UPORABA TEORIJE BREZLESTVIČNIH OMREŽIJ PRI MODELIRANJU OMREŽIJ KRAJINSKIH ESTETSKIH VREDNOT NA URBANIH OBMOČJIH

THE USE OF SCALE-FREE NETWORKS THEORY IN MODELING LANDSCAPE AESTHETIC VALUE NETWORKS IN URBAN AREAS

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IZVLEČEK

Namen naloge je oblikovati model omrežja krajinskih estetskih vrednot, določiti njegove lastnosti ter oceniti uporabnost predlaganega pristopa modeliranja v urbanem okolju. Podatki o krajinskih estetskih vrednostih, ki smo jih potrebovali za vzpostavitev modela mreže, so bili zbrani na način, ki je primeren za urbana okolja. Modeli omrežij krajinskih estetskih vrednot so bili razviti na temelju šestih različnih povezav vrednosti: največje rasti v vrednosti, najmanjše rasti v vrednosti, največjega padca v vrednosti, najmanjšega padca v vrednosti, največje razlike v vrednosti in najmanjše razlike v vrednosti. Razporeditev vozlišč omrežja in povezave med njimi ustrezajo značilnostim brezlestvičnih omrežij. Ta empirična ugotovitev je podlaga za izvajanje simulacij sprememb strukture omrežij, prav tako omogoča modeliranje vedenja sistema. Ker je omrežje krajinskih vrednot brezlestvično, lahko prepoznamo vozlišča in središča omrežij ter simuliramo spremembe, ki se pojavijo zaradi odstranitve izbranega vozlišča, središča in spremembe ranga izbranega vozlišča na raven središča. Simulacije pokažejo, kakšne ukrepe bi lahko sprejeli, da bi optimizirali organizacijo urbaniziranega območja – tako za razvoj turizma kot drugih funkcij prostora.

ABSTRACT

The main aim of the research was to create models of landscape aesthetic network, to determine the character of those networks and to give a proposition of usefulness of the proposed modeling approach in the urban area. Landscape aesthetic value data which was necessary to create network models was collected using the method which is appropriate to urban areas. Models of aesthetic landscape networks were drawn on the basis of six ways of linking values: the maximal increase in value, the minimal increase in value, the maximal decrease in value, the minimal decrease in value, the maximal difference in value and the minimal difference in value. The distribution of nodes and links showed that the networks were scale-free. This empirical statement gives scientific basis to perform simulations of the changes in their structures, which in turn allows modeling certain behaviors of the system. While identifying the developed network models of landscape value as scale-free, the author identifies their nodes and centers, and simulates changes that occur in a given model as a result of removing chosen nodes, centers and elevating certain nodes to the rank of centers. Simulations show what kind of action can be taken to optimize the organization of the urbanized area, both for the development of tourism and other functions of the space.

KLJUČNE BESEDE

brezlestvično omrežje, model, krajina, vrednota, prostorsko planiranje, prostorske analize

KEY WORDS

scale-free network, model, landscape, value, spatial planning, spatial analyses

1 INTRODUCTION

One can mention two meanings of a "model" (Bajerowski et al., 2003). Firstly, a model is a pattern which can be used or should be used repeatedly, and copied. Secondly, a model is a simplified, rough version of a different item, object or structure. It can be a schematic reproduction of a single item or a whole group of items. Some features of the items are reproduced, especially those that allow to visualize the original properly enough (Bajerowski et al., 2003; Chojnicki, 1966). In the research presented below, the author applies to the second definition of a model, assuming that it is possible to build a model of landscape aesthetic values on the basis of data of the landscape aesthetics and the coordinates of the value. On account of the fact that the data (the values) make a connection network, the model has been described as a network model. Such presentation of the space features, modeling, allows them to undergo research, and among others, it enables the analysis of aesthetic values with the aim of designing an optimal use of the value potential or planning to improve landscape aesthetics conditions. The problem of landscape management of urban areas is constantly a present issue (Cieślak, 2012; Domański, 2011; Jansson and Lindgren, 2012; Lee and Oh, 2012). The concept to use the theory of scale-free network by Barabasi in order to create the conditions to rise the effectiveness of land development planning, for tourism and recreation, may serve as a solution.

2 SCALE-FREE NETWORKS

Albert - László Barabási was the first person who identified a network as scale-free. He discovered that the distribution of the Internet tele-information network nodes does not correspond to the usual distribution (Barabási, Réka and Hawoong, 2000). Barabási used his mathematical model of global network to analyze different phenomena and it turned out that the distribution of the nodes is untypical only for the Internet. In that way, it is possible to analyze many other social, technological or biological phenomena. Each phenomenon, which has a network structure, e.g. the connections of communication system, terrorists' connections or the connections of landscape aesthetic values, can be analyzed paying special attention to the nature of scale-free networks and their features. Examples of random networks and scale-free networks are presented in Figure 1 and Figure 2.

A)

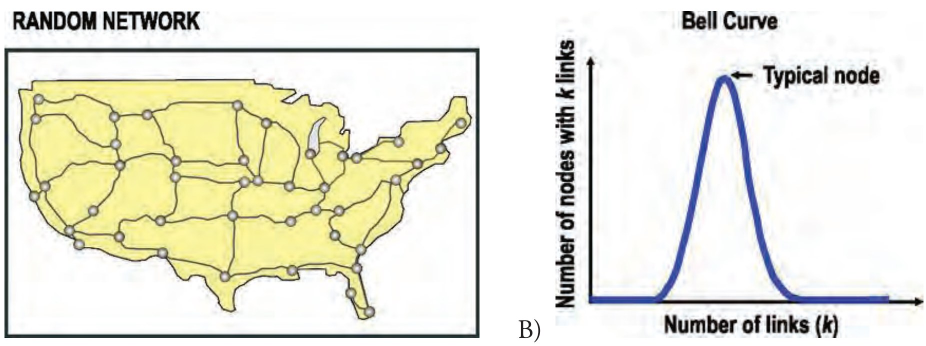


Figure 1: A) An example of random network – the system of roads in the USA. B) Poisson distribution. Source: Barabási, 2003, pp. 71.

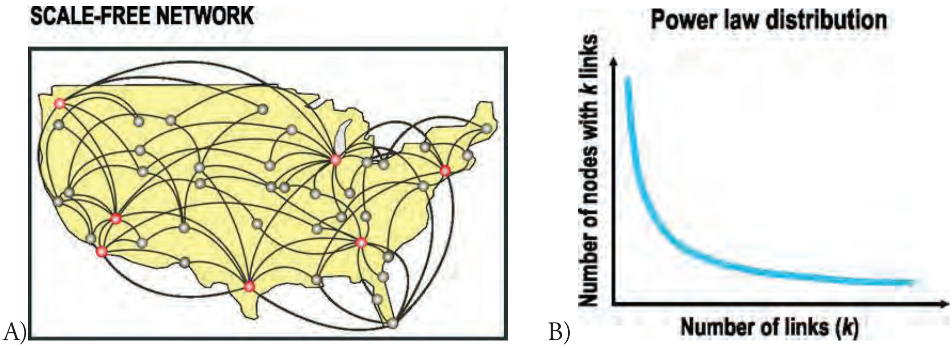


Figure 2: A) An example of scale-free network –the network of airline connections in the USA. B) Power series. Source: Barabási, 2003, pp. 71.

The general characteristics of scale-free networks can be described in several points (Barabási and Bonabeau, 2003; Barabási, 2001; Barabási , Réka and Hawoong , 1999, 2000; Cohen, 2002; Ercal and Matta, 2013; Li, Wang and Guan, 2014; Lou, S-L et al, 2013; Newman, Barabási and Watts, 2006; Yan, Ahmad and Yang, 2013; Yilmaz et al., 2013):

- the occurrence of hubs – the majority of nodes have few connections with others, whereas some nodes have a great number of connections. These nodes, called hubs, can have hundreds, thousands, or even million connections. In such a case, the networks distinguish themselves as scale-free.
- a great sensitivity to intentional "attacks" on hubs – scale-free networks are very sensitive to attacks organized intentionally on a given point – a network hub. An intentional attack on several hubs may lead to a total destruction of the network.
- resistance to random "attacks" – an accidental attack on a node does not have such a detrimental effect as it has on random networks. Owing to the composite structure, there are always some connections left that keep the whole network active.
- the scale-free networks are characterized by the phenomenon of the preferential choice of connections (in the increase of the real networks, the more developed nodes have more possibilities to establish connections. When a new node appears, it has a tendency to connect with nodes that have a large number of connections, and this favorable feature makes the nodes have more and more connections in contrast to the adjacent nodes that have fewer connections).
- the versatility of use – considering those features, the knowledge about the scale-free networks could be used in new fields of science.

Determining whether a network is scale-free is vital for understanding the behavior of the system. For the need of this study, one has analyzed mainly those features of scale-free networks that are connected with the sensitivity of the network to any changes made to its structure (Virtual Round Table on ten leading questions for network research, 2004).

3 A MODEL OF LANDSCAPE AESTHETIC VALUE OF URBAN AREAS

It isn't simply choice to select right method to assess landscape aesthetic value. As we can read: 'A few special landscapes may have 'universal' or 'outstanding' values, but almost all landscapes will be valued in multiple ways by those people who are closely associated with them. It is important that those making decisions affecting landscapes are aware of the potential nature and range of cultural values, particularly where these values are not accounted for using standardized landscape assessment techniques' (Stephenson, 2008). Different methods can be used to collect and evaluate the data necessary to create network models.

In researches which are presented in this article the data used for drawing up the aesthetic value network model of landscape has been obtained from the assessment of landscape aesthetic value using Wejchert's impressions curve method (Wejchert, 1974) modified by Bajerowski (Bajerowski et al., 2007; Kowalczyk and Strumiłło-Rembowska, 2009). This method was chosen because of its usefulness to evaluate landscape of urbanized areas. City landscape assessment cards have been used as well and described (Kowalczyk, 2012). Supplementing the Wejchert's method with the landscape evaluation cards positively influenced the evaluation process because of additional consideration of space features like noise or smell. The research has been conducted in Olsztyn – a city in the northeastern part of Poland, and a capital city of Warmia and Masuria province. The city area encompasses 87.9 km^2 (including inter alia: 11 lakes and over 18.5 km^2 of forests). The city values oblige to take actions concerning landscape management, development of tourism and recreation. As it has been assumed, the basic units represent the area of Olsztyn, and the values obtained in the process of landscape assessment have been ascribed to their centers – they differentiate the geographic space in the aspect of landscape value. As a result of the assessment, the aesthetical landscape value has been obtained and represented by units situated in specific places in the administrative limits of Olsztyn. 1336 unit values have been obtained, all having a precision geodetic localization (Figure 3). Detailed information about collecting data and evaluation of those processes is described in Kowalczyk's publications (2012, 2012a).

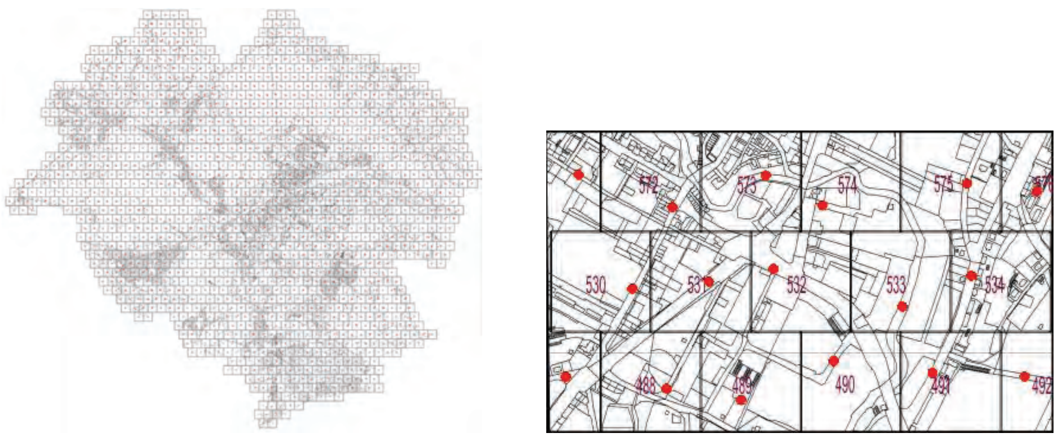


Figure 3: The researched area – Olsztyn city with basic unit grid of landscape aesthetic value and assessment viewpoints (red spots) marked on it.

Then the network models of landscape aesthetic value have been drawn. In the research, the network models of landscape aesthetic value have been drawn up using a simple algorithm of emerging spatially diverse regions that connect into networks according to six basic rules:

- on the way of the maximal increase in value;
- on the way of the minimal increase in value;
- on the way of the maximal fall in value;
- on the way of the minimal fall in value;
- on the way of the maximal difference in value;
- on the way of the minimal difference in value.

The network-node regions, meaning regions that are spatially distinguishable on account of network connections, are recently the leading form of spatial organization (Bajerowski and Biłozor, 2005). Therefore, the analysis of those networks is utterly important. Schematic deductive example of drawing up a network model according to the minimal increase in value rule is presented in Figure 4.

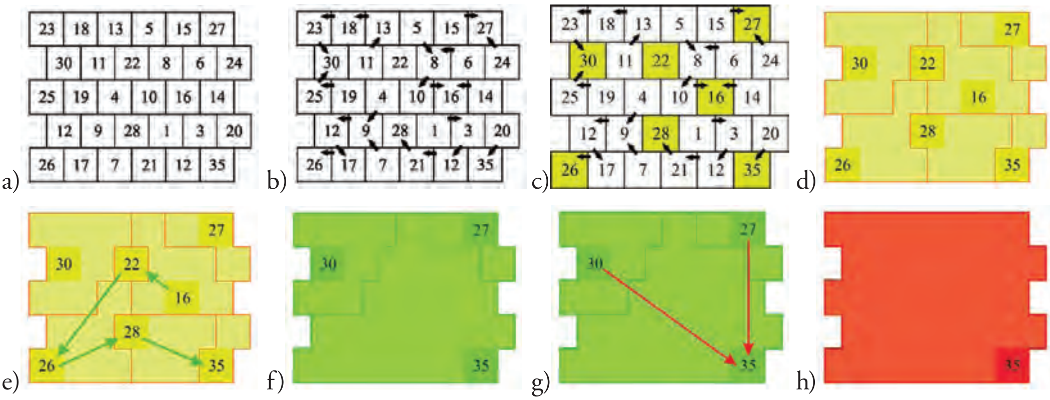


Figure 4: Schematic deductive example of drawing up a network model according to the minimal increase in value rule: a) basic fields of assessment with illustrative values; b) the initial step of combining values in the way of minimal increase; c) the first level of aggregation: yellow fields – nodes of newly-formed "regions"; orange lines – the borders of those "regions" d) the first level of aggregation; e) combining values in the way of minimal increase on the second level of aggregation; f) the second level of aggregation; g) combining values in the way of minimal increase on the third level of aggregation; h) the third level of aggregation.

Analogically to the illustration presented above, the network models of landscape value have been drawn. Consequently, the diagrams presenting spatial diversity of landscape aesthetics in Olsztyn have been acquired according to the six proposed ways (Figures 5, 7, 8, 10, 11, 12). In each created model, one can distinguish nodes and hubs which, depending on the rules proposed for decision-making, differ in character. For the purpose of the subsequent analyses, hubs and nodes diversify into:

- positive hubs – nodes of the highest order and of the highest set values (formed in the way of the maximal increase in value),
- negative hubs – nodes of the highest order and of the lowest set values (formed in the way of the maximal fall in value),
- hubs – nodes of the highest order that can assume different set values (in the way of the minimal difference in value),
- positive nodes – nodes formed on the way of the maximal and minimal increase in value, however, lower in hierarchy than the positive hubs formed in the lower levels of aggregation.
- negative nodes – nodes formed on the way of the maximal and minimal fall in value, however, lower in hierarchy, than negative hubs formed in the lower levels of aggregation.

— nodes – nodes formed on the way of the maximal and minimal difference in value, however, lower in hierarchy than the hubs formed on lower levels aggregation.

It has to be underlined that terms "positive" and "negative" are used with reference to landscape aesthetics.

Linking the basic fields according to the way of the **maximal increase in value**, one received:

— 136 new regions on the I level of aggregation;
— 18 new regions on the II level of aggregation;
— 5 new regions on the III level of aggregation and
— 2 new regions on the IV level of aggregation.

The diagram of the received landscape value network model according to the analyzed way is shown in Figure 5.

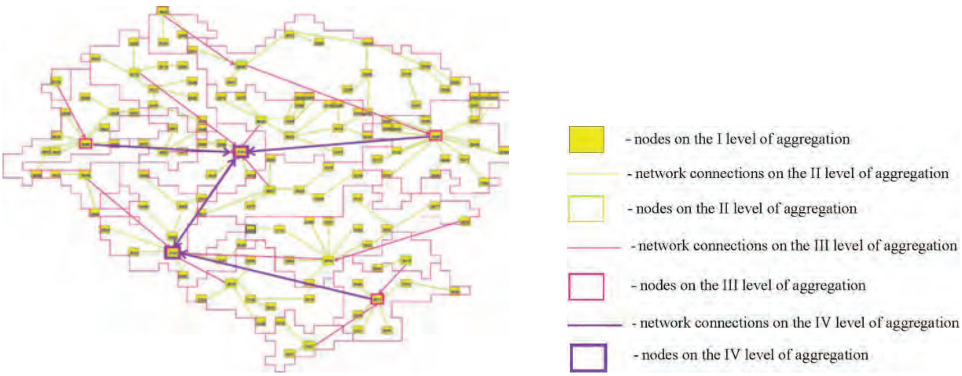


Figure 5: Network model of landscape value generated according to the way of the maximal increase in value.

In the network model formed on the way of the maximal increase in value, one can distinguish two positive hubs. They were formed on viewpoint 297 and on viewpoint 862. Both viewpoints have the same highest number of points of landscape aesthetic value assessment. They are the viewpoints from where the most beautiful view spreads (Figures 6a and 6b).

a)  b) 

Figure 6: A photograph taken on viewpoint: a) 297 and b) 862, in which the two positive centers has been formed on the way of maximal increase in value.

As a result of the aggregation of the fields of the **minimal increase** in value, one has received:

- 196 new regions on the I level of aggregation;
- 41 new regions on the II level of aggregation;
- 8 new regions on the III level of aggregation;
- 2 new regions on the IV level of aggregation.

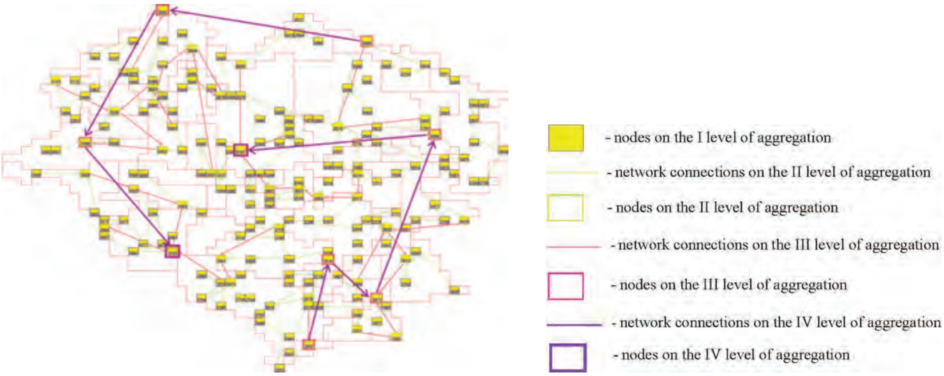


Figure 7: A network model of landscape value generated according to the way of minimal increase in value.

The network model formed on the way of the minimal increase in value is very similar to the model analyzed above. Similarly, the model has the same two positive hubs (viewpoint 297 and viewpoint 862, Figure 6a and 6b).

Linking the basic fields according to the way of the **maximal fall** in value, one has received (Figure 8):

- 141 new regions on the I level of aggregation;
- 25 new regions on the II level of aggregation;
- 3 new regions on the III level of aggregation;
- 1 new region on the IV level of aggregation.

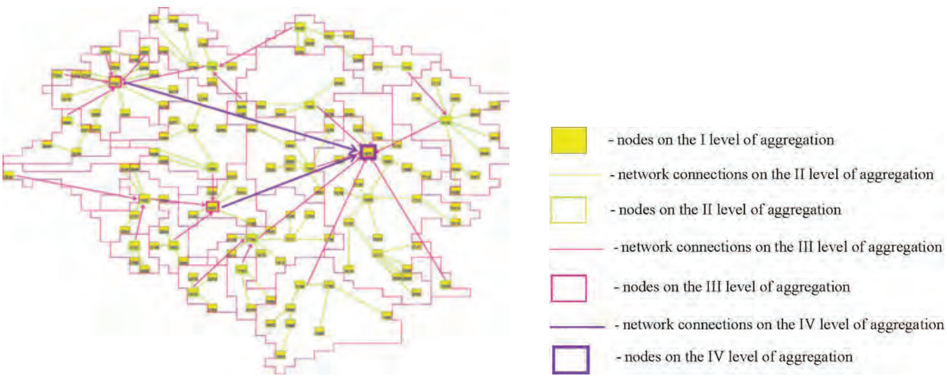


Figure 8: Network model of landscape value generated according to the way of the maximal fall in value.

The network of maximal fall in value has generated one negative hub of the lowest value of assessment of 1670 viewpoints, on the viewpoint 875 (Figure 9).

Figure 9: A photograph taken on viewpoint 875, in which a negative center has been formed on the way of the maximal fall in value.

As a result of linking the fields of **the minimal fall in value**, one has received (Figure 10):

- 183 new regions on the I level of aggregation;
- 39 new regions on the II level of aggregation;
- 9 new regions on the III level of aggregation;
- 1 new regions on the IV level of aggregation.

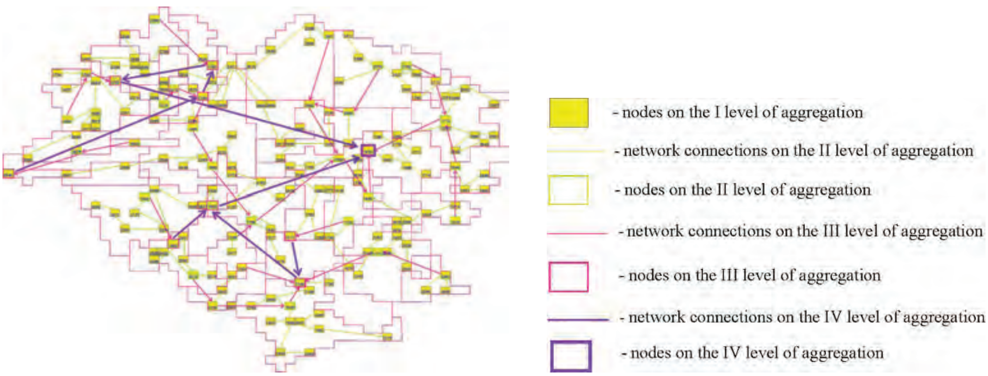


Figure 10: Network model of landscape value generated according to the way of the minimal fall in value. Sources: own study.

The model drawn up in the way of the minimal fall in value has a very similar structure to the model presented above, although it is more complex. Here as well, one negative hub has been formed – the same as the one presented above (viewpoint 875, Figure 9). Both models formed as a result of the minimal and maximal fall in value show the way in which the aesthetic landscape value lowers. Those areas should be avoided by tourists or local people and strollers, though it will not change the existing condition. Therefore, the model shows the areas requiring deliberate elimination by the change of aesthetic landscape value. The above-described models include the extreme hubs. The ways of their formation and diversity end in the highest and the lowest values. The ways of value increase show how to reach the most attractive view, and the ways of value decrease show how to reach or bypass the least attractive view.

A different situation can be observed in the case of the network model generated according to the way of maximal difference in value and the minimal increase in value. Those two network models differ greatly from each other and from the previously analyzed models. The way of their formation is more complex, especially in the way of the minimal difference. The model developed according to maximal difference in value shows how to move in the space to change the value of aesthetic view in a maximal way. This model should be used, among others, in verification of planned and existing tourist trails. It shows which connection should be avoided in the process of designing routes of sightseeing and walking alleys.

Linking the basic fields according to the way of **the maximal difference** in value, one has received (Figure 11):

— 147 new regions on the I level of aggregation;
— 28 new regions on the II level of aggregation;
— 6 new regions on the III level of aggregation;
— 2 regions on the IV level of aggregation.

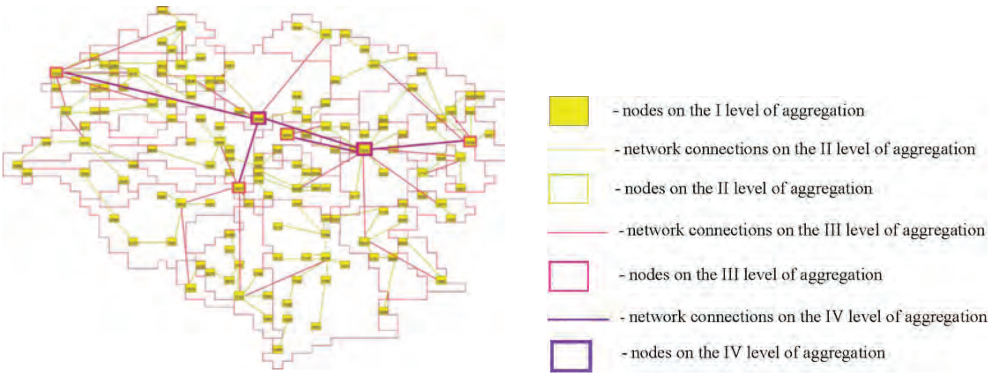


Figure 11: Network model of landscape value generated according to the way of the maximal difference in value.

As a result of linking the fields of the **minimal difference** in value, one has received (Figure 12):

— 273 new regions on the I level of aggregation;
— 94 new regions on the II level of aggregation;
— 25 new regions on the III level of aggregation;
— 13 new regions on the IV level of aggregation;
— 6 new regions on the V level of aggregation;
— 3 new regions on the VI level of aggregation;
— 1 new region on the VII level of aggregation.

The network model formed in the way of the minimal difference in value is the most complex network in comparison to the ones that have already been described.

Hubs and nodes should represent areas with satisfying views and additionally having other advantages. The process of projecting – inter alia – walking alleys and optimization of touristic space organization in a given area is an example of utilizing a network model of landscape aesthetics. In the author opinion, the minimal increase in value model supports that process most accurately.

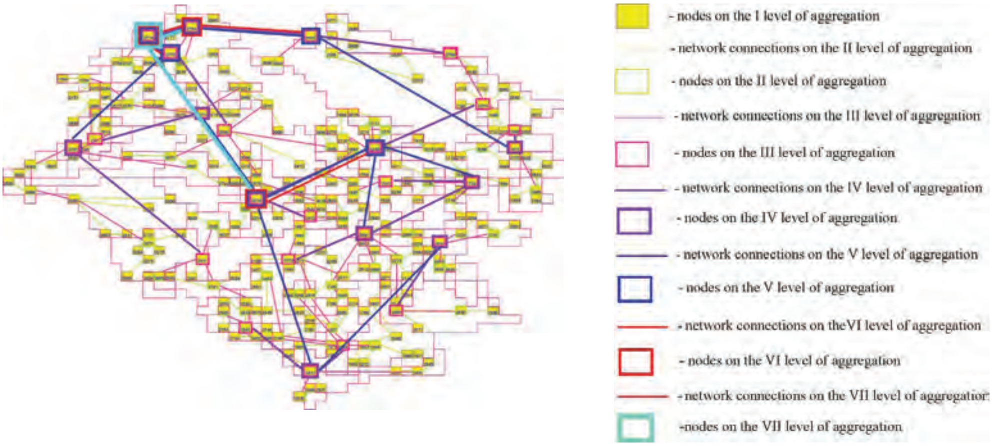
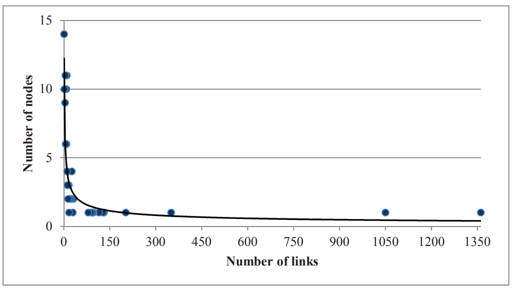


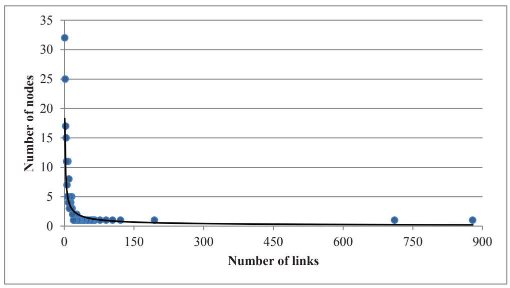
Figure 12: Network model of landscape value generated according to the way of the minimal difference in value.

4 THE ASSESSMENT OF NETWORK NATURE

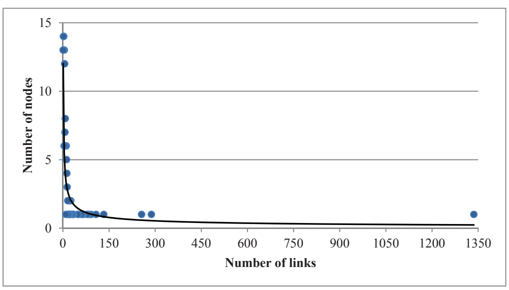
In such organized network, one has counted the number of connections assigned to each node of the network on each level of aggregation. Additionally, one has determined the "character" of those connections (Graphs 1-6).



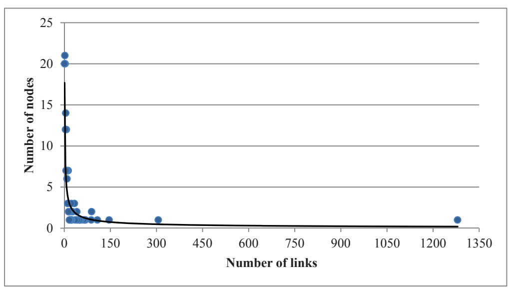
Graph 1: A distribution of spatial connections network according to the rule of the maximal increase in value. The y-axis - number of nodes (view points) and x-axis - number of links.



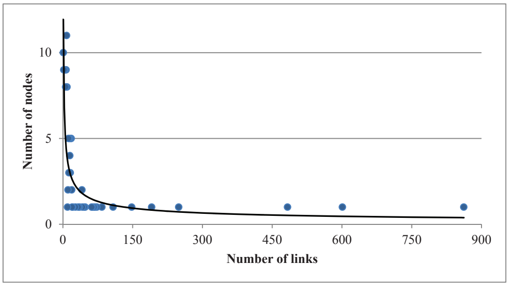
Graph 2: A distribution of spatial connections network according to the rule of the minimal increase in value. The y-axis - number of nodes (view points) and x-axis - number of links.



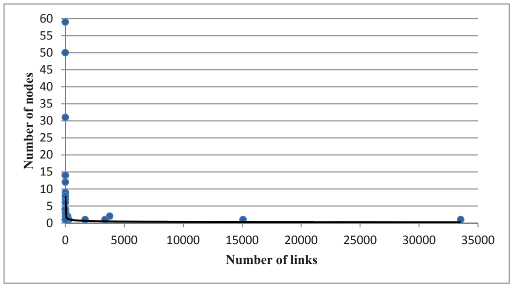
Graph 3: A distribution of spatial connections network according to the rule of the maximal fall in value. The y-axis - number of nodes (view points) and x-axis - number of links.



Graph 4: A distribution of spatial connections network according to the rule of the minimal fall in value. The y-axis - number of nodes (view points) and x-axis - number of links.



Graph 5: A distribution of spatial connections network according to the rule of the maximal difference in value. The y-axis - number of nodes (view points) and x-axis - number of links.



Graph 6: A distribution of spatial connections network according to the rule of the minimal difference in value. The y-axis - number of nodes (view points) and x-axis - number of links.

On accomplishing the analysis of the results, it has been stated that the distribution of the connections did not have an isolated maximum (which is characteristic for random networks; Barabási, 2003), but it has been described by the increasing function, which means that there is the power series distribution of the connections. On the basis of that one can state that the network is scale-free. According to the suggested decision-making regulations, several central nodes have appeared in the researched area. Considering that, the networks have proved to be scale-free. Due to the nature of the analyzed networks, their features can be used to identify landscapes that ought to be particularly preserved and reinforced, as well as those that require changing.

5 THE USE OF THE MODEL – SIMULATION

The relation between landscape aesthetic values has been the basis for forming the connections between particular points. On the way of the aggregation, a sort of nodes hierarchy has been highlighted. On given levels, the major nodes have formed as many connections as there has been the number of minor nodes in the area they affected. As a result, one could distinguish nodes and hubs of the network model described in chapter 3.

The simulations aim to illustrate the behavior of the network model in the case of the interference in its structure. To conduct the simulation, one has chosen a network formed on the way of the minimal increase in value.

In the theory of scale-free networks, one of the basic features of the networks is their resistance to random attacks and sensitivity to intentional 'attacks' on hubs. Devastation of nodes or centers can be done through cutting off the possibility of observation of the landscape, both by the physical destruction of the space or prevent access to the observation of view. As it is shown on the simulation below (Figure 13), a random attack on a hub does not have such a destructive influence on the network as the attack on the hub has (Figure 14). Owing to the composite structure, there are always some connections left that keep the whole network active. However, an intentional attack on several hubs may lead to a total destruction of the network. The hubs, as the most crucial hubs in a network, link almost everything together. A node damage in the analyzed network model is presented in Figure 14.

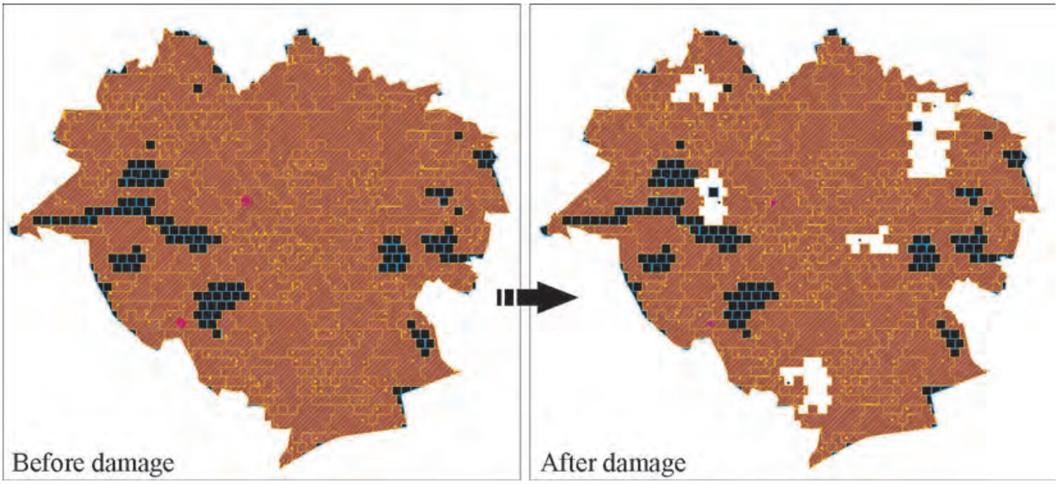
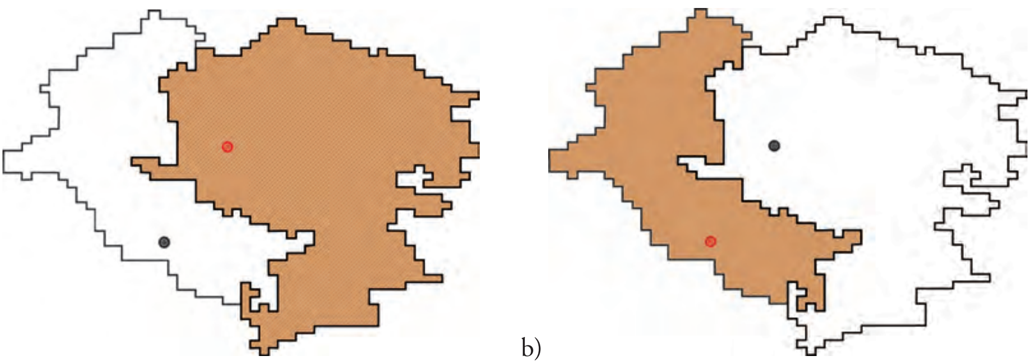
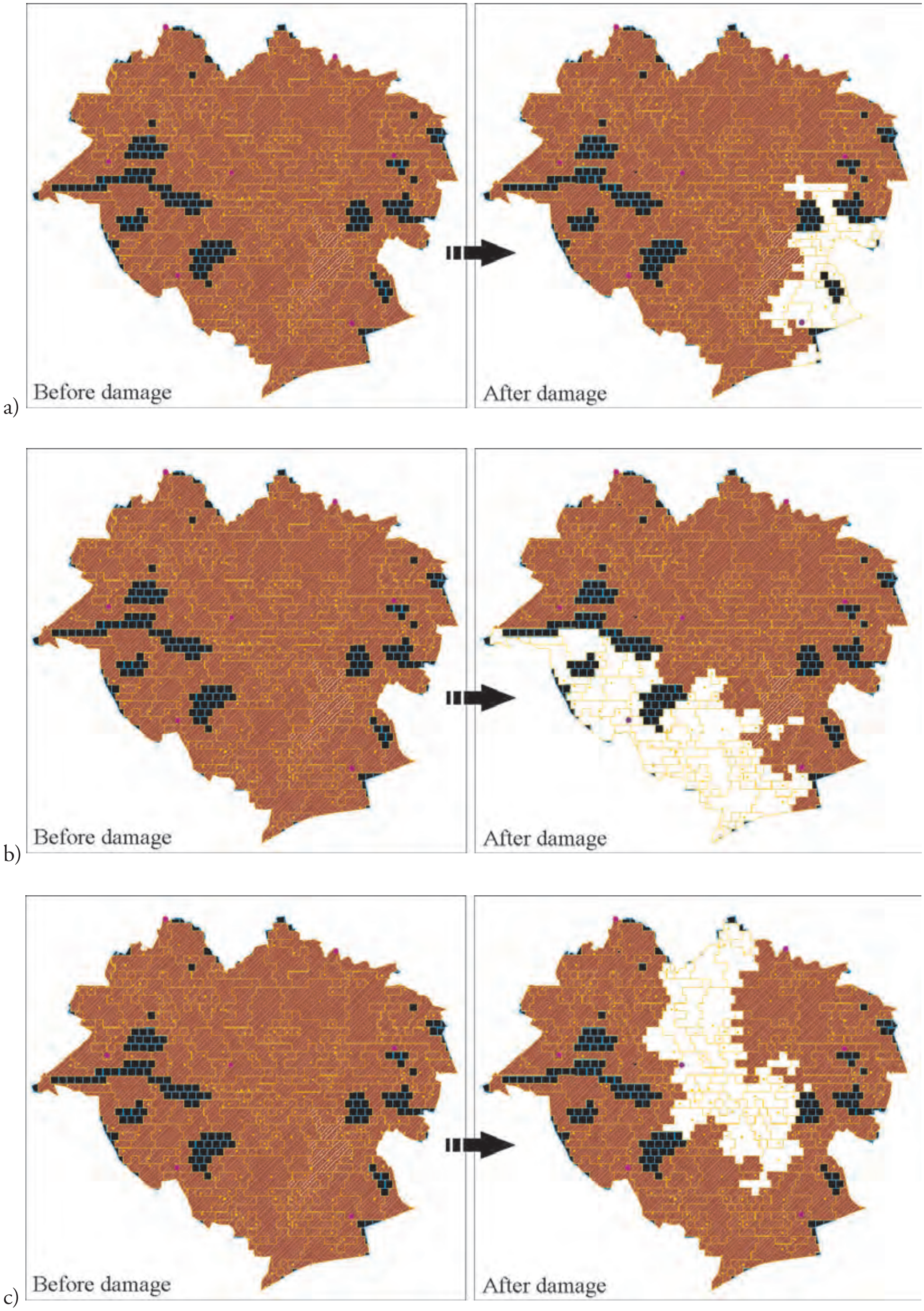


Figure 13: A damage of five random nodes in a scale-free network received on the way of the minimal increase in value. Legend: - borders of the areas of nodes connections influence, - centers in the network model, - nodes in the network model, ■ - areas excluded from the research; no-entry and inaccessible areas (e.g. military areas, lakes, factories), - areas in which the connections (the structure of the network) will be destroyed if a node is damaged, - damaged nodes.



a) b)

Figure 14: a) A damage of the first hub in a scale-free network model received on the way of the minimal increase in value. b) A damage to the second hub in a scale-free network model received on the way of the minimal increase in value. Legend: - borders of the areas of nodes connections influence, - centers in the network model, - areas in which the connections (the structure of the network) will be destroyed if a node is damaged, - damaged centers.


a)
Before damage
After damage
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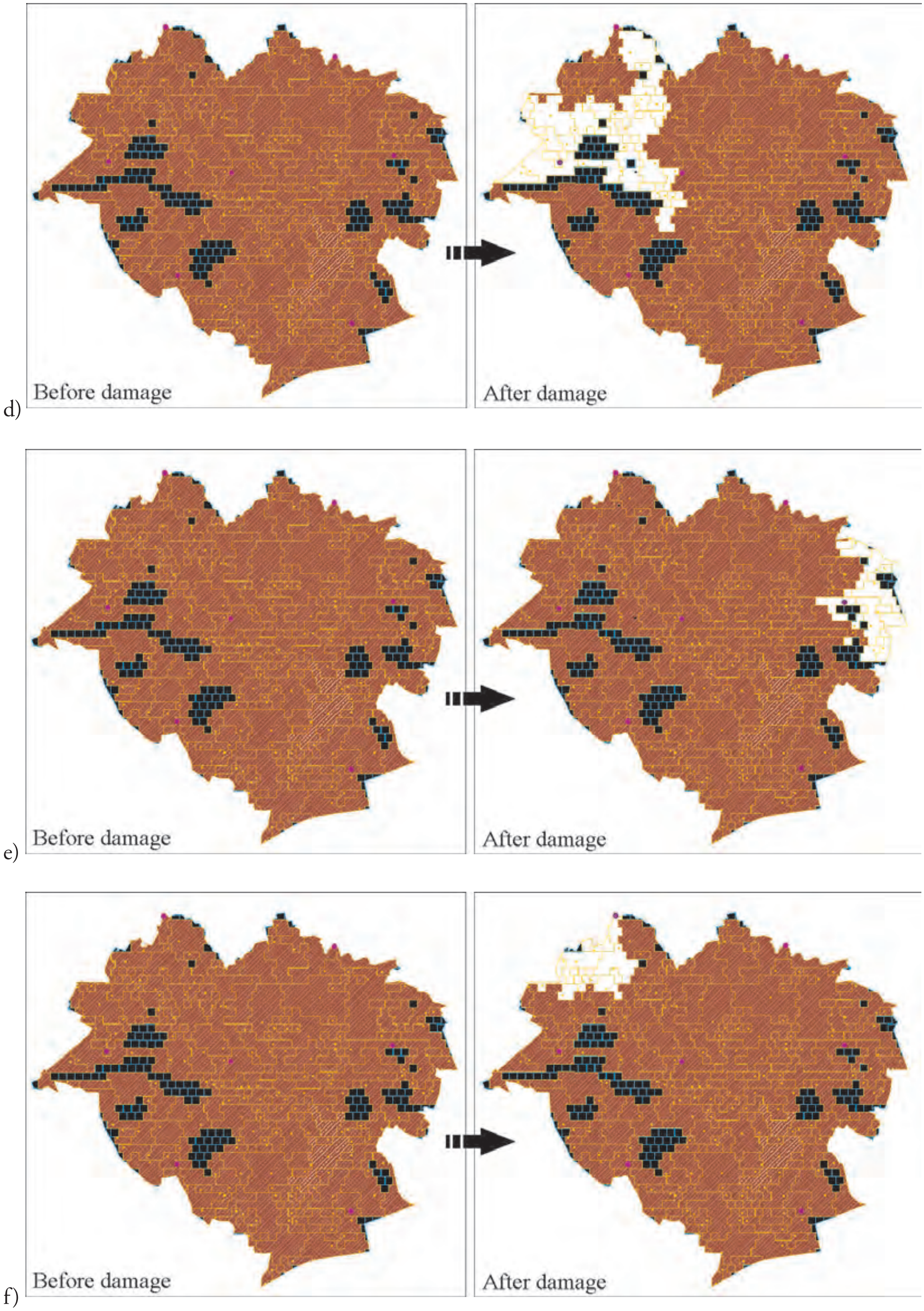
c)
Before damage
After damage


Before damage
After damage
d)
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e)
Before damage
After damage
f)

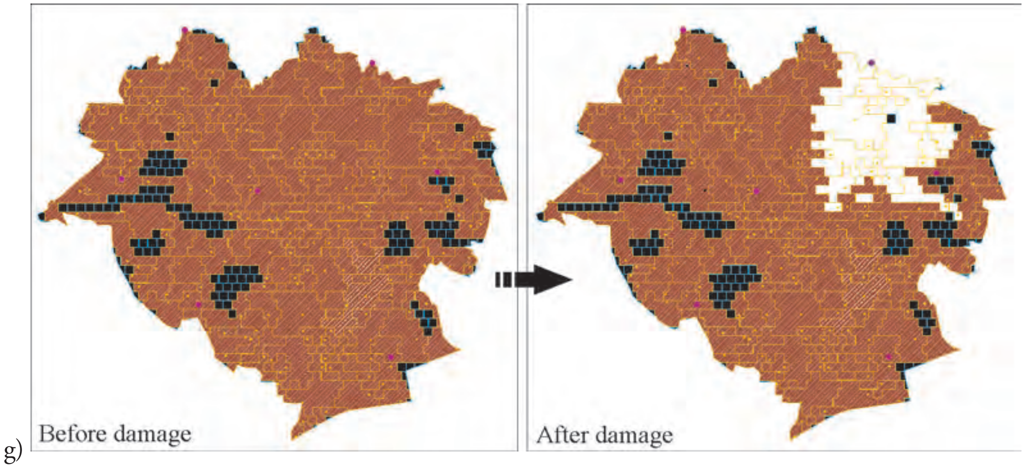
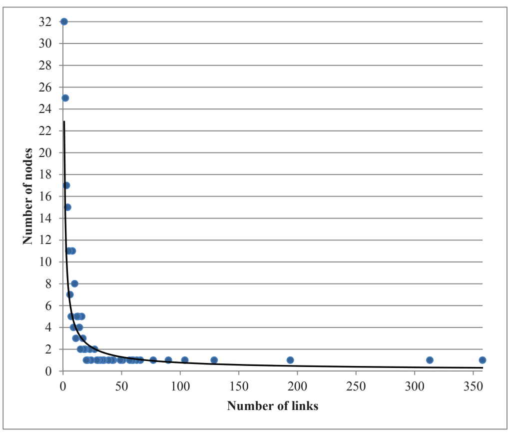


Figure 15: Simulation of an attack on the hubs of a scale-free network received on the way of the minimal increase in value, after increasing the degree of the scale-free nature of the network (on the way of generating new hubs). Numbers of hubs: a) 129, b) 297, c) 862, d) 896, e) 980, f) 1527, g) 1483. Legend: - borders of the areas of nodes connections influence, - centers in the network model, - nodes in the network model, - areas excluded from the research; no-entry and inaccessible areas (e.g. military areas, lakes, factories), - areas in which the connections (the structure of the network) will be destroyed if a node is damaged, - damaged centers.

The hubs influence zone, in comparison to the nodes influence zone, is immense. The influence can be compared to the role of service or the power of influence of a beautiful landscape on a given area. Further, the author has increased the degree of scale-free nature of the analyzed network model and checked what result would be achieved. The simulation of the "increase of the degree of the network scale-free nature" and the elimination of given hubs is shown in Figure 15. The process has consisted in adding five additional hubs to the analyzed network by changing the landscape's value. The value has been increased to the level of the value of the existing hubs. The selected nodes are characterized by the high landscape aesthetic value and they have the potential to become hubs.



Graph 7: A distribution of hubs and connections in a network model received on the way of the minimal increase in value – a simulation of adding hubs. The y-axis - number of nodes (view points) and x-axis - number of links.

In order to determine if the nature of the newly created network model, in the sense of "not being a scale", did not change, one has counted the number of hubs and nodes in the same way it was counted during forming the previous models, and determined the distribution of nodes and links. Similarly to the previous cases, the distribution has not had an isolated maximum and it has been described by an increasing function (power series distribution). The relation is shown in Graph 7.

6 CONCLUSION

To summarize the conducted studies, it can be stated that the main goals have been achieved. On the basis of landscape aesthetic value data, the landscape aesthetic value models have been created on the tested area.

1336 pieces of input data about landscape aesthetic value were used to create the model. Because of the extensiveness of the issue, the methods of landscape aesthetic value evaluation and the rules of collecting input data were described as a separate issue (Kowalczyk, 2012, 2012a). The models were created in the six ways: the maximal increase in value, the minimal increase in value, the maximal decrease in value, the minimal decrease in value, the maximal difference in value and the minimal difference in value. In such organized network models, the distribution of connections and nodes of the network was determined as the one following the power-law, which is characteristic of the scale-free networks. On that basis, the features of those networks were used to simulate changes in their construction, and thus to model the aesthetic value of the landscape. The simulations were made on the landscape aesthetic value model which had been created in the way of the minimal increase in value. The validity of choosing this model from the six available comes from the fact that it offers an optimal management of the aesthetic value of landscape. The conducted research shows that the model created in this way uses the entire potential of landscape in network connections, e.g. it connects gradually (not directly) an unattractive point with the most attractive point (center). Firstly, the simulation of an accidental damage of the nodes in the network model was done. This simulation showed that the structure of the network was not considerably destroyed and its durability was retained. The next step was to conduct the simulation of intentional damage of centers which were identified in the network model, one after another. A significant breakdown of the network structure and its dis-functions, due to the destruction of its most important connections, were observed. The next step was to simulate adding five centers to the network and repeating the simulation of damaging those centers. After adding the centers to the network model, better resistance to damages of the network structure was observed. The responsibility of having high landscape aesthetic value was divided. Damages of one center resulted in other centers taking over its functions. As a result of the analysis of the above-mentioned simulations, it has been stated that the network with a higher number of hubs is more stable. Damages, or even temporary exclusions (e.g. shutting the node due to a cycling race or road repair) in such network have less destructive effect on its structure. Forming new hubs, maintaining and "improving the old ones" will positively influence the aesthetics of a city and development of tourism. The development of new hubs, in the selected places of positive hubs, would be connected with the process in which landscape would undergo effective aesthetic changes.

In the networks, the negative hubs have been highlighted. The hubs ought to be "destroyed" through improving the aesthetics of those places. The transpositions would be based on the management of the information about those places. The network models illustrate the relations of landscape aesthetic value and the same time indicates which land ought to be changed so that its use is optimal (determining a proper function). They are the base for conducting further research, e.g. modeling walking alleys and touristic routes, modeling the space in order to improve landscape aesthetics in the city, etc. Those problems and this method verification were partly presented in the publications which describe the tourist information signature map and an iconic model (Kowalczyk, 2012, 2012a). The tourist information signature map shows how to move in the city space in the way that aesthetic value of the landscape will be raising; where we can start our trip and end up in the most beautiful place. The map can be used to explore the whole city space but also to see some selected parts. It is relevant that during sightseeing the aesthetic value of landscape is rising, pleasing the visitors. Others method, which the author was familiarized with, did not consider such a solution. The drawn up network method can solve the problem of the improper management of landscape potential in the selected area. Research showed that landscape aesthetic network models can be a useful tool (procedure) in landscape aesthetic value management and space planning processes.

References:

Bajerowski, T., Bal A., Biłozor A., Gerus-Gościewska M., Sidor I., Szurek M., Turkowska O., Wielgosz A. (2003). Podstawy teoretyczne gospodarki przestrzennej i zarządzania przestrzenią. Poland, Olsztyn: Wydawnictwo Uniwersytetu Warmińsko-Mazurskiego w Olsztynie.

Bajerowski, T., Biłozor, A. (2005). Theory of Barabási scale-free networks as a new tool in researching the structure and dynamics of regions, Committee for Spatial Economy and Regional Planning; Studia Regionalia, 15, Poland, Warszawa: Polish Academy of Science.

Bajerowski, T., Biłozor A., Cieślak I., Sanetra A., Szczepańska A. (2007). Ocena i Wycena Krajobrazu. Poland, Olsztyn: Educaterra.

Barabási, A.-L. (2001). The physics of the Web. http://www.barabasilab.com/pubs/CCNR-ALB_Publications/200107-00_PhysicsWorld-PhysoftheWeb/200107-00_PhysicsWorld-PhysoftheWeb.pdf, accessed: 18. 8. 2014.

Barabási, A.-L. (2003). Linked. USA: Penguin Group.

Barabási, A.-L., Bonabeau, E. (2003). Scale-Free Networks, Scientific American, 50-59.

Barabási, A.-L., Réka, A., Hawoong, L. (1999). Mean-field theory for scale-free random networks. Physica A: Statistical Mechanics and its Applications, 272(1-2), 173–187. DOI: http://dx.doi.org/10.1016/s0378-4371(99)00291-5

Barabási, A.-L., Réka, A., Hawoong, L. (2000). Scale-free characteristics of random networks: the topology of the world-wide web. Physica A, 281(1-4), 69–77. DOI: http://dx.doi.org/10.1016/s0378-4371(00)00018-2

Chojnicki, Z. (1966). Zastosowanie modeli grawitacji i potencjału w badaniach przestrzenno-ekonomicznych. Studia KPZK Polish Academy of Science, 14.

Cieślak, I. (2012). Współczesna waloryzacja przestrzeni zurbanizowanej. Poland, Olsztyn: Wydawnictwo Uniwersytetu Warmińsko-Mazurskiego w Olsztynie.

Cohen, D. (2002). All the word's a Net. New Scientist, 174, 2338, 24–29.

Domański, R. (2011). Gospodarka przestrzenna. Podstawy teoretyczne. Poland, Warszawa: Polish Academy of Science.

Ercal, G., Matta, J. (2013). Resilience Notions for Scale-free Networks. Procedia Computer Science, 20, 510–515. DOI: http://dx.doi.org/10.1016/j.procs.2013.09.311

Jansson, M., Lindgren, T. (2012). A review of the concept 'management' in relation to urban landscapes and green spaces: Toward a holistic understanding. Urban Forestry & Urban Greening, 11(2), 139–145. DOI: http://dx.doi.org/10.1016/j.ufug.2012.01.004

Kowalczyk, A. (2012). Valuation and Valorisation of Urban Landscape in Olsztyn. Urban public space – economics and management perspectives. Studia Regionalia, 34, 77–94.

Kowalczyk, A. (2012a). The iconic model of landscape aesthetic value. European Spatial Research and Policy, 19(2), 121–129. DOI: http://dx.doi.org/10.2478/v10105-012-0018-3

Kowalczyk, A., Strumiłło-Rembowska, D. (2009). Symulacja utraty wartości estetycznej krajobrazu miasta Olsztyn na skutek katastrof pożarowych. Katastrofy naturalne i cywilizacyjne. Zagrożenia i wyzwania dla bezpieczeństwa, 1, 333–342.

Lee, D., Oh, K. (2012). A Landscape Ecological Management System for Sustainable Urban Development. APCBEE Procedia, 1, 375–380. DOI: http://dx.doi.org/10.1016/j.apcbee.2012.03.062

Li, T., Wang, Y., Guan, Z-H. (2014). Spreading dynamics of a SIQRS epidemic model on scale-free networks. Communications in Nonlinear Science and Numerical Simulation, 19(3), 686–692.

Lou, S-L., Chen, G., Chen, S-Y., Huang, W. (2013). Scale-free networks via attaching to random neighbors. Physica A: Statistical Mechanics and its Applications, 392(17), 3531–3536. DOI: http://dx.doi.org/10.1016/j.physa.2013.03.043

Newman, M., Barabási, A.-L., Watts, D.J. (2006). The structure and dynamics of networks. Princeton University Press.

Stephenson, J. (2008). The Cultural Values Model: An integrated approach to values in landscapes. Landscape and Urban Planning, 84(2), 127–139. DOI: http://dx.doi.org/10.1016/j.landurbplan.2007.07.003

Wejchert, K. (1974). Elementy kompozycji urbanistycznej. Poland, Warszawa: Wydawnictwo Arkady.

Virtual Round Table on ten leading questions for network research (2004). The European Physical Journal B - Condensed Matter, 38(2), 143–145. DOI: http://dx.doi.org/10.1140/epjb/e2004-00109-x

Yan, D., Ahmad, S. Z., Yang, D. (2013). Matthew effect, ABC analysis and project management of scale-free information systems. Journal of Systems and Software, 86(2), 247–254. DOI: http://dx.doi.org/10.1016/j.jss.2012.08.013

Yilmaz, E., Uzuntarla, M., Ozer, M., Perc, M. (2013). Stochastic resonance in hybrid scale-free neuronal networks. Physica A: Statistical Mechanics and its Applications, 392(22), 5735–5741. DOI: http://dx.doi.org/10.1016/j.physa.2013.07.011

Kowalczyk A. M. (2015). The use of scale-free networks theory in modeling landscape aesthetic value networks in urban areas. Geodetski vestnik, 59(1): 135–152. DOI: 10.15292/geodetski-vestnik.2015.01.135-152

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