Upgrading Urban Plan Production Process Using GIS: Case Study: Production of Land Value Data Layer

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Key words: Urban development plan, GIS, Land value data layer

SUMMARY

Nowadays there is a high rate of urban expansion which can not be ignored in proper urban management. Parallel to the urban expansion we are faced with an increase in urban problems, which will lead to complexities dealing with the urban management and planning processes. A city is a set of condensed and broad functionalities which requires handling of huge amount and diverse types of geospatial data. There are a number of spatial and aspatial urban data to be organized and used by urban planners and decision makers. Such decisions by urban planners highly influence the functionality of different components and physical structure of cities. Hence, urban planners and decision makers have to be more sensitive in the decision making process and by analyzing qualified data, make the best decisions. Urban planners will usually use urban development plans as a tool in their decision-making.

Urban development plan production needs a broad range of spatial and aspatial data to be used to upgrade the plans provided having an organized and optimum management of them. Considering the nature of data used in the urban plan productions and different sciences and technologies available for data management, geospatial information systems (GIS), can effectively be implemented for urban development plan production.

This paper intends to investigate principals of urban planning and urban development plan production process, in addition to evaluate the role of GIS in the process. Considering the importance of determination of different land uses required in a city in urban development plan production process and the impact of land value in this matter, production of land value data layer has been successfully undertaken in a district in Tehran using GIS and neural network algorithm.

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1. INTRODUCTION

Nowadays high rate of urban expansion has resulted to increase of urban problems. Allocation of spaces and required land uses, dwelling, traffic and public transportation are among such problems. Urban planners are trying to solve these problems by proposing technical approaches through urban development plans (UDP). Preparing UDP is a multistage process using a huge amount of geospatial data. The management of such broad and diverse data is impossible without using new sciences and technologies. GIS is a computer-based information system that enables capture, modeling, storage, retrieval, sharing, manipulation, analysis and presentation of geospatially referenced data [19]. As the majority of information used in UDP is geospatial in nature, GIS can be effectively used as a spatial planning support system to handle different urban planning and management issues. It is necessary to point that full realization of UDP has enormous effects in solving the urban problems.
One of the most important factors in failure to realize UDP is ignoring the land value which highly affects in realization of the concerned land uses.
This paper intends to investigate principals of urban planning and urban development plan production process, in addition to evaluate the role of GIS in the process. Considering the importance of determination of different land uses required in a city in urban development plan production process and the impact of land value in this matter, production of land value data layer has been successfully undertaken in a district in Tehran using GIS and neural network algorithm. It has to be pointed out that the land value data layer in addition to its importance in a site selection process, will be highly used by a range of users such as banks, public organizations, real state offices and municipalities.

2. URBAN PLANNING AND UDP

Urban planning is determining and drawing up plans for the future physical arrangement and condition of a community [4].
Urban planning through UDP tools follow two main aims [5]:

1. Organization of major urban activities (such as housing, business, entertainment and communication).
2. Optimizing spatial distribution of qualitative and quantitative facilities in urban areas.

UDP includes a set of diverse plans that each of them is a multistage process using a huge amount of geospatial data to be used for proposing solutions in the study area.

3. APPLICATIONS OF GIS IN URBAN PLANNING

GIS are the formalized computer-based information systems capable of integrating data from various sources to provide the information necessary for effective decision making in urban planning. Other information systems for urban planning include database management systems (DBMS), decision support system (DSS) and expert systems [1]. GIS serve both as a database and as a toolbox for urban planning (Figure 1). Current GIS support efficient data retrieval, query and mapping. Planners can also extract data from their databases and input them to other modeling and spatial analysis programs. When combined with data from other tabular databases or specially conducted surveys, geospatial information can be used for effective planning decision. As a toolbox, GIS allows planners to perform spatial analysis using geoprocessing functions such as map overlay, connectivity measurement and buffering. Of all the geoprocessing functions, map overlay is probably the most useful tool. This is because planners have a long tradition of using map overlay in land suitability analysis which itself is an important component in urban planning [1,2].

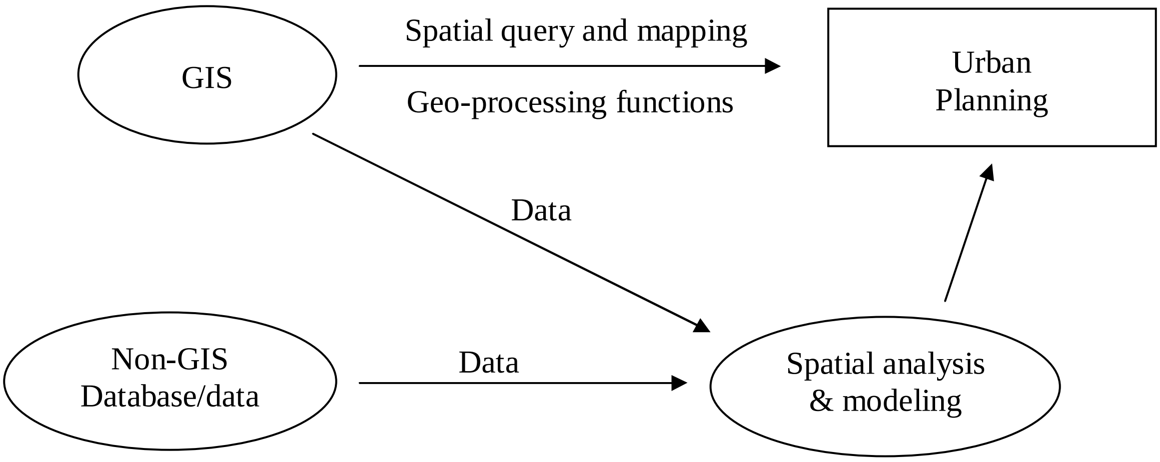

Figure 1: GIS and urban planning [1]

Database management, visualization, spatial analysis and spatial modeling are the main uses of GIS in urban planning. GIS are used for the storage of land use maps and plans, socio-economic data, environmental data and planning applications. Planners can extract useful information from the database through spatial query. Mapping provides the most powerful visualization tools in GIS. It can be used to explore the distribution of socio-economic and environmental data and display the results of spatial analysis and modeling exercises. Spatial analysis and modeling are used for spatial statistical analysis, site selection, identification of planning action area, land suitability analysis, land use transport modeling and impact assessment. Interpolation, map overlay, buffering and connectivity measurement are the most frequently used GIS functions in spatial analysis and modeling. Use of the above functions varies according to different tasks and stages of urban planning [1,2].

Many benefits exist in using GIS in urban planning which some of them are described below [1]:

- Improved mapping – better access to maps, improved map currency, more effective thematic mapping and reduced storage cost.
- Greater efficiency in retrieval of information.
- Faster and more extensive access to the types of geographical information important to planning and the ability to explore a wider range of “what if” scenarios.
- Improved analysis.
- Better communication to the public and staff.
- Improved quality of services, for example speedier access to information for planning application processing.

Gautam [18] provided a broad review of Urban Plan Production Business Process (UPPBP). He aims at optimization of UPPBP by suggesting changes in institutional, technological and managerial aspects of its functionality, to make it more robust and fit to meet its emerging challenges. In order to create a logical base to take off with the idea of optimizing the mentioned business process, an exhaustive questionnaire was designed and a survey of four State Government Urban Planning Departments was conducted. Based upon the conclusions of the survey the diagnosis of the process was carried out by executing internal and external scanning of the process with thrust on one of the Departments namely The Town & Country Planning Department of Himachal Pradesh. Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis and metrics were drawn to formulate future strategies to materialise the intended optimisation of the process. Simultaneously, an overview of Geo-ICT and GIM technology was undertaken with reference to their potentials and limitations for application in optimisation of UPPBP. In the next phase the UPPBP as envisaged in The Himachal Pradesh Town & Country Planning Act, 1977, was structured into sub-processes and activities, wherein recommendations for substitution of appropriate modern enabling technology at every demanding activity level were crisply given. To support the core optimised process model of UDP and ensuring continuous business improvement in the processes such as Organization model, Quality model and Workflow management model are also conceptualised. Such models are not in practice at all in the existing UPPBP model. An attempt to evaluate the improvement on implementation of the optimised process model is also made after identifying the possible indicators / criteria and by developing a qualitative improvement scenario, since some quantitative evaluation was impossible in the absence of right type of comparable data. However, the results of the evaluation proved that there would be around 30% reduction in overall plan preparation time on implementation of optimized process model. The highest betterment is recorded with respect to time criterion followed by cost but the latter will accelerate with time as capital investments will decrease steadily in due course of time. It is thus evident that the timely preparation of plans will firstly, arrest the problem of unplanned or ad-hoc development scenario in the absence of comprehensive plans, secondly, reduce temporal escalation in development costs and lastly increase social acceptability of plans, which is the ultimate goal of any social planning. Thus the process will certainly be in position to achieve the objectives of planned development and help in providing social justice and a liveable environment to the masses. The success in achieving objectives in turn will make the process favourite and widely acceptable making the restoration of its glory possible. The requirements for implementation of the optimized process were also worked out in form of guidelines. The research indicates positive results but to quantify the same some prolong research backed by exhaustive and appropriate database is required.

4. THE EXPECTED GIS TASK FORCES IN UDP PROCESS

There are a number of expected GIS task forces to support UDP. The major ones are as follows [3]:

- Information retrieval and display.
- Information classification.
- The possibility of short and long term planning to meet the future needs. For example, performing a site selection for new land use planning considering the population rate and its densification at a given district.
- The possibility of performing some statistical computation such as the number, average, standard deviation for the houses within the specific area.
- The possibility of thematic map production.

In addition to the above-mentioned capabilities, there can be a number of complicated modeling such as follows:

- The impact assessment analysis of making a new road in an area.
- The cost of performing an urban plan in an area, considering the existing houses.
- Estimating the allowed densification in an area.
- The level of required specific land use (such as an educational infrastructure) in an area.

5. NECESSITY OF CONSIDERING LANDS AND THEIR VALUE IN UDP PRODUCTION PROCESS

Urban population has highly increased in the last decades and this trend continues in most countries. The same trend is more visible in developing countries such as Iran. The population expansion result to lack of lands in future, therefore optimum use of land has to be considered. Hence UDP providers should try to propose optimum land uses considering the land shortage.

The proposed land uses by UDP providers are spatially distributed in various parts of cities and realization of UDP is based on realization of the land uses. One of the important factors to be considered is land value. One factor in failure of realization of UDP is undermining financial resources and economical outcomes of the plans [6] and lack of required financial as well as legal infrastructures [7]. Such a matter is so important that lack of reliable financial supports for public organization specially municipalities is resulted to failure of attempts to realize UDP which is shown in Figure 2 [6].

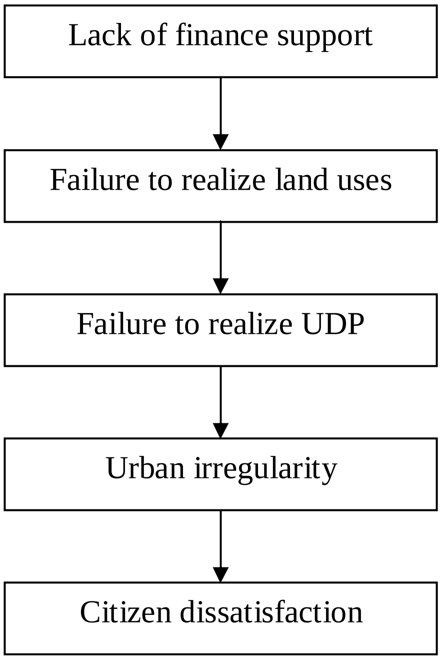

Figure 2: Financial support impact in UDP realization [6]

If an estimation of UDP realization cost at the time of their production be available, it will be highly beneficial in upgrading UDP production process. Therefore, it is necessary to provide various data layers for UDP providers. Considering land value data layer, the required cost for realization of land uses can be estimated.
Real estate appraisal is a process for producing this data layer. Nowadays a number of research have been undertaken in the field of accomplishment of real estate appraisal. In the next parts we discuss about real estate appraisal.

6. REAL ESTATE APPRAISAL

Market value is defined as the most probable price which a property should bring in a competitive and open market under all conditions requisite to a fair sale, the buyer and seller each acting prudently and knowledgeably, assuming the price is not affected by undue stimulus [11]. Real estate appraisal is the action of judging the market value of land and its improvements (principally the building), which is usually done by experts.
Assessors deal with the estimation of market value through gathering the required data as much as possible, integrating them on the basis of land as the common foundation and finally carrying out the analysis using different methods and experiences. Appraisal data that will be collected and analyzed will fall into one of the following Categories [11]:

1. General
2. Specific
3. Comparative

General data is an overall category that pertains to information about the four forces (physical, economic, governmental and social) originating outside a subject property and those forces' influence on that property's value. General data provides a background basis for analysis of international, national, and regional trends that affect value. Examples of general data would be Census publications.

Specific data pertains primarily to information about the site. Examples of specific data would be title and recorded information such as legal description, special assessments, zoning, easements, other public restrictions and physical information about the site.

Comparative data consists of cost, sales, and income information on individual properties. When properly screened and confirmed, comparative data is used directly in the cost, market and income approaches to assess the subject property. Examples of comparative data are development costs for comparable subdivisions and economic rental rates.

First initiatives in development of organized real estate valuation boards go back to 1960s [16], when considerable attentions were paid for creation of systematic procedures and resulted in development of a new definition for the real estate appraisal as mass appraisal. This is defined as a systematic appraisal of groups of properties as of a given date using standardized procedures and statistical testing [12]. The general trend of mass appraisal process is as follows [11]:

1. Problem definition
2. Preliminary survey and planning
3. Data collection and analysis
4. Application of the approach to value
5. Estimated value reconciliation
6. Finalize estimation

Evolution of the mentioned initiatives proceeded by analog to digital conversion revolution in late 1970s [17] that resulted in pervasiveness of digital computation methods towards automation of real estate appraisal’s tiresome procedures. However, the general trend of mass appraisal remained the same. Besides, the computational methods used to develop computer assisted mass appraisal (CAMA) systems are mainly limited to levels 3 and 4. These levels include most of the expertise required for property value estimation, too.

7. ACCOMPLISHMENT WAYS OF REAL ESTATE APPRAISAL

There are three approaches used to real state appraisal consist of sales comparison, income and cost approaches [11].

Applying the sales comparison approach, the assessor compares similar properties that have been recently sold. Factors such as size, location, quality, condition and date of sale are recognized. This approach can be used for all types of properties where there are sufficient sales for analysis.

Using the income approach, market valuations are determined based on the income generating capability of similar properties. Rental income, operating expenses, maintenance costs, insurance and rates of return are analyzed in formulating market values. This approach is commonly used for commercial/ industrial properties.

The third method used to determine market value is the cost approach. Base values for all properties are determined using the current cost to replace improvements, less depreciation, plus the value of the land. Property values are then adjusted to reflect current market conditions.
It should be considered that the sales comparison approach apply more, because it is simple and comprehensive. For realization of this method some districts should be defined for searching and finding similar properties which will be done through market segmentation.

8. MARKET SEGMENTATION

The inherent spatial immobility of land and property means that location is an intrinsic attribute of a dwelling. While the appraisers generally agree that the location is the most important factor affecting the value, its modeling and standardization for the property valuation has proved difficult [10].
There are some agreements that housing market is composed of a set of submarkets [8, 10, and 13]. While the appraisal models require a specific level of homogeneity to be developed accurately and submarkets provides this condition, market segmentation is considered as a determinant process in mass appraisal.
Market segmentation is mainly based on exploration and classification of data on the basis of location. Submarkets could be created based upon: a) environmental or locational characteristics; b) quantitative characteristics of dwellings (e.g. type, size and age) and c) analysis of house prices [10]. Besides, these approaches are classified as statistical techniques, like clustering and principal components [8] and location-based techniques.
In general, submarket specification has typically been performed on an ad hoc basis in which researchers stratify a sample based on prior expectations related to municipal boundaries, school districts, racial divisions, or housing types, estimate hedonic regressions for the individual submarkets separately and derive F-tests to determine whether the resulting reduction in sum of squared residuals is significant. If it is, the posited submarkets are assumed to be appropriate [13].
Goodman and Thibodeau discussed that in this procedure the submarkets are imposed rather than be modeled [13]. They argued that the effective factors on values have to be considered as nesting factors and be modeled in a hierarchical linear model.

For a single-family detached house, we consider the value of the house, nested within a neighborhood, a school district, a metropolitan areas, etc. Some of these effects may be nested hierarchically such as blocks within neighborhoods. Others, such as ethnic areas, religious parishes, or housing types, may cross-school or municipal boundaries and will not necessarily be nested, hierarchically or at all [13].
One of the main capabilities of the proposed hierarchical linear model is its automation and flexibility in considering alternative specifications for submarkets delineation [13]. On the other hand, Goodman and Thibodeau introduced the importance of contiguity and testability of the defined submarkets [13].
Considering the above-mentioned issues, the best-suited artificial neural network (ANN) would be Kohonen self organizing feature maps (KSOFM). KSOFM is known as an efficient tool for analysis and visualization of high dimensional data. It maps nonlinear statistical

relationships between high dimensional input data into simple geometric relationships as this mapping roughly preserves the most important topological and metric relationships of the original data elements and thus, inherently clusters the data.

Kauko provided a broad review of general and appraisal related literatures about KSOFM utilization [15]. He introduced capabilities of KSOFM in market segmentation and value estimation and concluded that it would work better than previously mentioned ANNs, especially in market segmentation. He also presented an alternative based on KSOFM integration with linear vector quantization (LVQ). The added value of this method demonstrated as enabling locational comparisons and relating intricately connected variables (market, physical environment, socio-economic, possibly psychological, political, and administrative factors).

Also, Carlson utilized KSOFM to handle some locational relationships for market segmentation in Finland [9]. He used a training dataset with 4750 samples of one-family houses and a two dimensional KSOFM network fed by locational factors as distance to some attractive sites, shore, lakes, roads, railway and high voltage transmission. The derived conclusion is used to define the relationship of prices to the mentioned spatial factors and depicts KSOFM suitability in mass appraisal.

9. METHODOLOGY

One important factor in this step is investigating and defining impact factors in land value. There are many factors that land value is based on them, however, considering the developing societies, problems in accessing the significant database that contains these factors, we should select some factors that are reliable and can be extracted from existing topographic datasets and maps using GIS. The mentioned factors are as follows:

1. Access to street
2. Street frontage
3. Currently usable area
4. Distance to educational centers
5. Distance to health services
6. Access to highway
7. Available utilities
8. Distance to recreational areas
9. Topography
10. Distance to religious places
11. Distance to play gardens

KSOMs are proposed handling these factors. KSOMs ANN could be adopted with the mentioned issues properly. The methodology process has shown in Figure 3.

Defining structure of the desired ANN, the general recommendation and results provided by Kauko [15] is followed in this paper.

10. CASE STUDY

Dealing with appliance of the methodology, part of Tehran (capital of Iran) contains about 10000 dwelling was selected and extracted from a 1:2,000 map produced under auspicious of Iranian National Cartographic Center (NCC).

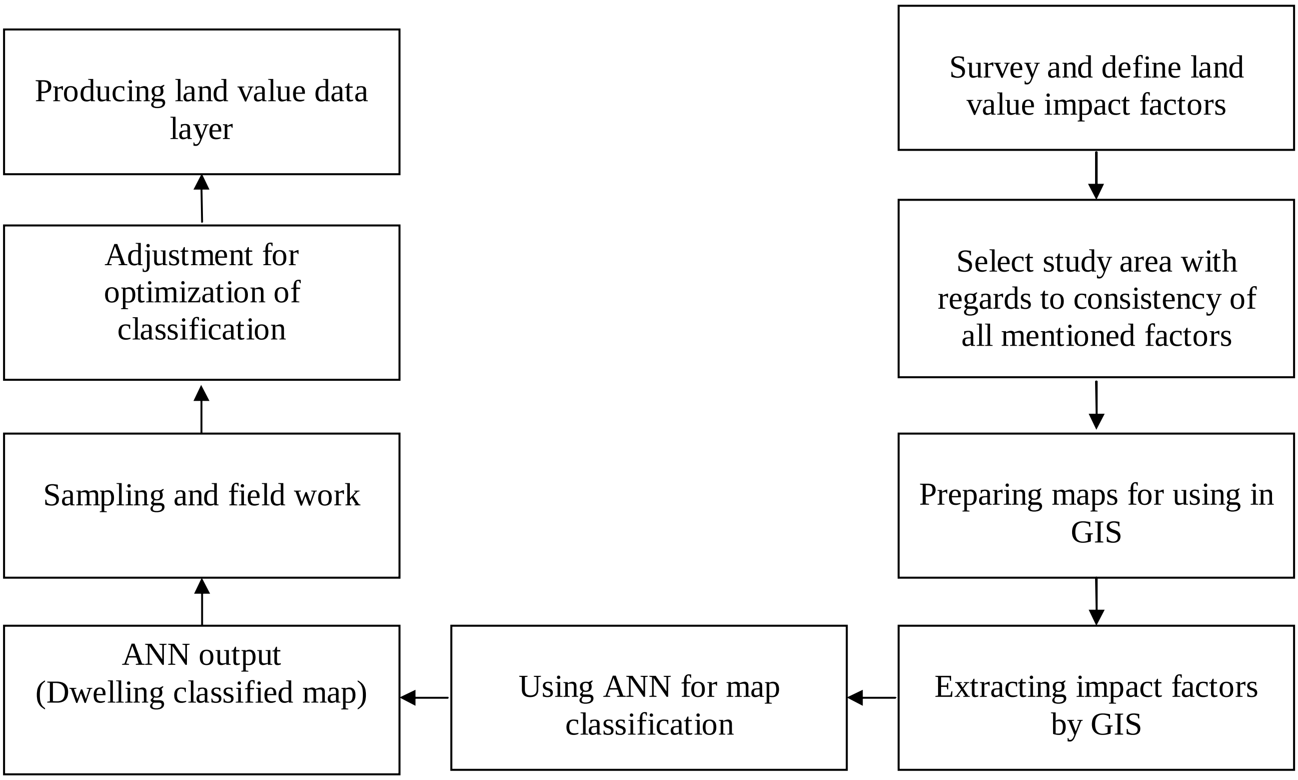

Figure 3: The proposed methodology process

The required locational factors of these dwelling are calculated in a GIS environment by using Arcview software. In the next step this map should be classify by ANN considering the mentioned factors in methodology.

The KSOM network that will be used here is developed using Matlab 7 programming language and we should define the optimum dimension for the net. The output of feeding these data into the mentioned ANN would be a map that presents comparable dwelling. Then by accomplishment of a field work, the accuracy of this map will be tested and then by adjustment, the performed classification is normalized and the value data layer will be produced.

11. CONCLUSION

Considering urban planning data types and UDP production process, these processes should be based on GIS to solve the problems. In addition, the lack of comprehensive databases consisting of required data for urban planning would be considered. GIS and their spatial capabilities, can extract a number of required data from existing topographic and cadastral datasets. Produced land value data layer is a reason for this matter.
The impact assessment of this data layer in upgrading UDP production process will be the next steps of this research.

REFERENCES

1- *Yeh, A. G-O (1999):* Urban planning and GIS, In: Geographical Information System, Principal and Technical Issues, Eds. Longely P.A., Goodchild M.F., Maguire D.J., Rhind D.W., John Wiley and Sons,USA, Vol. 1.
2- Zorica Nedovic`-Budic`, 2000, Geographic Information Science Implications for Urban and Regional Planning, URISA Journal, Vol. 12, No. 2.
3- Nourian, F. and Sharif, M., 2000, A view on Detailed Plan Production process in urban planning and processing Inc., Tehran GIS center, Municipality of Tehran.
4- Sharmand Engineering Consultants, 1998, The Methodologies of Realization of Urban Developments Plans in Iran (In Persian), Vol. 1, Center for Urban Planning Studies.
5- Sharmand Engineering Consultants, 2000, The Methodologies of Realization of Urban Developments Plans in Iran (In Persian), Vol. 3, Center for Urban Planning Studies.
6- Zista Engineering Consultants, 1992, Evaluating Plan of Urban Master Plan in Iran, Iran's Plan and Budget Organization.
7- Mozaieni, M. 1992, Urban Planning and Determination of some New Concepts, Proc. The First International Conference on Physical Planning (National and Regional), Iranian Center for Studies and Research for Urban Planning and Architecture.
8- Bourassa S.C., Hoesli, M. and Peng V.S., 2003, Do housing submarkets really matter?, Journal of Housing Economics, Volume 12, 2003, pp. 12-28.
9- Carlson, E., 2002, Kohonen Map, GIS and the Analysis of Real Estate Sales, FIG XXII International Congress, Washington, D.C. USA, April 19-26, 2002.
10- Debbis, W.G., Lamont, I.G. and McCluskey, W.J., 2000, The Application of spatially derived location factors within a GIS environment, Proceedings, Integrating GIS and CAMA Conference, Miami, pp 132-141, 2000.
11- Division of Property Taxation of Colorado, 2004, Land Valuation Manual, Division of Property Taxation of Colorado, published in January 1989 and revised in January 2004.
12- González M.A.S. and Formoso C.T., 2003, Mass Appraisal with Genetic Fuzzy Rule-Based Systems, 10th European Real Estate Society Conference, Helsinki, Finland, 10-13 June 2003.
13- Goodman, A.C. and Thibodeau T.G., 1998, Housing market segmentation, Journal of Housing Economics, Volume 7, 2003, pp. 121-143.

14- Goodman, A.C. and Thibodeau T.G., 2003, Housing market segmentation and hedonic prediction accuracy, Journal of Housing Economics, Volume 12, 2003, No. 3, pp. 181-201.
15- Kauko, T., 2002, Modeling the Locational Determinants of House Prices: Neural Network and Value Tree Approaches, Ph.D. Thesis, Utrecht University, Netherlands, 2002.
16- Kertscher, D., 2002, On the Way to a valuation-GIS/Valuation Information System, FIG XXII International Congress, Washington, D.C. USA, April 19-26, 2002.
17- Rossini, P., 2000, Using Expert Systems and Artificial Intelligence for Real Estate Forecasting, Sixth Annual Pacific-Rim Real Estate Society Conference, Sydney, Australia, 24-27 January, 2000.
18- Gautam A.N., Optimisation of Urban Plan Preparation Business Process using Geoinformation Technology & Management Techniques, 2003, Master Thesis, the International Institute for Geo-information Science and Earth Observation.
19- Worboys M. and M. Dukhham, 2004, GIS: A Computing Perspective, Second Edition, CRC Press.

BIOGRAPHICAL NOTES

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