Jurgis ZAGORSKAS

CITY COMPACTNESS AND MODELING OF SUSTAINABLE DEVELOPMENT

Summary of Doctoral Dissertation
Technological Sciences, Civil Engineering (02T)

1355

Vilnius VGTU LEIDYKLA TECHNIKA **2007**

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

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Doctoral dissertation was prepared at Vilnius Gediminas Technical University in 2003–2007.

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The dissertation will be defended at the public meeting of the Council of Scientific Field of Civil Engineering in the Senate Hall of Vilnius Gediminas Technical University at 1 p. m. on 18 January 2008.

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The summary of the doctoral dissertation was distributed on 18 December 2007.

A copy of the doctoral dissertation is available for review at the Library of Vilnius Gediminas Technical University (Saulėtekio al. 14, LT-10223 Vilnius, Lithuania).

VILNIAUS GEDIMINO TECHNIKOS UNIVERSITETAS

Jurgis ZAGORSKAS

MIESTŲ KOMPAKTIŠKUMAS IR DARNIOSIOS PLĖTROS MODELIAVIMAS

Daktaro disertacijos santrauka
Technologijos mokslai, statybos inžinerija (02T)

Vilnius LEIDYKLA TECHNIKA 2007

Disertacija rengta 2003–2007 metais Vilniaus Gedimino technikos universitete.

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Disertacija bus ginama viešame Statybos inžinerijos mokslo krypties tarybos posėdyje 2008 m. sausio 18 d. 13 val. Vilniaus Gedimino technikos universiteto senato posėdžių salėje.

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Disertacijos santrauka išsiuntinėta 2007 m. gruodžio 18 d.

Disertaciją galima peržiūrėti Vilniaus Gedimino technikos universiteto bibliotekoje (Saulėtekio al. 14, LT-10223 Vilnius, Lietuva).

VGTU leidyklos „Technika“ 1355 mokslo literatūros knyga.

General characteristic of the dissertation

Topicality of the problem – effectiveness of city spatial form and structure is the key factor for attaining sustainable development. Sprawl gives growing travel costs, bigger energy consumption and cost for environment maintenance. Gradual and more concentrated development is more effective: existing facilities are developed, waste lands are filled, artificial covering per person is minimized. It is the making and core of balanced and sustainable development.

Nowadays cities of Europe and Lithuania have similar development trends and are facing similar problems. The population in cities is constant or shrinking, but the cities are spreading to the surrounding territories, dependence on private transport is increasing thus paralyzing the transportation system of the cities. There are social problems with new rise of individual housing, relict multifamily blocks with single functioning and monotonic look, growing of slums or isolated communities for rich people. In post-industrial cities (e.g. almost all Lithuanian cities) there are lots of abandoned lands which were used for industry and now are vacant. In last decades the development was directed to new territories and it resulted in unperceivable boundaries of the cities and damaged surroundings. There are no distinct concentration places of provision centers, because they were scattered and built far from the centers of the cities.

The cities must be developed appreciating the environmental cost of development. The land must be used intensively with taking as small amount as possible. The utilization of derelict land, adaptation, bigger population densities (around 60 people/ha), mixed use of buildings and territory, smart planning and public transportation must be in the foreground.

In developed countries, such as USA, GB, Germany, Finland, Australia, Canada, Japan the main stress is put on achieving compact urban form. Discussions on sustainable development are stimulated by UN and COM official documents. In literature there are found several sustainability concepts, but mostly matching the goals is the compact city conception.

Lithuanian towns are now facing the same problems as there were in more economically developed European countries some years before. The market economy is the main factor changing development patterns in Lithuania. We must use the practice of developed countries to recognize and escape the mistakes done there at the early stage. The theory can be adopted only if there will be understanding on political level.

Aim and tasks of the work – the aim of work was to find common development trends in European and Lithuanian cities, to define driving forces of development and predict sustainability problems.

Sustainability has many links with physical form of built up territory and can easily be defined by physical form of the cities. The goal of this work is to find links between sustainability and spatial urban form and to measure it in numerical expression.

To reach the aim of work these tasks were set:

1. To analyze urbanization processes and contemporary development trends. To establish main driving forces of urban processes in Lithuanian towns.
2. To survey sustainable city theory and find out about compact city theory.
3. To investigate city sustainability and compactness evaluation researches, to define methods most suitable for exploration of spatial city form sustainability and spatial distribution rationality.
4. To estimate compactness of 7 biggest Lithuanian towns.
5. To analyze in detail the degree of rationality and possibilities for perfection of Kaunas town spatial structure elements.

Scientific novelty

1. The contemporary methods for analysis of city form are surveyed, defects and advantages of these methods are found.
2. Improved method for calculating city compactness is established and examined measuring compactness of the 7 biggest Lithuanian towns. This kind of research is done in Lithuania for the first time.
3. An innovative and original method of defining rationality of city spatial structure is developed on basis of city form description as structure of finite elements.
4. The new method is used to evaluate the rationality of spatial distribution of Kaunas town structure elements. Such precise research and calculations are done for the first time in the world and shows new possibilities given by computer calculations and GIS.
5. Multi-criteria analysis is used to estimate the sustainability of districts in Kaunas city and to define influence of retail centers on city structure. Integration of multi-criteria methods and GIS is depicted.

Methodology of research includes analytical, expert and statistical analysis methods. For estimation of total city structure distribution rationality the method used by scientists from Dresden Institute of Ecology was developed. This method was proved using CORINE land cover data from satellite images. The data was processed by GIS engine to make spatial distribution model. Built up territory was divided into cells. Subsequent calculations were done in AutoLISP programming language due to the convenience of this programming

language when dealing with datasets of nondescript size and structure. The results were visualized using AutoCAD computer program environment.

For estimation of rationality of city structure elements distribution the developed methodology was tested on Kaunas city case study, using the data obtained from municipality, describing population, working places and places of public attraction. The data was processed by GIS and calculations were done using algorithms written in AutoLISP programming language. The results were visualized using AutoCAD program.

Multi-criteria analysis of Kaunas city built up territory equivalence to sustainable development pattern was done using expert ranking and COPRAS method. Analysis of retail centers influence on Kaunas city structure was done using Multiplicative Summarized Optimal Criterion Method. Calculations were done using LEVIS computer program and results were visualized again using standard GIS facilities.

Practical value. The work extends the conception of sustainability of spatial structure. The methods for numerical expression and objective measurement and comparison of urban form compactness and spatial distribution rationality are discussed and developed.

The obtained research results show the compactness of Lithuanian towns. The calculations of Kaunas city structure elements spatial distribution disclose the current situation and indicate sustainability problems in the city. This methodology will be used by VGTU Spatial Planning Institute while making general plans of Lithuanian towns. It will help to find the best territory for development and optimize the current structure of towns.

The multi-criteria methods are used with GIS to evaluate and compare characteristics of territory. The results were used in specialized plan of retail centers distribution in Kaunas city. The methodology can be used in different planning and researching works to support motivation of decision makers.

Defended propositions

1. Rational spatial structure provides higher effectiveness and quality of life.
2. The calculations of city spatial structure rationality are useful to find the ways for optimization and minimize energy consumption.
3. Definition of general town compactness and city spatial structure rationality help to find and estimate the sustainability of different elements in physical city structure.
4. To give full advantage of new technologies the multi-criteria methods must be integrated with GIS using RS data.

The scope of the scientific work. The scientific work consists of the general characteristic of the dissertation, 4 chapters, conclusions, list of literature, list of publications and addenda. The total scope of the dissertation – 123 pages, 38 pictures, 19 tables and 1 addenda.

1. Global urbanization and modern concepts of urban development

Urbanization is the main process changing the surface of the Earth. Every year world population is increasing in 90 millions and it is growing in progression. It is expected that in the year 2050 75 % of world's population, which will be then about 12 billions, will live in cities. Almost all the growth of population is taking place in the developing countries, which don't have resources for development. As the population will grow the world is going to face different problems because the consumption will increase and even renewable resources can come to the end or rejuvenation become too slow to supply the needs. The degradation of environment has already started – report of UN shows that from year 1945 till now 17 % of natural land was damaged, air pollution increased dramatically reducing the crops in US from 5 % to 10 %. It is supposed that this effect is even stronger in the territories of Europe and China. The cities are main consumers of energy, main generators of pollution, the biggest environment hazards and the problem for ecological stability.

While in developing countries urbanization and growth of the cities is caused by increase of population and moving of population from rural areas to the cities, in developed western countries the territories of the cities are also increasing. The main driving force of this process is moving of people to the suburban areas to individual houses. This trend is very dangerous when it develops to a mass scale. Living in suburban territories means dependence on automobile, consequently it creates congestion of roads, up to 10 times increases energy consumption per person and causes bigger pollution. The nature resources are also damaged and natural land reserve is decreased.

Although the process of growing of the cities can't be stopped the measures must be taken to minimize the energy consumption. Architecture and town planning must become instruments for creating harmony between cities and natural environment. Interest in ecological problems is increasing and world scientists from different fields of knowledge are discussing about global world perspective. Different proposals are given for the future town development. UN report "Our Common Future" proposed the conception of sustainable development and it became the main conceptual trend in modern town planning. Sustainability has the biggest potential in the urbanized territories where most part of consumption and pollution by world civilization is

taking place. There are 4 main concepts of sustainable development and different combinations of these concepts. The best matching with sustainable development is the "Compact City" concept (Table 1).

Table 1. Assessing the sustainability of urban concepts (Jabareen Y. R.)

Concepts / Criteria	Neotraditional development	Urban Containment	Compact City	Eco-city
Density	0. Moderate	0. Mod.	1. High	0. Mod.
Diversity	1. High	0. Mod.	1. High	0. Mod.
Mixed land use	1. High	0. Mod.	1. High	0. Mod.
Compactness	0. Mod.	0. Mod.	1. High	–1. Low
Sustainable transportation	0. Mod.	0. Mod.	1. High	1. High
Passive solar design	–1. Low	–1. Low	–1. Low	1. High
Ecological design	0. Mod.	–1. Low	–1. Low	1. High
Total score:	***1***	***–2***	***3***	***2***

The main arguments for the compact city are:

1. Higher level of control over urban processes, reuse of previously developed facilities and derelict land, bigger urban vitality, rational city form and preserved outskirts of the towns.
2. Effectiveness of public transport and decreased fuel consumption, lower pollution per person.
3. Possibility of mixed use development due to higher population density.
4. Savings of energy in heating and other facilities as the result of dense urban fabric.
5. Possibility of social mix when different tenure and comfort level tenements are close together.

Although there are many proponents of compact city there are also opponents who argue that it ignores naturally going on processes of decentralization and possible benefits of it.

In the world context Lithuanian cities have similar development tendencies as in European countries with lower economies – neighbor countries Latvia, Estonia, Poland. Lithuanian cities can become quite similar to the cities of more developed countries in near future. The structure changes and development of cities is greatly dependent on economical, political and social processes. The biggest stimulus for change Lithuanian towns got from changed economical situation after fall of Soviet Union. The latter changes affected increasing differences between regions and towns and prove to be not at all

sustainable. The desirable future development for Lithuania must be targeted to preservation of natural resources. Large-scale changes in urbanization or population growth for Baltic region are not predicted by specialists. In nearest decade the main change biggest Lithuanian towns are going to face will be moving of people from multi-family blocks to the individual houses in surrounding territories. This is clearly seen by examples from history of more developed countries. Other well-defined development trend will be related to growing traffic flow in trans-European highways and the development of facilities connected with transit. This can debase the life quality and existing urban structures creating sprawl along the roads and further deconcentration.

It is of the most importance to manage development appreciating the impact it makes to life quality and sustainability. Sustainability is the main goal in urban development and search of rational spatial form must become the main task in planning.

2. Estimation of city form rationality. Spatial interaction of urban structure elements

The interest in city form research is growing; rationality of city form is discussed and measured quite often. Main theme in this field of research is sprawl of the cities. Means for stopping the sprawl are proposed, disadvantages are described and measured. The process of sprawling is often studied using satellite images and GIS. The use of GIS in urban modeling and implementation multi-criteria methods with GIS are the newest topics. Another category of research is city form and its influence on traveling and private motorized mobility. The impact of information technologies on city structure and population behavior is also quite popular theme of recent researches but opinions of different authors are contradictory.

City compactness is figuring as one of the main goals in EU, USA and other developed countries strategic planning documents. In developing countries such as China with growing population city compactness is also measured but the scope of problem is the opposite – how to build in such population densities that the living conditions would be tolerable.

The city form is characterized mainly by population density, intensity of land use and distribution of different structure elements. Most often the characteristic of population density is analyzed. Intensity of land use is more complex thing to define but it has bigger practical value.

Using GIS for exploring characteristics of urban territories includes initial stage of preparing data. There are substantial differences in methods on this level depending on the task and type of initial data. For example the division of

territory into cells for analysis can vary from concentric circles to triangular or octagonal cells.

The methods for measuring city form rationality (the terms compactness, effectiveness are used in literature also) can be divided into three types:

1. Methods for measuring overall rationality of built up territory form. The analogy of law of gravitation and moment of inertia is most often used to estimate spatial interaction between structure elements. The result is often expressed in non dimensional value and can be used to compare different cities.
2. Methods for modeling and analyzing city structure by dividing it to finite elements. These methods give more accurate results and can be used to predict future development, impact of it on sustainability, to compare development alternatives.
3. Methods for analysis of the characteristics of territory are used to point the problem areas, best locations for development. Modern methods are multi-criteria assessment methods integrated with GIS.

Urban structure is the result of human activities and the main factors describing it are the location of places where people are staying or being attracted. In urban structures the action happens in particular places (usually in buildings). These places represent stationary part of structure and travel from one place to another defines mobile part of structure defined by their locations. From this comes statement that urban structure can be defined by locations of buildings and other places of action. The function of such places and distances between them can describe spatial interaction between structure elements.

The main question using contemporary computer technologies, able to process huge amount of data, is how detailed the division must be to describe the structure at best. From previous statement we find that it is worthy to divide the structure into elements representing separate buildings or places of building scale. Smaller division will not help to find more precise results at city or district scale and it won't be reasoned.

Table 2. Spatial interaction between the action places of different function

Places / Places	Living	Working	Public attraction
Living	0.15	0.55	0.45
Working	0.55	0.18	0.25
Public attraction	0.45	0.25	0.15

Functional use of action places in the cities can be divided into three main categories: living places, working places and places of public attraction. Different spatial interaction coefficients between different categories can be defined by city population travel study or by empirical statements (Table 2).

For the calculations the vectors are established for each category of objects and spatial interaction is estimated by formula:

$$g_{ij} = k_f \cdot \frac{s_i \cdot s_j}{d_{ij}^2}, \tag{1}$$

where g_{ij} represents spatial attraction between objects i and j, k_f is the coefficient of attraction between different categories of objects, s_i and s_j are the weights of objects i and j, d_{ij} is the distance between objects.

For each category of object the sum of gravitation vectors are calculated by formula:

$$a_n = k_{ff_1} \frac{\sum_{1,i} g_{ni}}{s_n} + k_{ff_2} \frac{\sum_{1,j} g_{nj}}{s_n} + k_{ff_3} \frac{\sum_{1,k} g_{nk}}{s_n}, \tag{2}$$

where a_n is the relational value of gravitation, k_{ff} – coefficients of attraction between different categories of objects, g_n – gravitation between two objects calculated by formula 1, i, j, k – number of objects in each category.

For the analyzed area the average gravitation of each category of objects and overall average gravitation are calculated:

$$T_{category} = \frac{\sum G_{category} [a_1 \quad .... \quad a_i]}{i}, \tag{3}$$

$$T = \frac{T_{living} + T_{working} + T_{attraction}}{3}. \tag{4}$$

The value T describes the compactness of area and the values of T for different categories of objects describes rationality of distribution of these objects.

3. City compactness computation

Calculations used for describing and computing city compactness usually are made by applying gravitation or moment of inertia law analogies for mathematical description. The main problems, noticed in recent researches that make calculations imprecise are usually connected to the initial data and methods of structure division into finite elements.

One of main errors that are usually made is taking to account objects that have very small weight. This problem is substantial when comparing the compactness of different scale areas. To tackle this problem the small values must not be taken in account.

Other problems are of geometrical platform. When the analyzed area is divided to cells the distances are usually taken between the centers of the cells. This is not correct in many cases when built up territory is not in the centre of the cell. To improve calculation accuracy the distances must be taken between the centers of gravity of the cells.

The gravity calculated by formula 1 itself does not give correct results when comparing areas of different characteristics. For better compatibility the proposal is to use gravitation relative to object weight:

$$g_{ij}^{s} = \frac{g_{ij}}{s_{ij}}, \tag{5}$$

where g_{ij} is the gravitation calculated by formula 1, and s_{ij} – gravity of the object or cell.

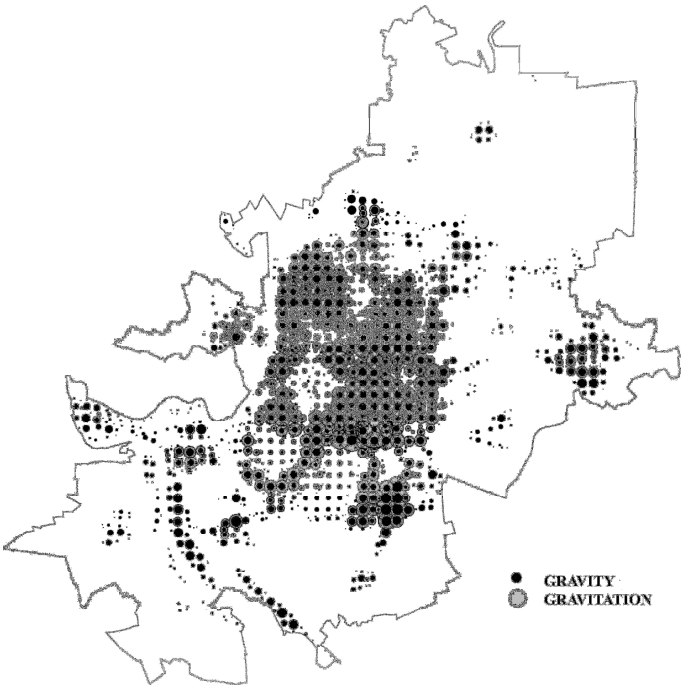

Fig 1. The gravitation of cells in Vilnius city

Computing the compactness of 7 biggest Lithuanian towns (Vilnius, Kaunas, Klaipėda, Šiauliai, Panevėžys, Alytus, Marijampolė) was made taking in account all these problems. The data used for calculations was prepared from the land surface database CORINE provided by Lithuanian Environment Ministry. The land surface is divided to 5 categories and many subcategories. Each subcategory were given the coefficient specifying the land use intensity. The territories of the cities were divided into square cells 500x500 m size each. This gave from 350 to 1450 cells with built up territory. The data was prepared using GIS program and calculations were made using AutoLISP programming language convenient for description of spatial data. The results were visualized using AutoCAD program. The gravity and gravitation of each cell were presented in circles of different size (Fig 1).

The results show that the most compact are the Kaunas and Panevėžys cities. The least compact are the cities of Alytus and Marijampolė (Table 3). The results are not completely correct because of the faults in initial data. The main problem is with categories of artificial land cover – the single family housing territories are considered the same as multifamily housing where population densities and consequently the gravity is up to 5 times bigger.

The results are at most convincing but from empirical study it appears that the Panevėžys city is the most compact in Lithuania. For more precise calculations the initial data must be prepared differently than in CORINE system. Categories of different types of built up territories must be taken in account. The data can be prepared from satellite images of the cities.

Table 3. Data and estimated compactness of 7 biggest Lithuanian cities

Name of the city	Population (in thous.)	Sum of gravity	Average gravity	Average gravitation	Average relational gravitation T
Vilnius	665	302.23	0.21	5.43	**4.22**
Kaunas	368	236.48	0.23	5.87	**5.92**
Klaipėda	209	175.19	0.29	4.87	**4.84**
Šiauliai	144	98.98	0.26	5.35	**4.58**
Panevėžys	131	67.58	0.26	5.03	**5.67**
Alytus	77	48.66	0.21	4.64	**3.70**
Marijampolė	52	36.22	0.29	4.46	**3.55**

The described method illustrates the possibilities of applying GIS and computer technologies with satellite imaginary. This method can be used to

measure and compare compactness on the scale of city territories. For more precise calculations satellite images are nor very suitable at the moment.

4. City form analysis applications, potential of methods and course of development

City form can be described by locations of the parts of city structure. City structure is usually described in functional purpose of the territory part. Different functions attract each other and create the movement in the city.

When describing sustainability of the form the main factors are the distances between objects in city structure. The less are the distances the smaller is consumption for attaining the same result. This is why the mixed use territories and objects are preferred for attaining sustainability. However in post-industrial cities the territory is usually very mono-functional and the function must be taken in account.

Table 4. Weight establishment for different category objects

Category	Weight units
Living places	Residents of the building
Working places	Workers working daily in the building
Places of public attraction	Number of daily attracted people to the building

In Kaunas city form analysis the city structure (unmovable part) was divided to the objects presenting the buildings with their weights established from data how many people the buildings are attracting daily (Table 4). The objects were divided to three categories – living places, working places and places of attraction.

Table 5. Gravitation between different categories of objects (Sum of gravitation/ average gravitation/ relative gravitation)

Places / Places	Living	Working	Public attraction
Living	54061 / 2.47 / 0.09	8184 / 0.37 / 0.02	45432 / 2.07 / 0.1
Working	8184 / 1.73 / 0.09	5128 / 1,08 / 0,04	23072 / 4.88 / 0.18
Public attraction	45432 / 15.5 / 0.11	45432 / 15.5 / 0.11	153142 / 52.25 / 0.21

The gravitation between different categories of objects was calculated using attraction coefficients (Table 5). This shows the sustainability of different parts of city structure.

The same model was used for prediction of average daily travel distances. The prediction is based on assumption of daily travel needs. An average distances from each object to each category of objects were calculated and multiplied by the weight of the object and average travel distance was calculated:

$$D_{daily\_travel} = 0{,}3 \cdot D_{average}^{liv-liv} + 0{,}7 \cdot D_{average}^{liv-work} + 1{,}3 \cdot D_{average}^{liv-attr} + 0{,}32 \cdot D_{average}^{work-work} + \\ + 0{,}5 \cdot D_{average}^{work-attr} + 0{,}15 \cdot D_{average}^{attr-attr}, \quad (6)$$

where D represents average distances between categories of objects.

The method was applied for predicting of two Kaunas city development alternatives influence to sustainability of city structure. The first was presumption that in planned free economy zone by Kaunas city 15 000 working places will be created. The second alternative was the changes of living places dislocation if the 25 % of people from multifamily blocks have moved to individual housing areas in periphery. Both are possible trends in future development of Kaunas city and the calculations have shown that average daily travel distance per person in Kaunas city will increase in both cases. Today predicted distance is 8.8 km, in the case of Kaunas free economy zone development it would increase to 11.5 km, in the case of migration of residents from multifamily blocks to suburban areas the average daily travel distance would increase to 12.3 km.

Other category of applications is GIS and multi-criteria decision support methods integration to estimate the sustainability of form and character of built up environment.

Kaunas city districts were analyzed to estimate congruence with theoretical compact city model. Five attributes to characterize the district were selected as follows:

1. Population density (x_1) has an optimal value, which is 60 people/ha and is dimensioned by points (1–10 interval).
2. Level of even distribution of population (x_2) is second strongest factor showing how the district is built-up. The best building style in the terms of compactness is of constantly changing density, and building with intervals or sharp change in density shows less sustainable development of a district.
3. Population and working places ratio (x_3) shows possibilities to work near the living place for the citizens and in this way to make shorter daily trips.

4. Population and objects of public attraction ratio (x_4) shows the possibilities for the citizens to find provision objects, services, fulfill daily needs near the living place.
5. Density of public transport network in the district (x_5). Public transport stops and number of routes are calculated and divided by the sum of living places, working places and public attraction places.

The results of city districts sustainable structure estimations are visualized using standard GIS tools (Fig 2). The darker areas indicate better sustainability.

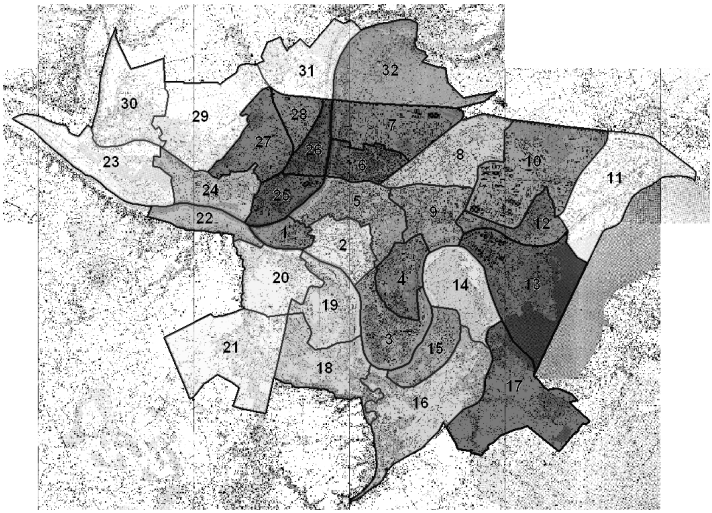

Fig 2. Graphical chart of city compactness in the city districts

Multi-attribute decision support method was applied to analyze the impact of provision centers on the city as a complex system. The task is described by many attributes. Influence on the city is described as a sum of effects the provision centers give to the quality of life of neighborhood and other city population, the work of city transportation system, architectural and urban perception of the city. On the basis of expert judgment the weights of attributes are estimated. The normalization of the attributes of effectiveness is done using linear normalization method. The gamut of impacts is estimated and numerical expressions are obtained, different objects are compared. From ideal values the optimal alternative is made. The Multiplicative Summarized Optimal Criterion method was used. The results determined effectiveness of existing objects and future development strategy and were used in Kaunas city municipality dislocation of provision centers special plan.

The best results gave provision centers built by renovation of previously built trading objects. It is mainly because there was positive reaction in community and the problems of traffic were solved already. These centers are usually of local or district importance only.

The bigger scale objects created more problems and the ranking reflects it. There were also some big objects of a city importance appreciated nicely because of glaring architectural expression but mostly these big centers were ranked low.

6. General Conclusions

After studying the contemporary trends in urban modeling, describing the mathematical models of city structure, developing calculation methods and performing analysis, there were formulated the following scientific and practical conclusions:

1. The processes of urbanization in the world are becoming intense; in 1965 36 % of world's population lived in towns, in 2000 – 50 % and by the year 2050 it will become 75 % if the tendencies will not change. Planet's population is increasing by 30 000 daily and it is growing in progression. More rational use of territory and resources in the cities is imperative.
2. In global context Lithuanian towns are similar with EU towns of countries with same level of economical development. GDP in Lithuania in comparison with EU average GDP is growing by 3 % yearly from year 2000 and has come to 61,6 % of average EU GDP already. In these economical circumstances Lithuanian towns are changing rapidly, but spare and nature protecting development is more admissible for Lithuania territory.
3. City form and structure determines the consumption of energy and other resources. In every certain situation there is optimal city compactness when consumption becomes minimal and the best performance is achieved. Compact city conception among the other popular future development conceptions is matching the goals of sustainable development at best. Compact city concept is validated in many strategies and other political level documents, however it is usually abstract and has no quantitative expression.
4. Compactness of urban form is characterized by population density, density of built-up territory and intensity of land use. For mathematical description town structure must be divided to smallest finite elements – buildings. The function of use can be divided to 3 categories: living, working and attraction places.

5. Recent scientific studies of urban form concentrate on rationality of physical form, relation to energy consumption, population mobility and travel demand. For research of city form GIS, RS technologies and multi-criteria estimation methods can be integrated along with other computer based methods.
6. The calculations of city compactness can be based on gravitation and moment of inertia law analogies. To simplify the calculations the centers of gravity can be used as object locations.
7. The described methodology of computing city compactness shows the problematic places in city structure and the scale of problems. Research has shown that the most compact in Lithuania are Kaunas and Panevėžys cities (rates of compactness T accordingly 5.92 and 5.67), the less compact are Marijampolė and Alytus cities (3.7 and 3.55 accordingly). Lithuanian towns have a strong tendency to sprawl and repeat the history of more developed countries.
8. The research of Kaunas city spatial structure has shown high application possibilities in planning. Estimation of travel demand has demonstrated that by moving 20 % of population from multifamily to individual houses in suburbs, daily travel distance per person would grow from 8.813 km to 12.33 km. Kaunas city territory analysis evidenced that the biggest sustainability problems are met in the mono-functional use areas of multifamily blocks built during Soviet Union period and suburban individual houses being built currently. These areas have accordingly too big and too low population densities.
9. Analysis of particular planning problems has shown that multicriteria methods are suitable for assessment of present town structure, alternative development trends and impact on the whole city structure. Multicriteria methods are compatible with GIS. This enables to improve data collection accuracy, presentation and visualization.

List of published works on the topic of the dissertation in the reviewed scientific periodical publications

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development of economy, 2006, Vol XII, No 4, p. 347–352. ISSN 1392-8619.
3. TURSKIS, Z.; ZAVADSKAS, E. K.; ZAGORSKAS, J. Sustainable city compactness evaluation on the basis of GIS and Bayes rule. *International Journal of Strategic Property Management*, 2006, Vol 10, No 3, p. 185–207. ISSN 1648-715X.

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6. ZAGORSKAS, J. Miestų kompaktiškumas ir darnus vystymasis. Iš *Tarptautinės konferencijos „K.Šešelgio skaitymai" pranešimų medžiaga.* Vilnius: Technika, 2005, p. 14–23. ISBN 9986-05-798-1.
7. ZAGORSKAS, J. Miestų kompaktiškumas ir jo įvertinimo metodai. *Tarptautinės konferencijos „K.Šešelgio skaitymai" pranešimų medžiaga.* Vilnius: Technika, 2004, p. 4–9. ISBN 0955-09-651-9.

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MIESTŲ KOMPAKTIŠKUMAS IR DARNIOSIOS PLĖTROS MODELIAVIMAS

Mokslo problemos aktualumas – neefektyvi miesto forma lemia didėjančias transportavimo, šildymo ir kitas energijos sąnaudas, gyvenamosios aplinkos priežiūros kainą.

Šiuo metu urbanizacijos procesas yra labiausiai keičiantis žemės planetos paviršiaus vaizdą procesas. Žmonės vis labiau traukiasi iš kaimo vietovių ir keliasi gyventi į miestus. 1950 metais miestuose gyveno 29 % planetos gyventojų, 1965 – jau 36 %, 2000 – 50 %, o 2050 prognozuojama, kad mažiausiai 75 % žmonių gyvens miestuose. Miestai kelia didžiausią pavojų ekologiniam stabilumui ir žmonijos išlikimui.

Problemos daugumoje šių dienų miestų yra panašios – perkrovimas transportu, neturintys unikalumo miegamieji rajonai, spartus monotoniškų priemiestinių zonų augimas, neeksploatuojami pramonės rajonai, sudarantys dykvietes įsiterpusias į išaugusio miesto struktūrą. Lietuvos miestų problemos ir plėtros tendencijos yra panašios į labiau ekonomiškai pažengusių ir laisvos rinkos tradicijas turinčių šalių miestų jau praeitus etapus, todėl galima vadovautis jų planuotojų sukaupta patirtimi, nekartoti padarytų klaidų ir kai kurias miestų planavimo priemones bandyti pritaikyti Lietuvos miestuose.

Dabartinėje miestų augimo proceso stadijoje būtina sukurti sąlygas gyventojų išlaikymui kuo mažesnėmis sąnaudomis. Architektūra ir planavimas turėtų tapti įrankiais, sukuriančiais miestų ir aplinkos harmoniją. Jungtinių tautų ataskaita „Mūsų bendra ateitis“ pasiūlė darnios plėtros koncepciją, tapusią svarbiausia kryptimi šiuolaikinėje urbanistikoje. Darniosios plėtros sąvoką labiausiai atitinka kompaktiško miesto koncepcija.

Darbo tikslas ir uždaviniai. Darbo tikslas – ištirti Lietuvos miestų kompaktiškumą, sukurti metodiką miestų erdvinei struktūrai analizuoti.

Darbo tikslui pasiekti buvo suformuluoti šie uždaviniai:

1. Analizuoti kompaktiško miesto teoriją ir jos raidą, miestų vystymosi tendencijas ir urbanistines kryptis.
2. Išnagrinėti taikomus miesto formos įvertinimo metodus, parinkti metodus tinkamus urbanistinei miesto erdvinės struktūros analizei.
3. Įvertinti keleto didžiausių Lietuvos miestų kompaktiškumą ir Kauno miesto erdvinę struktūrą darnumo aspektu.

Mokslinis naujumas

1. Išanalizuotas santykis tarp darnios miestų plėtros idėjos ir miesto formos bei struktūros elementų išdėstymo teritorijoje. Tyrinėta ir

pagrįsta praktiniais skaičiavimais darnaus kompaktiško miesto teorija. Miesto formai ir darnumui įvertinti panaudotos GIS technologijos kartu su daugiakriterinės analizės metodais. Tokio detalumo tyrimai atlikti ir taikyti vieną iš pirmųjų kartų pasaulyje.

2. Pirmą kartą Lietuvoje šiuolaikinėmis priemonėmis ir metodais įvertintas Lietuvos miestų kompaktiškumas. Atlikta Kauno miesto teritorijos panaudojimo intensyvumo analizė. Įvertinta ir palyginta atskirų Kauno miestų dalių darna ir kompaktiškumas.

Tyrimų metodika. Darbe buvo naudojami analitiniai, ekspertinės ir statistinės analizės metodai. Naudotasi GIS, palydovinių vaizdų technologijomis integruojant daugiakriterinio vertinimo metodus.

Praktinė vertė. Susistemintos ir palygintos darnios miestų plėtros idėjos. Nustatytos miestų formą įtakojančios plėtros tendencijos ir problemos. Atrasti ir apžvelgti tinkamiausi metodai miestų ir jų teritorijos dalių kompaktiškumo nagrinėjimui. Įvertintas Lietuvos miestų kompaktiškumas ir darna.

Ginamieji teiginiai

- Miesto erdvinės struktūros matematinis modelis.
- Miesto modelio sudarymo metodika.

Darbo apimtis. Darbą sudaro bendra darbo charakteristika, 4 skyriai, išvados, literatūros sąrašas, publikacijų sąrašas ir priedai. Bendra disertacijos apimtis – 123 puslapiai, 38 paveikslai, 19 lentelių ir 2 priedai – kompiuterinių programų tekstai ir duomenys bei skaičiavimo rezultatai.

Pirmajame disertacijos skyriuje analizuoti pasauliniai urbanizacijos procesai, įvertintas koncepcinių modelių atitikimas darniajai plėtrai. Analizuota kompaktiško miesto teorija.

Antrajame disertacijos skyriuje apžvelgiami pastarųjų metų moksliniai darbai susiję su miestų formos tyrinėjimais. Išskirtos pagrindinės tyrimų kryptys, naudojami metodai ir priemonės. Aprašytas miesto formos kompaktiškumo įvertinimo matematinis modelis. Pasiūlytas miestų struktūros skaidymo į baigtinius elementus ir erdvinės sąveikos tarp jų įvertinimo metodas.

Trečiajame skyriuje pagal patobulintą Drezdeno Ekologijos instituto mokslininkų metodą įvertintas 7 didžiausių Lietuvos miestų kompaktiškumas.

Ketvirtajame skyriuje detaliai nagrinėjama Kauno miesto erdvinė struktūra, skaidant ją į skirtingų funkcinių paskirčių elementus. Pagal elementų svorį ir funkciją nustatoma jų erdvinė sąveika ir išdėstymo teritorijoje

racionalumas, surandamos probleminės teritorijos. Miesto teritorijos dalių darnumui įvertinti ir atskirų struktūros elementų (prekybos centrų) poveikiui miesto struktūrai įvertinti pritaikyti daugiakriteriniai vertinimo metodai.

Bendrosios išvados

1. Urbanizacijos procesas įgauna vis didesnį mastą pasaulyje. 1965 metais 36 % Žemės gyventojų gyveno miestuose, 2000 metais jau 50 %, o 2050 metais prognozuojama, kad mažiausiai 75 % žmonių gyvens miestuose. Planetos gyventojų skaičiui kas dieną didėjant 30 000 ir augant progresiškai, artėjama prie katastrofos, jei nebus atrasti būdai racionaliau naudoti teritoriją ir išteklius, ypatingai miestuose.
2. Pasauliniame kontekste Lietuvos miestai turi panašias plėtros tendencijas kaip vidutinio ekonominio išsivystymo Europos šalių miestai. Esant dabartiniam BVP augimui, kai nuo 2000-ųjų iki 2007-ųjų per metus BVP rodiklis priartėdavo prie ES vidurkio ~3 % ir 2007 metais pasiekė 61,6 % lyginant su ES vidurkiu reikšmę, Lietuvos miestai gali pasikeisti ir supanašėti su ekonomiškai labiau pažengusių ES narių miestais. Lietuvai priimtina plėtra, tausojanti gamtines vertybes, kuriomis Lietuva išsiskiria ES.
3. Miestų forma ir užstatymas ženkliai lemia energijos suvartojimą. Egzistuoja optimalus miesto kompaktiškumas, kai sunaudojamas mažiausias energijos kiekis tiems patiems tikslams pasiekti. Kompaktiško miesto koncepcija tarp kitų šiuolaikinių urbanistinių koncepcijų labiausiai atitinka darniosios plėtros principus. ES, JAV bei kitų išsivysčiusių šalių plėtros strategijose dažnai minimas miestų kompaktiškumas ir pripažįstama, kad tai yra vienas svarbiausių siektinų tikslų. Nors kompaktiško miesto sąvoka įteisinta politinio lygmens dokumentuose, ji yra abstrakti ir neturi skaitinės išraiškos.
4. Urbanizuotos teritorijos kompaktiškumą nusako gyventojų tankis, užstatymo intensyvumas ir teritorijos panaudojimo intensyvumas. Struktūrą tikslinga skaidyti iki pačių smulkiausių baigtinių elementų – atskirų pastatų. Pagal funkciją objektus tikslinga skirstyti į gyvenamosios, darbo ir traukos objektų kategorijas.
5. Pastarųjų metų moksliniuose tyrimuose analizuojamas miestų formos racionalumas, miesto formos įtaka susisiekimui, gyventojų mobilumui ir kelionėms, suvartojamos energijos kiekiui. Urbanistinių struktūrų tyrimams naudojama GIS programinė įranga. Kompleksiniam įvertinimui patogiausia naudoti daugiakriterinius įvertinimo metodus.
6. Urbanistinės formos kompaktiškumui ir racionalumui įvertinti bei struktūros elementų erdvinei sąveikai nustatyti tinka gravitacijos dėsnio ir

inercijos momento interpretacijos. Skaičiavimams supaprastinti galima naudoti teritorijos ar jos dalių svorio centrus.

7. Aprašyta miestų kompaktiškumo įvertinimo metodika išryškina miestų kompaktiškumo problemas, parodo jų mastą ir priežastis. Atlikti skaičiavimai parodė, kad kompaktiškiausi yra Kauno ir Panevėžio miestai (kompaktiškumo rodikliai T atitinkamai 5,92 ir 5,67), o labiausiai išsidriekę – Marijampolės ir Alytaus miestai (3,7 ir 3,55 atitinkamai). Lietuvos miestai turi tendenciją staigiai plėstis į priemiestinius individualių gyvenamųjų namų kvartalus ir pakartoti rinkos ekonomikos tradicijas turinčių šalių klaidas.

8. Atlikta Kauno miesto urbanistinės struktūros elementų erdvinės sąveikos analizė gali būti taikoma sprendimų priėmimui motyvuoti, kelionių poreikiui nustatyti, plėtros poveikiui tirti ir prognozuoti. Atlikta analizė išryškino problemines teritorijas ir parodė, kad individualių gyvenamųjų namų kvartaluose neįmanoma taupiai naudoti energijos dėl mažo gyventojų tankio ir susidarančių didelių kelionių atstumų, kai vidutinis kelionės ilgis gyventojui per parą padidėja nuo 8,813 km iki 12,33 km, o daugiabučių tankis yra per didelis dabartinėms sąlygoms.

9. Atlikta kai kurių planavimo uždavinių analizė parodė, kad daugiakriteriniai vertinimo metodai gali būti taikomi įvertinant esamą padėtį, plėtrą ir jos pasekmes bendram urbanistinės sistemos darnumui, analizuojant gyventojų aptarnavimą, nustatant teritorijų tinkamumą tam tikros kategorijos elementų plėtrai, planuojant susisiekimo sistemos plėtrą, įvertinant investicijų poreikį. Daugiakriterinius metodus patogu integruoti su GIS, tai leidžia analizuoti teritorijos charakteristikas, kurias nusako keleto kriterijų sistema.

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CITY COMPACTNESS AND MODELING OF SUSTAINABLE DEVELOPMENT

Summary of Doctoral Dissertation
Technological Sciences, Civil Engineering (02T)

Jurgis Zagorskas

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Daktaro disertacijos santrauka
Technologijos mokslai, statybos inžinerija (02T)

2007 12 05. 1,5 sp. l. Tiražas 100 egz.
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