International Journal of Business, Human and Social Sciences
ISSN: 2517-9411
Vol:7, No:9, 2013

# Measuring of Urban Sustainability in Town Planners Practice

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***Abstract*****—**Physical urban form is recognized to be the media for human transactions. It directly influences the travel demand of people in a specific urban area and the amount of energy used for transportation. Distorted, sprawling form often creates sustainability problems in urban areas. It is declared in EU strategic planning documents that compact urban form and mixed land use pattern must be given the main focus to achieve better sustainability in urban areas, but the methods to measure and compare these characteristics are still not clear.

This paper presents the simple methods to measure the spatial characteristics of urban form by analyzing the location and distribution of objects in an urban environment. The extended CA (cellular automata) model is used to simulate urban development scenarios.

***Keywords*****—**Cellular automata (CA), Mixed used planning, Spatial analysis, Urban compactness, Geographic information systems (GIS).

## I. Introduction

URBAN sustainability problem has become most popular topic among politicians and urban planners in recent years. As a result of a growing consensus that we need to improve the sustainability of our urban settlements many systems of indicators for monitoring sustainability of urban environment and even certification systems for sustainable urban communities like BREEAM Communities, CASBEE for Urban Development and LEED for Neighborhood Development were created [1]. Systems of sustainability indicators usually are not related directly to urban form, they include mostly indicators that provide information on various aspects of the interplay between the environment and socio-economic activities. Most prominent examples are the system created by United Nations Commission on Sustainable Development (it is often referred as CSD indicator set, the system now contains 96 indicators, including a subset of 50 core indicators), set of sustainable development indicators (SDIs) by Eurostat, *etc.* Although these systems are well known on a political level and are widely discussed between the politicians and economists, they are based on aspatial data and therefore fail to provide monitoring and understanding of urban form. Urban form and design have a considerable impact on the economic performance of the cities and on the quality of life of the population. The planners and local authorities therefore need different approach and methods to support their decisions. Without such methods efficiency of urban planning is hampered by the lack of integrated instruments for formulating, generating and evaluating urban plans.

Sustainability in the urban context is a notion that is widely used but little understood, because of myriad diverse environmental, social and economic factors that influence it [2]. It remains a broadly defined concept that has been applied to mean everything from environmental protection, social cohesion, economic growth, neighborhood design, alternative energy, and green building design [3], [4]. Different authors have different perspective on urban sustainability – besides usual environmental, social and economic themes authors can emphasize ecological features [5], energy consumption and emissions [6], [7], amenity, accessibility, equity and environmental performance [8]. This leads to uncertainties and disputes when discussing urban sustainability.

In this article we concentrate on few sustainability criteria that characterize the physical urban form, *i.e.* spatial distribution of urban elements. It is commonly agreed between town planners that proper distribution of urban elements is the key factor to achieve sustainability of urban environment. Therefore the most important criteria for sustainability are considered compact and dense distribution of urban form elements and mixing of functions which leads to mixed land use, urban diversity, lively, safe and interesting neighborhood [9].It implies the need to measure mentioned characteristics.

There were several attempts to create a tools for urban sustainability assessment and establish methods and techniques to measure urban sustainability characteristics [4], [7], [10], [11], [12]. Such tools could give a great support for urban planners; however they are still in the experimental stage of development and are not widely used. As critical study of recently developed tools show, in most cases there is no mechanism for local adaptability and participation; and, only those tools which are embedded within the broader planning framework are doing well with regard to applicability [13]. Also good communication is required to provide these new methods to the end-users (such as urban planners, architects and engineers) and there are such attempts currently made (e.g. European project BRIDGE – sustain a BleuRbanplannIng Decision support accounting for urban metabolism [12]).

There has been a constant evolution of planning evaluation methods, from cost benefit analysis (CBA) to planning balancesheet (PBS) and multi-criteria analysis (MCA), from environmental impact assessment (EIA) to strategic

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environmental assessment (SEA) and social impact assessment (SIA). This evolution has represented recognition of the complexities of the evaluation process in urban planning and has resulted in a move to scientifically and technically more sophisticated methods: from 'simple' calculation methods to complex assessment frameworks. But at the same time with complexity gap between planning evaluation theory and urban design practice was increasing. The adoption of simpler evaluation methods is needed in practice of today. This is linked to the requirements of planning practice and policy, since practice needs normative and positive theory [14].

Although methods to analyze characteristics of compactness and level of function mixing still did not gained popularity there is a trend that they will become more functional and urban planners will start using them in the nearest future. The driving force for this to happen is the availability of good quality satellite images and advancement in remote sensing applications and software. The main source for spatial data today has become satellite images of urban territories, which are readily available tothe users. Besides that at the end of the year 2012 the *Google Maps* with *Street View* was launched. It lets explore urban environment through 360-degree street-level view and easily find landmarks, height and types of the buildings, obtain other information useful in urban planning [15]. *Google Street View* is considered a reliable method for assessing characteristics of the built environment [16]. There are many other open data sources for planners available like that of CORINE Land Cover in Europe, where satellite images are already processed and prepared for analysis.

Type of analysis described in this paper helps urban planner to understand the interaction of spatial elements in urban structure and predict the changes. The tool for analysis is created to work with standard GIS data formats, uses ESRI ArcObject model, and it is written in Python programming language. Tool can be easily embedded into commercial products like ArcGIS and similar.

In our case study the urban growth in Lithuania in last decades was taking place in outskirts of the cities, the green field development was allowed almost everywhere and the expansion was influenced mostly by willingness of the people to move outside the city (big part of Lithuania's population today desire to live closer to the nature, have their private house and land plot), market forces (people were given credits very freely) and degradation of existing multifamily houses and their environment (in the bigger cities of Lithuania up to 60 percent of people still live in multifamily block houses built in Soviet Union period).

Case study example of Utena town in Lithuania is given to illustrate how comprehensive planning approach is influencing the effectiveness of urban structure. Proposals for better planning practices in case study of Lithuania are given.

## II. Methods

Sustainable urban density in different regions and countries is understood in different ways – in Europe, highly economically developed countries of North America, Australia, etc.– the main problem for planners is to deal with sparse development (term "urban sprawl" is generally used) and the attempt of planners is usually to create higher population densities and more diverse environment. The post-industrial European city is characterized by dispersed urbanization, resulting in increased travel, substantial use of land, social disparities and costs that are unsustainable in the long term. Consequently, most European countries have set the goal of limiting urban sprawl by prioritizing increased density in already built-up areas [17]. In this research such approach is applied also; however it can be contrary in developing Asian countries with tendency to overbuild the territory. In every case spatial distribution and density analysis can help to find the solutions and support the measures.

### *A. Measuring the Sustainability of Spatial Distribution of Urban Elements*

Spatial distribution of elements in urban form is generally agreed to be sustainable if it is highly clustered, compact and mixed formation. To analyze, measure, and compare these characteristics the urban form must be divided into few categories of elements. Urban form elements for analysis can be districts, neighborhoods, housing blocks or separate buildings according to the map scale and level of detail.

The sustainability of spatial distribution can be calculated in many ways. To simplify the calculation different formulas can be adopted like those of gravitation, moment of inertia, etc. Here gravitation formula was adopted (1). For the calculations the vectors are established between each pair of urban elements and spatial interaction is estimated by formula:

$$g_{ij} = \frac{s_i \cdot s_j}{d_{ij}^2}, \quad (1)$$

where $g_{ij}$ represents spatial attraction between elements *i* and *j*, $s_i$ and $s_j$ are the weights of objects *i* and *j*, $d_{ij}$ is the distance between objects.

The gravity calculated by (1) itself does not give correct results when we meet big contrast in weights of objects. For better compatibility the proposal is to use gravitation relative to object weight:

$$g_{ij}^s = \frac{g_{ij}}{s_{ij}}, \quad (2)$$

where $g_{ij}$ is the gravitation calculated by formula 1, and $s_{ij}$ – gravity of the element.

These operations can easily be performed by creating simple scripts for calculation. The core algorithm for calculation can be as follows:

```
elements = [ list of center coordinates and weight ]
gravitation = [ empty list ]
forel1 in elements:
sum=0.0
forel2 in elements:
dist= distance (el1,el2)
if (dist> 0):
sum=sum+(el1.weight*el2.weight/(dist*dist))
gravitation.append(sum/el1.weight)
```

The list of gravitation values relative to object weights is created and then the average gravitation can be calculated additionally to compare the compactness of the whole urban structure:

```
sum = 0.0
for g in gravitation:
   sum = sum + g
T = sum / gravitation.length
```

Resulting number T will represent the compactness value which can be compared with other urban formations or other development alternatives.

### *B. Measuring the Level of Mixing of Urban Elements*

The spatial interaction between urban objects differs according to the type of objects. Urban objects between which interaction is taking place are usually buildings, because most of the human activity takes place in buildings. In calculations described in this article other urban objects like parks, streets and public spaces are skipped. The objects are divided into three categories – living places, working places, places of public attraction (retail centers, clubs, other commercial, cultural and social infrastructure objects). The data can be collected for separate buildings or building blocks. The best and most precise way is to collect a number of residents, workers and visitors for each building (see Table I).If such data is not available it is possible to model the data by assigning the numbers according to the area and function of the building.

TABLE I
OBJECT CATEGORIES IN URBAN STRUCTURE

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

Spatial interaction is different from gravitation index, because it measures actual processes happening in the urban environment. Here the same formula can be used but in addition to it the gravitation coefficients must be added and the gravitation must be calculated between different categories of objects using their coefficients (3). By described calculations the travel demand can be found if the data is correct.

For each category of elements the sum of gravitational vectors is calculated by the formula:

$$a_n = k_{ff_1}\frac{\sum_{1,i} g_{ni}}{s_n} + k_{ff_2}\frac{\sum_{1,j} g_{nj}}{s_n} + k_{ff_3}\frac{\sum_{1,k} g_{nk}}{s_n} \quad , \qquad (3)$$

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 is calculated:

$$T_{category} = \frac{\sum G_{category}[a_1 \quad .... \quad a_i]}{i}, \qquad (4)$$

$$T_{mixing} = \frac{T_{living-working} + T_{working-attraction} + T_{attraction-living}}{3}. \qquad (5)$$

The value $T_{mixing}$ describes the level of mixing of urban elements and the values of T for different categories of objects describe rationality of the distribution and integration of specific categories of elements into the whole urban structure.

### *C. Predictive Methods for Land Use Dynamics*

The planners and decision makers need the tools not only to measure the compactness and level function mixing, but also the tool to predict urban growth. Among such tools the Cellular Automata (CA) is most prominent and fast-track. This tool is used for scientific research today, but because of simplicity it can be easily adopted for many tasks in town planners everyday work. With this tool the planner and the decision maker can predict future development and also build different development scenarios, they are used as a tool to support land use planning and policy. CA generated models are tools to support the analysis of the causes and consequences of land use dynamics [18], [19], [20].

For more than 20 years different models are used to predict the urban growth. The basis for these models is modified Cellular Automata (CA). CA is an iterative modeling of a process. It is being applied in many fields, and also to model urban growth. Cellular automata is an iterative process which operates on a grid of cells each containing a value that represents the state of the cell at time t. The change in a cell's state between initial time t and the following time (t + 1) is determined by a neighborhood function. The state of cell i at time (t + 1) can be defined as:

$$S_i^{(t+1)} = f(S_i^t, Q_i^t) \qquad (6)$$

where $S_i^{(t+1)}$ – state of a cell *i* at time *t+1*, and $Q_i^t$ –state of neighborhood cells at time *t*.

Neighborhood functions are called Von Neuman or Moore functions according to the number of adjacent cells considered. However standard Von Neuman or Moore functions are usually replaced by extended functions where bigger number of adjacent cells influences the state of analyzed cell. Towns exist as a structure where every element interacts with every other element directly or indirectly, therefore the functions can include all the existing elements of urban structure, but the influence of other elements will depend on the distance. Such functions usually include distance calculation and are described as "if …. then" statements. The general "if ... then" rules of CA model for simulation of urban growth patterns were described already few decades ago [21]. But only in recent years, cellular automata (CA) models for urban growth simulation have become popular amongst the academic researchers. CA models are relatively simple, flexible and intuitive but at the same time capable of modeling complex dynamic systems such as urban systems. Although CA model has clear definition and strict rules like rectangular grid of cells many relaxations of rules are allowed when modeling simulating urban growth[22]. There can be different transition rulesin CA, but the factors that influence such rules are usually repeated. The most popular are road accessibility (81%) and distance to urban centers (50%). CA can generate the urban development according to the rules set by the planner or it can find the rules according to the previous development pattern. In any case CA generated urban model must be analyzed to get the characteristics of compactness and level of function mixing to get some practical use of it.

The model described in this paper cannot be called CA strictly, because the cell transition rules are changed in such a way that each cell is influenced to bigger or smaller degree by every other cell of urban structure. The model is not limited to few adjacent cells, but rather the whole urban structure is taken into consideration. CA is based on iteration cycles, and in model presented here iteration is equal to one year. The algorithm for each iteration can be described as a cycle and inside this cycle the core algorithm for calculation of average distances is embedded. The number of cells developed during each cycle must be given *a priori*.

The proposed methods for calculation of spatial sustainability characteristics of urban form are combined with an enhanced CA model to create a practical tool for prediction of urban growth and evaluation of sustainability of planned growth. Such approach is scientifically new and hopefully will be interesting for practitioners, not only for academic circles. It has both predictive and descriptive parts combined together and has a wider field of adaptation and usage than CA or descriptive methods themselves.

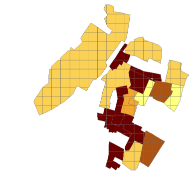
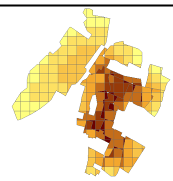
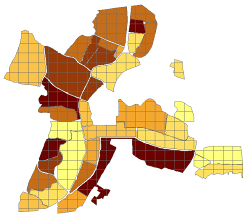
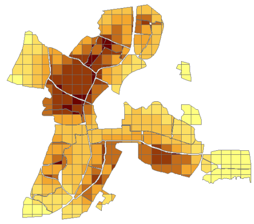
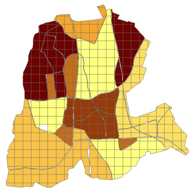
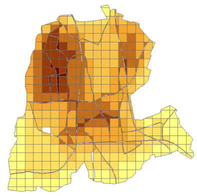
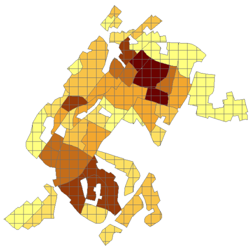
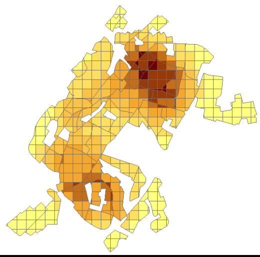
All mentioned examples of using CA for urban growth simulation have modeling uncertainties because they are just an approximation to reality. These uncertainties have impacts on the outcome of urban simulation. Development of urban areas depends greatly on region, demographic situation, migration, market and of course planning, and many of these factors are not predictable. Therefore CA model usage to simulate urban growth is questionable, but this model can be used to analyze the planner's decisions and help to improve them.

To describe spatial distribution of urban elements most often the GIS software is used. The software usually has functions to calculate common spatial statistics, measure spatial distribution and analyze spatial patterns when the map is properly prepared [14]. These can provide very general characteristics of spatial distribution like mean center, mean distance between the objects or even clusterization of features. This information is useful in general, but the functionality of software is often limited and does not give exact spatial characteristics in urban analysis. The most efficient way efficient way of organizing data and executing operations to obtain spatial statistics is batch processing with scripts.

## III. Calculations and Results

Most simple tool was created to analyze the existing towns and compare the sustainability of their form using formulas (1) and (2). The data needed for such a calculations can easily be obtained by analyzing satellite images. In this case similar by size and territory towns Falkoping, Hudigskvall, Visby in Sweden and Orimattila in Finland were selected to analyze and compare the compactness. Analyzed territory was divided into 50x50m rectangles and approximate population density according to the type of buildings was found for each rectangle. The densities ranged from 12-20 people/ha in residential housing blocks up to 120 people/ha in multifamily multi-storey housing blocks.The results are represented in schemes showing the gravitation each cell has created. It can be therefore easily estimated where the planner needs to increase the density and where the centers of weight are located in the urban structure. Besides these graphical schemes the overall compactness coefficient is calculated by which it is possible to compare the different urban formations. Table II shows that in most cases the towns have more than one clearly defined gravity center. If these gravity centers are located far from each other, the degree of compactness is decreasing like in case of Visby. The most compact towns from selected were towns of Hudigskvall and Orimattila with three gravity centers located closely to each other. In this first example the degree of function mixing was not calculated, because only the population density was considered. To calculate the degree of function mixing more detailed analysis of satellite images and *Google Street View* is needed. Usually to define the main objects of public attraction is enough to find the biggest retail centers and shops, and then assign the weights by the size of the object or car parking lot. In the case with working places the data obtained from satellite image is not very reliable and more thorough study must be done using the registry and statistics of local companies, or making survey by phone. When the information about all 3 kinds of objects (see Table I) is obtained the level of function mixing can be defined by the calculation of mean distances between different categories of objects (5).

TABLE II
ESTIMATION OF THE COMPACTNESS OF SELECTED MEDIUM SIZE TOWNS

| Town name | Population | Area, ha | Scheme of population density | Scheme of gravitation | Compactness coefficient T |
|---|---|---|---|---|---|
| *Falköping*, Sweden | 16 350 | 854 |  |  | 4.52 |
| *Hudigskvall*, Sweden | 36 429 | 1058 |  |  | 5.16 |
| *Orimattila,* Finland | 16 352 | 814 |  |  | 5.11 |
| *Visby*, Sweden | 22 593 | 1574 |  |  | 4.90 |

This method can also be used to calculate the travel demand. The consistency of daily trips made by inhabitants has to be studied and described in the number of daily trips made from home to work, from home to public attraction object, from work to other working places, from work to the objects of public attraction etc. Having thus categorized daily trips and mean distances, it is possible to calculate theoretical travel demand.

With these calculations the planner can estimate not only existing towns, but also see how compactness, level of function mixing and travel demand changes after adding new development objects.

To analyze overall compactness of the urban structure the area of the buildings can also be used instead of population density. Most of the towns have digital maps. From digital maps the area of buildings can easily be obtained knowing the height (number of floors) of the buildings. In this case the scheme showing which objects contribute to more sustainable, more compact urban environment, and which objects are reducing overall compactness of analyzed territory can be drawn is different way – showing object weight and relative gravity the object created (Fig. 1).

In example we see bigger town Vilnius (523 050 inhabitants, 401 $km^2$) divided into rectangular 500m x 500m cells with weights representing the area of the buildings for each cell. Example shows which districts are peripheral and therefore do not contribute to the overall sustainability of urban structure. The districts with highest gravitation values can be defined with just a glance. The mean distances between buildings support the planner and politics with useful information related to average travel distances, expenses to maintain transport and energy supply infrastructure. It can also be used to estimate the consequences of big development projects like construction of new commercial objects, assigning the place for new living districts *etc.*

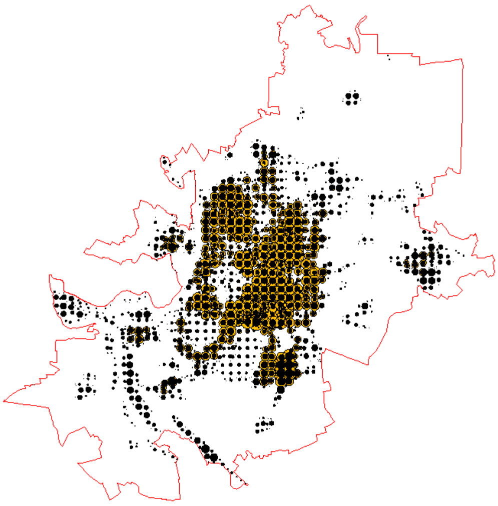


Fig. 1 Visual presentation of object weight relation to created gravitation ratio for Vilnius town, Lithuania (● – cell weights, ● – relative gravitation)

Another experiment estimates the town planner's decision. General plans of the towns are the main planning documents where the urban formations – villages, towns and cities are planned concerning whole urban formation and the decisions made in this planning document need sustainability assessment most of all. General plan of a town describes mainly the territories where some kind of development is allowed or prohibited and the existing objects. The territories for future development can be of two types – green field (development in completely new, untouched territories) and brown field (the development of previously used derelict land). The planning decisions are made according to many arguments, and government or private developer initiative is usually the most important. Sometimes the planner or the politicians add some ideas themselves, sometimes citizens of the town influence the decisions made in general plan. In any case such decisions can change the whole urban structure and must be checked for sustainability.

In this case study the general plan of town Utena with 32 500 inhabitants was selected as a typical recently prepared general plan in Lithuania. To make the assessment of the planned development empty cells were marked in the places where the development can take place (Fig.2). It was specified which type of object can appear in the empty cell according to the decisions in general plan. According to the number of objects constructed in recent years it was assumed how many objects of different type will appear every year in the future. The optimistic scenario was selected and approximation gives these numbers:

- 30 single family houses to accommodate 2.4 inhabitants each;
- 15 places of public attraction, each visited by 50 people daily;
- 5 working places, each for 10 workers.

It must be mentioned here that in the Baltic countries, especially Lithuania, the planners have the problems with assigning too big territories for development. This comes from the will not to limit the development and get economic benefits from increased production in construction market, not seeing the unsustainability of such development from the other side. Politicians also play role in assigning these waste territories for development, by this they declare the equity for all land-lords and the possibilities for growth of economy. In this way the result is that in recent general plans in Lithuania the territories for green field development from two to five times bigger than needed are assigned. In the case of Utena town general plan Fig. 2 with empty cells clearly demonstrates it – the existing town territory is approximately of the same size as planned development. In reality such assignments lead to the chaotic and sparse development which occurs even without planning.

In case study of Utena existing town objects were analyzed and described as urban elements in three different categories described in Table I. The developed objects are also of the same three categories as the existing objects and take part in the calculations of next year iterations after they appear. The chosen cell size is 1/10 of hectare which is average land plot for the private house in Lithuania. Cells of the same size are used for all categories of objects; one cell matches either one house with 2.4 inhabitants, one office or business/production place with 10 working places or one object for public attraction with 2 workers and 50 visitors per day.

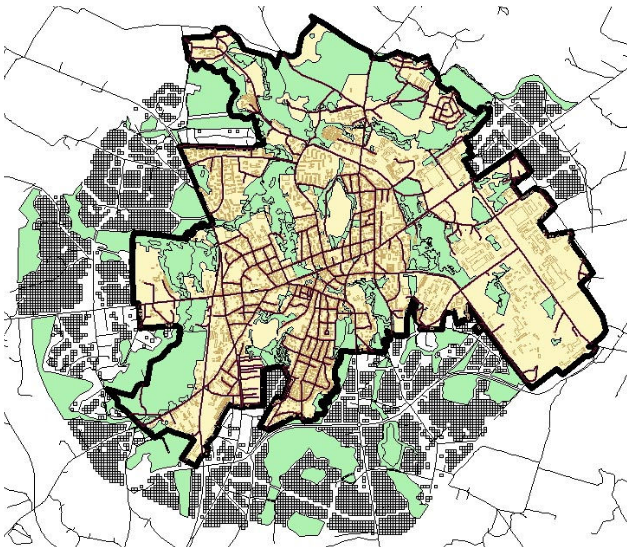


Fig. 2 Preparing the data for simulation of development ( – empty cells, ▬ – the territory of existing town)

The development frame is given by the planner, but actual development takes place progressively and starts in the cells which are most attractive for the development of specific category of object. There is also a degree of uncertainty in human behavior and other uncertainties like market price of the land parcels which depends greatly on the owner and therefore is hardly predictable. Therefore in this example two kinds of simulation were used – one with 30 percent degree of uncertainty and the other – with the development only of these cells that have best locations. To accomplish this the level of attractiveness of each cell was calculated in every iteration cycle where different distance factors were considered:

- Average distance to working places.
- Average distance to places of public attraction.
- Average distance to living places.
- Minimal distance to existing buildings (used when calculating attractiveness for object - public attraction place).
- Minimal distance to green areas (used when calculating attractiveness for living place object).

Every factor has its own calibration coefficient showing the importance of that factor. In Utena town case study calculations we used three different formulas to find which cells are most attractive for the living place, working place or public attraction object. The importance of the factors or calibration values was determined according to the survey of travel consistency of residents of Utena town. 70 respondents gave the information about usage of transport, trips made daily, weekly and monthly, number of trips to work, social infrastructure and other important objects that their family made.

To add the uncertainty it was assigned that 30% of housing development takes place in random cells. Fig. 3 shows the CA modeling results with uncertainty and is very close to the real development pattern taking place in Lithuania at the moment. It shows that oversized territory assignments for development lead to chaotic and sparse development which can be observed in Lithuania currently. Magnified part of the CA simulation scheme shows living places appearing randomly in the middle of the fields and it became a part of Lithuanian landscape in reality.

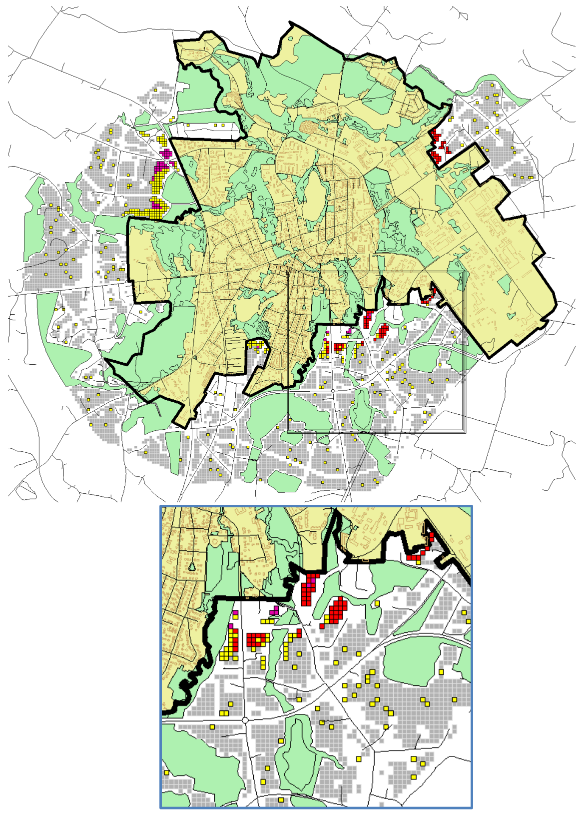


Fig. 3 CA simulation results up to the year 2030( - new living places, – new places of public attraction, – working places, – unbuilt)

Fig. 4 shows the CA simulation when only best locations are selected for development. This scheme shows the greatest mismatch between the decision made in Utena general plan and the development which can actually take place. The development simulation shown here is optimistic and based on assumption that most of the development will take place on green field territories, but actual development in Utena can fit the brown field sites and empty territories inside the town also. For this the cells inside the town can be created in the same manner as outside and these cells in most cases will be better located for development, therefore at the beginning it will take place inside the city without reaching the outskirts.

International Journal of Business, Human and Social Sciences
ISSN: 2517-9411
Vol:7, No:9, 2013

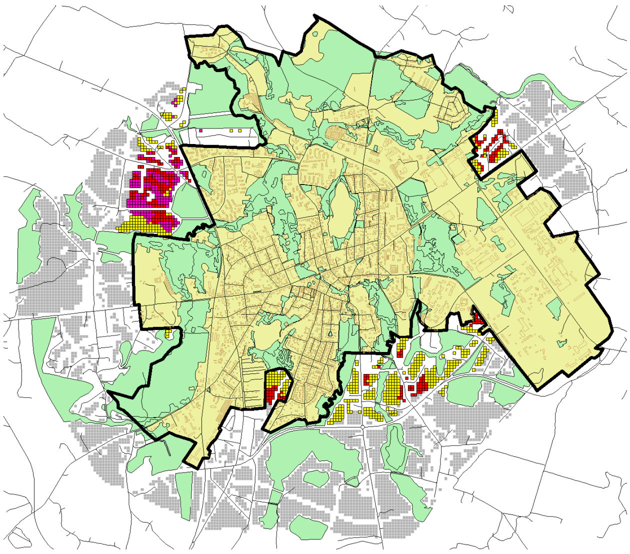


Fig. 4 CA simulation results up to the year 2030 meantto find the best places for new object placement ( - new living places, – new places of public attraction, – working places, – unbuilt)

With the help of CA analysis the decision makers would be able not only to assign proper areas for development, but also to put the different categories of objects in the best locations.

## IV. Discussion

Urban analysis has been quick to adopt and benefit from development in technology (microcomputer, GIS, remote sensing) and techniques (statistics, landscape metrics, mathematical programming), but conventional urban analysis remains, for the most part, aspatial. Usually only changes in land uses in urban environments are analyzed to provide a historical perspective of land use and give an opportunity to assess the spatial patterns, correlation, trends, rate and impacts of the change. Commercial GIS packages incorporate cartographic analysis techniques and spatial models, but generally these standard tools fail to adequately summarize locational information [23]. Urban planning decisions still are made without reliable methods and in many cases tend to be subjective and dependent on opinion of decision maker.

The tools for urban planners are currently being developed and are appearing in the forms of scripts for most popular commercial software. Such attempts are still not recognized in practice. To implement urban spatial analysis in practice simple and universal methods are needed. But even the most simple and readily available methods described in this article will not become popular without making urban spatial analysis obligatory through legislation. Some procedures in planning practice, like strategic environmental assessment (SEA) of planning decisions, were implemented in some of European countries in last decade, but in most cases they are just formally completed and actually ignored by planners, because they are based on a spatial information (e.g., quantities, areas) and do not give insight to urban processes. The existing assessment systems suit the needs and are convenient for politicians. In politics declarative manner is predominant and therefore achieving sustainability is usually limited to raising economic, social and environmental indicators. It is unlikely that this situation in legislation will change and therefore planners can accept the challenge to make spatially well-founded decisions only as their personal professional ambition.

## V. Conclusion

Existing tools for assessment and monitoring of urban sustainability are mostly based on the criteria systems. Criteria systems generally use only statistical information without further investigation of relations between urban structure elements or examining the physical form and locations of urban elements. Such criteria systems are used in monitoring the development, but do not support urban development decisions or help to select alternatives.

The urban form sustainability assessment tools are in development stage at the moment, they are used mostly by academia but not planners and decision makers. The academic researches concentrate mostly on calibration of models, but not on applicability in urban planning practice.

Urban planning practice needs methodologies that are simple, visually perceptive, and efficient in data collection and preparation.

To get substantial urban sustainability assessment results there is no need in precise and complex data. Most of data needed for calculations can be obtained from satellite images which are now freely available.

Most of urban planning practitioners use GIS software with possibilities for scripting. The simple scripts to calculate the mean distances, compactness and level of function mixing as well as to visualize the results can be programmed by common user without high degree in special knowledge. The example shown can be converted into different programming languages and adopted to preferred software.

Formulas presented in this research represent the core idea of urban sustainability assessment; they can be modified and enhanced to serve different purposes – from examination and comparison of sustainability of existing urban structures, comparison of development alternatives in terms of their contribution to overall sustainability of whole urban structure, to monitoring the urban structure changes and assigning territories for development.

## Acknowledgment

Authors thank to the Environmental Engineering Faculty and Research Institute of Territorial Planning of Vilnius Gediminas Technical University for supporting the publication of this research.

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