 23 anthropogenous characteristics of the land. In the cells of the matrix negative and positive values were positioned that inform about the power with which the given characteristic generates the need for including one of the eleven selected urban space functions in the analysed area. The summary score obtained from the columns of the matrix defines the value of probability while negative value of the score represents probability equal to zero. The function from the matrix obtaining the highest probability score will be the optimal function for the area studied. Negative and positive values in the matrix were determined using another questionnaire based survey where it was determined whether specified anthropogenous and natural area characteristics match the presented urban space functions. Table 1 presents the matrix of correlations between urban space functions and land characteristics.

Table 1. Matrix of connections of urban space functions (the land use function) with land features and with the present infrastructure. Source: [6]

No.	Urban space function / Land feature	*MN*	*MW*	*U*	*US*	*UC*	*P*	*ZP*	*ZC*	*WS*	*K**	*IT**
1	Electricity	8	8	9	8	8	10	0	5	3	4	10
2	Telephone	7	7	6	4	8	7	–8	3	–7	0	8
3	Waterworks	9	8	9	7	9	9	3	6	3	2	9
4	Sewage system	7	8	6	3	5	9	–6	1	3	3	8
5	Gas	7	8	4	2	4	8	–8	–2	3	4	9
6	Easy access by road	7	7	8	2	6	7	1	5	4	6	4
7	Railway	–10	–10	–7	–10	6	9	–9	–5	–8	9	9
8	Piers, beach	–7	–7	–6	8	–9	–10	0	–10	7	–8	–8
9	Restaurants	3	4	7	2	3	–7	1	–6	1	6	–9
10	Swimming pools	–5	1	4	8	4	–3	–7	–9	–7	–4	–1
11	Multi-family blocks of flats	–7	10	–2	–6	5	–4	2	–9	–8	–3	–7
12	Single-family houses	10	–8	–3	–3	–3	–9	5	–8	–9	–6	–8
13	Public buildings	–3	1	8	–9	2	–4	4	–7	–8	0	–5
14	Clubs, pubs	–6	3	7	1	4	–4	–8	–7	3	2	–4
15	Historical monuments	–9	–10	–7	–9	–6	–5	8	3	–6	–7	–7
16	Neighborhood with same function	3	2	–8	–6	1	8	–9	3	2	–4	3
17	Access to education	4	5	2	–6	1	–2	–9	–7	–9	3	–1

Continued Table 1

No.	Urban space function / Land feature	*MN*	*MW*	*U*	*US*	*UC*	*P*	*ZP*	*ZC*	*WS*	*K**	*IT**
18	Cinemas, theatres, cultural centers	–4	–3	6	–9	–5	–7	–7	–6	–8	3	1
19	Small floor space shops	4	4	10	3	–7	1	–4	2	–3	4	–1
20	Large format stores	–7	–5	1	–10	10	4	–10	–6	–9	9	5
21	Hard–surfaced roads	6	7	8	2	9	10	–3	9	–2	10	6
22	Cemeteries	–10	–10	–9	–10	–10	–10	2	10	–6	4	–2
23	Religious buildings	–1	3	–5	–3	–6	–2	4	9	–8	4	–6
24	Lake shorelines	–6	–10	–7	10	–9	–8	7	–9	10	–7	–8
25	Rivers and streams	–2	–7	1	4	–8	–4	3	–8	10	–6	–5
26	Canals and ditches	–10	–10	–10	–6	–4	1	–9	–1	7	5	4
27	Small standing waters	1	1	–5	6	–8	–4	4	1	6	–6	–7
28	Rows of trees	–4	–3	–6	–2	–1	–1	9	7	6	–6	1
29	Groups of trees, groves	1	–6	–9	6	–3	–1	7	3	6	–8	–1
30	Single trees	–2	–3	–3	4	–1	0	9	7	6	–6	3
31	Bush belts, hedges	3	3	5	–2	–1	0	10	7	6	3	2
32	Observation decks	–7	–8	–3	9	–8	–5	7	0	4	–7	–7
33	Southern exposure	5	4	–3	6	–5	–5	6	3	3	–10	–8
34	Western exposure	3	2	–4	5	–6	–5	3	3	3	–10	–4
35	No land slope	6	3	–3	–6	10	10	–3	6	–2	9	9
36	Small land slope	6	1	6	–3	5	7	5	7	4	8	8
	Sum of positive points	100	100	100	100	100	100	100	100	100	100	100
	Sum of negative points	–100	–100	–100	–100	–100	–100	–100	–100	–100	–100	–100
	Sum total	0	0	0	0	0	0	0	0	0	0	0

MN – areas of residential, single-family, MW – areas of residential, multi-family, U – areas of service – building, US – areas of sport and recreation, UC – areas of commercial buildings distribution with a sales area above 2000 m^2, P – areas of productive facilities, depots and stores, ZP – areas of the appointed green, ZC – Cemeteries, WS – areas of inland surface waters, K – areas of the transport, IT – areas of the technical infrastructure

Functions are optimized by the identification of land features present in the studied area and the probability of a given land use function occurring is determined on this basis. The sum obtained from the matrix columns specifies the value of the probability and a negative sign of the sum means a probability equal to zero. The function from the matrix which obtains the highest probability is the optimal function for the studied area. This function uses the maximum potential of the area, i.e. all features which positively influence its selection, with simultaneous minimization of costs.

3. Geoinformation use in the process of land use optimisation

Description of space that serves its analysis and evaluation must be based on geo-spatial data and use the language of geoinformation. Use of geoinformation as the technique of automated process of obtaining information about the surrounding world using remote sensing and photogrammetry techniques finds increasingly wide application in all types of spatial analyses [8]. Use of image geoinformation in evaluation of the status and possibilities for space development as well as analysis of mutual relations and dependences between areas representing different potentials may prove immensely useful tool in the terrain use optimisation process. Geoinformation allows appropriately early identification and location of possible spatial conflicts resulting from inappropriate space use. Appropriately early identification of such locations involving identification, taking the inventory, evaluation and valorisation of the space characteristics allows rational management of space around the developing town.

Aiming at optimisation of the urban space functions in Olsztyn:
1. the functions of urban space in Olsztyn was defined,
2. the so-called “non-urban” functions were located,
3. the problem (“non-urban”) functions were optimised [6–9].

Based on the data from site inspection and analysis of geoinformation it was determined that two “non-urban” type functions occur in Olsztyn. Those are agricultural areas and garden lots’ areas. Within the administrative borders of the city 11 agricultural areas and 8 areas of garden lots were identified. An example of land allocation optimisation procedure for selected areas is presented below. The areas selected for the analysis are situated in the north-western part of the city, within Redykajny estate identified by the symbol 1R (Fig. 1). Current way of land use area – agriculture and forestry.

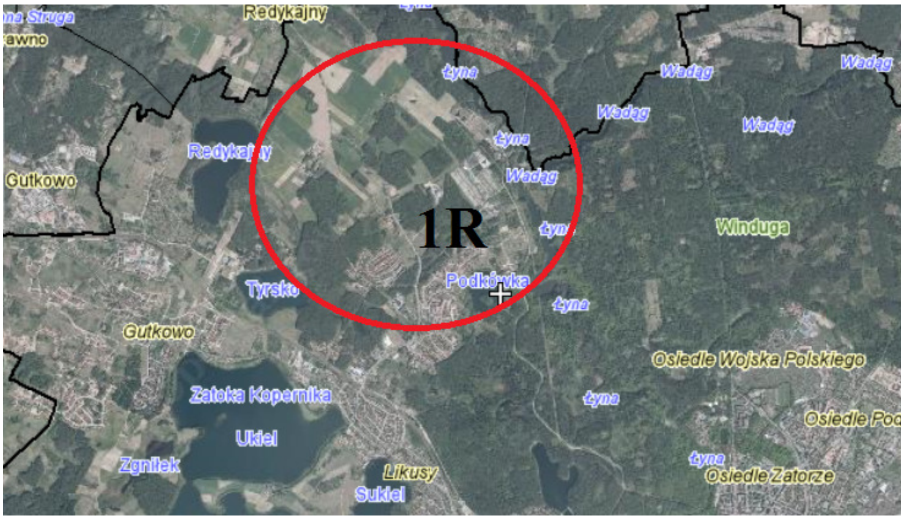

Fig. 1. Location area adopted for the analysis – 1R. Source: own elaboration

Based on the geoinformation obtained it was established that the agricultural area 1R (Fig. 2) situated around Lake Redykajny has access to electric power, water supply network, telephone network and that within its limits canals and melioration ditches, small areas of standing water, groups of trees and minor slope of land occur. In the nearest fields neighbouring the studied area residential multifamily and individual housing is present. The area is larger so neighbourhood of areas with the same function are present. There are also small usable area shops, churches and the shoreline of Lake Redykajny there.

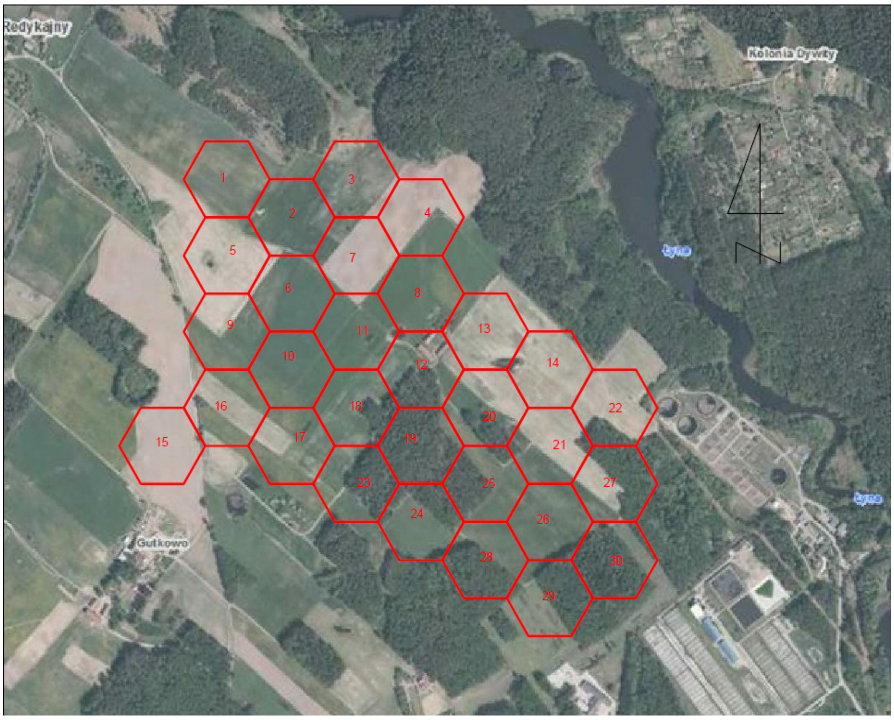

Fig. 2. Area adopted for the analysis – 1R divided into research fields. Source: own elaboration

Table 2 presents the matrix of correlations between the urban space function and the area characteristics of the analysed 1R area for field no 12. Optimal way of use this field, due to existing features of land is MN – areas of residential, single-family.

Table 2. Matrix of connections of urban space functions (the land use function) with land features and with the present infrastructure for field no 12

Lp.	Urban space function / Land feature	MN	MW	U	US	UC	P	ZP	ZC	WS	K	IT
1	Electricity	8	8	9	8	8	10	0	5	3	4	10
2	Telephone	7	7	6	4	8	7	–8	3	–7	0	8
3	Waterworks	9	8	8	7	9	9	3	6	3	2	9
8	Piers, beach	1	1	–5	6	–8	–4	4	1	6	–6	–7
10	Swimming pools	1	–6	–9	6	–3	–1	7	3	6	–8	–1
31	Bush belts, hedges	3	3	5	–2	–1	0	10	7	6	3	2
35	No land slope	6	3	–3	–6	10	10	–3	6	–2	9	9
6	Easy access by road	7	7	8	2	6	7	1	5	4	6	4
12	Single–family houses	10	–8	–3	–3	–3	–9	5	–8	–9	–6	–8
28	Neighborhood with same function	3	2	–8	–6	1	8	–9	3	2	–4	3
33	Southern exposure	6	7	8	2	9	10	–3	9	–2	10	6
34	Western exposure	–10	–10	–9	–10	–10	–10	2	10	–6	4	–2
	Sum	**51**	22	7	8	26	37	9	50	4	14	33

Table 3 presents the matrix of correlations between the urban space function and the area characteristics of the analysed 1R area for field no 30. Optimal way of use this field, due to existing features of land is ZP – areas of the appointed green.

Table 3. Matrix of connections of urban space functions (the land use function) with land features and with the present infrastructure for field 30

Lp.	Urban space function / Land feature	MN	MW	U	US	UC	P	ZP	ZC	WS	K	IT
29	Groups of trees, groves	1	–6	–9	6	–3	–1	7	3	6	–8	–1
31	Bush belts, hedges	3	3	5	–2	–1	0	10	7	6	3	2
36	Small land slope	6	1	6	–3	5	7	5	7	4	8	8
	Sum	10	–2	2	1	1	6	**22**	17	18	3	9

Table 4 presents the matrix of correlations between the urban space function and the area characteristics of the analysed 1R area for field 16. Optimal way of use this field, due to existing features of land is P – areas of productive facilities.

Table 4. Matrix of connections of urban space functions (the land use function) with land features and with the present infrastructure for field 16

No.	Urban space function / Land feature	MN	MV	U	US	UC	P	ZP	ZC	WS	K	IT
1	Electricity	8	8	9	8	8	10	0	5	3	4	10
2	Telephone	7	7	6	4	8	7	–8	3	–7	0	8
3	Waterworks	9	8	9	7	9	9	3	6	3	2	9
6	Easy access by road	7	7	8	2	6	7	1	5	4	6	4
7	Railway	–10	–10	–7	–10	6	9	–9	–5	–8	9	9
16	Neighborhood with same function	3	2	–8	–6	1	8	–9	3	2	–4	3
21	Hard–surfaced roads	6	7	8	2	9	10	–3	9	–2	10	6
28	Rows of trees	–4	–3	–6	–2	–1	–1	9	7	6	–6	1
34	Western exposure	3	2	–4	5	–6	–5	3	3	3	–10	–4
	Sum	29	28	13	10	40	**54**	–13	36	4	11	46

Optimal function for the analyzed area of Redykajny shown in Figure No. 3. From the geoinformation analysis indicate that optimal use of land for 14 field is a residential, single-family function. In this area it is also possible to introduce areas of the appointed green in 6 fields, areas of production facilities in six fields, cemeteries – 2 fields and areas of sport and recreation in one field. Analysis of the results of the optimization process confirms the need to change the function of the analyzed area. Current land development – agricultural or forested areas, no longer meets the expectations of the social and economic conditions.

Fig. 3. Optimal way of land use 1R. Source: own elaboration

Optimal states of space can be determined by analyzing the manner of development of areas designated in the process of spatial monitoring, i.e. qualitative and quantitative observation of the problem areas (conflict areas, “non-urban” areas). Optimization will indicate the directions for shaping spatial policy both on the scale of the whole city and in a particular district or a part of a district. Economic optimization will indicate how best to use natural and anthropogenic values of space and the current situation in the real estate property market. All information collected in the optimization process should become a tool in the creation of rational – optimal spatial management policy. Records analysis of valid planning documents in the area confirms the possibility of functions transformation. Optimal utilization of the area potential, defined in the optimization process will minimize the costs of transition.

4. Conclusion

Systems of spatial information as systems of obtaining, processing and access to spatial data and the accompanying descriptive information on objects identified within the given space facilitate significantly analyses of all types. The image geoinformation allows appropriate assessment of progressing changes as well as evaluation of the risk of presence of undesired space conditions. It also allows analysis of mutual relations and dependences between areas representing different potential, which proves immensely useful as the tool of spatial analyses. Geoinformation allows identification of the space characteristics that may have direct or indirect influence on the future possible status of the space. It also facilitates analysis of the influence of the individual spatial elements of the town on development of crisis situations.

The developed tool for selecting the optimal function may be useful in the process of space use plans development. It allows choosing the solutions that are the most favourable for the given area and elaborating solutions considering not only economic but also environmental aspects and human needs. Appropriately collected and interpreted geoinformation may form the base for efficient space management of which land use transformation is the main instrument.

References

[1] Korenik, S.; Słodczyk, J. 2005. *Podstawy gospodarki przestrzennej – wybrane aspekty*. Wydawnictwo Akademii Ekonomicznej we Wrocławiu, Wrocław.
[2] Chmielewski, J. M. 2004. *Teoria urbanistyki w projektowaniu i planowaniu miast*. Oficyna wydawnicza Politechniki Warszawskiej, Warszawa.
[3] Bajerowski, T. 2003. *Podstawy teoretyczne gospodarki przestrzennej i zarządzania przestrzenią*. Wydawnictwo Uniwersytetu Warmińsko-Mazurskiego, Olsztyn.
[4] *Słownik wyrazów obcych PWN*. Tokarski J. (red.). 1980. Państwowe Wydawnictwo Naukowe, Warszawa.
[5] Zukav, G. 1995. *Tańczący mistrzowie Wu Li*. Spojrzenie na nową fizykę. Dom wydawniczy REBIS, Poznań.
[6] Biłozor, A.; Jędrzejowska, K. 2012. Optymalizacja przestrzeni miejskiej – studium na przykładzie miasta Olsztyn, *Studia i Materiały Towarzystwa Naukowego Nieruchomości* 20(2).
[7] Renigier-Biłozor, M.; Biłozor, A. 2009. The significance of real estate attributes in the process of determining land function with the use of the rough set theory– pub, *Journal of the Polish real estate scientific society*. Olsztyn.
[8] Mróz, M.; Szumiało, M.; Mleczko, M. 2012. *Współczesna waloryzacja przestrzeni zurbanizowanej*. Pod red. Iwony Cieślak. Wydawnictwo UWM w Olsztynie.
[9] Biłozor, A. 2013. Development of a Decision-Making Algorithm for Determination of the Optimal Land Use Function, *Real Estate Management and Valuation* 21(3): 15–24. http://dx.doi.org/10.2478/remav-2013-0022