Constructing Fuzzy for Socio Economic Urban Growth Dynamic In Surabaya Based on GIS

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Abstract

Urban modeling is an important tool for efficient policy designing in a big city. Surabaya, a big city are now recognized as complex systems through which non-linear and dynamic processes occur. The paper present a methodological framework for urban modeling from socio economic point of view, which suggested framework incorporates a set of fuzzy systems. In this case, the variable consist of manufacture, hospital, school and shopping centre. Combining with spatial analysis in GIS, the result is a dynamic model was shown to be capable of replicating the trends and characteristics of an urban environment, in this case the city of Surabaya.

Keyword : urban modeling, socio economic, fuzzy, GIS

1. Introduction

Surabaya is the capital city of East Java.Geographically, it lies between the eastern and western parts of Indonesia, so this city plays an important role of the development of eastern part of Indonesia. Since the city of Surabaya has grown as an important center for economic development both at national and regional levels, the city itself is becoming much larger than before and now it can be classified as a metropolitan area because the number of the population already exceeded one million people. In 2010 population in Surabaya reach over 2,7 million. In parallel with this rapid growth in population, the urban expansion of the city has been similarly dramatic, growing from a geographical extent of less than 1 km² in the 1920s to over 1,150 km² in 2004 [1]. Many factor affect developing urban countries [2] include land cover factor (as water, town/village, green, agricultural, and urban built-up area), physical factors (road network, railway lines, city center/subcenter, bridges, rivers)and socio-economic factors (population and employment). Generally, main problem in managing and planning urban development is determining the urban model. Every city has different characteristic , it is make a sense that the method to build a model is different[3][4]. The paper emphasize on socio economic factor., There are several ways to build urban model. The paper focus to construct urban model by combine fuzzy and spatial analysis of socio economic factor The result is visualized in Geographic Information System (GIS).

2. Method Incorporate

First, it is important to choose the proper factor among socio economic factor. For this purpose, 764 data are gathered from 2005 to 2009. Table 1 shows some of socio economic data. Because some economic and social factor are intangible, it should be represented by something real. For example, education is represented by number of school, hospital for vital community service, shopping centre represent entertain, etc .

Table 1. Socio Economic data Surabaya on 2009

Kecamatan	Population per km	Manufact	school	hospital	Shop Cent
Surabaya Pusat					
Tegalsari	26655.94	12	32	2	5
Genteng	14498.71	6	24	2	2
Bubutan	30442.67	19	15	2	3
Simokerto	35728.67	26	15	2	3
Surabaya Utara					
Pabean Cantikan	20251.88	26	8	1	2
Semampir	23503.39	18	33	3	0
Krembangan	26759.83	31	21	2	1
Kenjeran	16918.26	59	16	2	0
Bulak	5460.746	20	9	1	0

Because there are many data, it should be decided which is significant in socio urban developing. Statistically, all data is tested in SPSS software to find rating of significances.Figure 1 illustrate an example the result of SPSS test. Figure 1 illustrate an example the result of SPSS test.

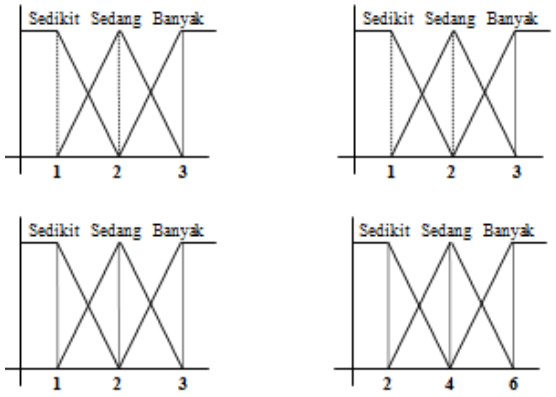
Correlations

		Kepadatan 2009	Industri
Kepadatan 2009	Pearson Correlation	1	.130
	Sig. (2-tailed)		.485
	Sum of Squares and Cross-products	3.146E9	802908.538
	Covariance	1.049E8	26763.618
	N	31	31
Industri	Pearson Correlation	.130	1
	Sig. (2-tailed)	.485	
	Sum of Squares and Cross-products	802908.538	12097.484
	Covariance	26763.618	403.249
	N	31	31

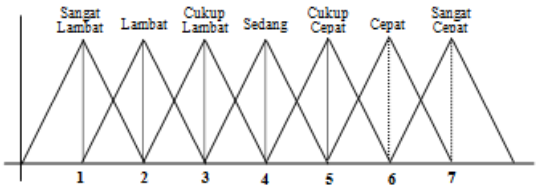
Figure 1. Result of SPSS Test

Figure 1 illustrate correlation between number of manufacture as representative of industry and population. Population is chosen as representative of urban development in big city [3][4][7] After test amount data, the result shows there are 4 significant variable such as hospital, manufacture, school and shopping centre. Then, all data are engagedstatistically to choose the significant variables.

Second, determine suitable method. In the urban system, there are many complex combinations of factors and subsystems. So, the tools such as mathematical theories and models must be used with full consciousness of complexity, Fuzzy solving methods were proposed because it has flexibility to simplify complexity in urban modeling.[F. Habib and A. Shokoohi]. In Fuzzy Logic, variables consist of partially overlapping qualitative fuzzy sets. Refer to [5] , Fuzzy Mamdani is choosen. Membership function is build from all variable mention before. Figure 2 shows one of input membership and output function.



(a)



(b)

Figure 2. Membership Function
(a). Input
(b). Output

Each fuzzy set is described by a linguistic variable familiar to its quality while quantitative (numerical) information is appointed to the proper fuzzy sets by the correspondent membership function. The knowledge base is represented as linguistic "IF…THEN" rules, connecting hypotheses to conclusions through a certainty factor. In this research, rule is performed to determine development in term VERY LOW, LOW, LOW ENOUGH, MEDIUM, HIGH ENOUGH, HIGH, VERY HIGH. Figure 3 shows part of rule base in this research

R1 : IF industri = tinggi v sekolah=sedikit v rumah sakit=sedikit v swalayan =sedikit
THEN perkembangan = sangat lambat
R2 : IF industri = sedang v sekolah=sedang v rumah sakit=sedikit v swalayan =sedikit
THEN perkembangan = lambat
R3 : IF industri = sedikit v sekolah=banyak v rumah sakit=sedikit v swalayan =sedikit
THEN perkembangan = cukup lambat
R4 IF industri = sedikit v sekolah=sedang v rumah sakit=sedikit v swalayan =sedikit
THEN perkembangan = sedang
R5 : IF industri = sedikit v sekolah= sedang v rumah sakit= sedikit v swalayan = sedang
THEN perkembangan = cukup cepat
R6 : IF IF industri = sedikit v sekolah= sedang v rumah sakit=dikit v swalayan = sedang

Figure 3. Rule base

Then, the knowledge extraction module for the suitability systems incorporates the following approach. First we calculate the percentage of urban cells that belong to each fuzzy set of each input variable. Then we divide the value returned for each set with the percentage of all cells (develop or not) that belong to this fuzzy set. Finally we normalize these values for each single variable separately. Finally accumulation corresponds to compromising different individual conclusions into a final result. Fuzzy logic combined to GIS provides a proper framework for expressing and mapping the urban growth dynamics.

3. Architecture of The Model in GIS

The goal is to develop a model that simulates in a realistic way the urban growth evolution while it allows the communication of its knowledge. The overall system is described by flow diagram in figure 4, combine GIS and fuzzy. These are to:

- reproduce efficiently the underlying spatio-temporal patterns of the urban growth dynamics,
- express in comprehensible linguistic terms the knowledge acquired and
- sustain a generic form of the model that is disengaged from data limitations.

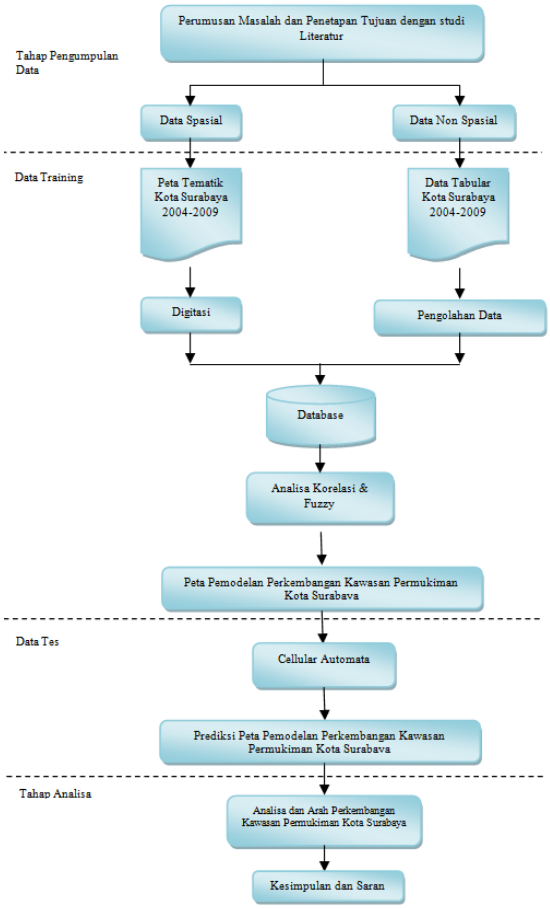


Figure 5. Flow diagram overall

In order to be useful and realistic, urban models depend on real-world data such existing urban land uses and growth patterns, existing road network, location of various facilities, availability of infrastructure facilities etc. that can be integrated and mapped in a modelling scenario. Figure 5 shows the object of research, Surabaya, in map.

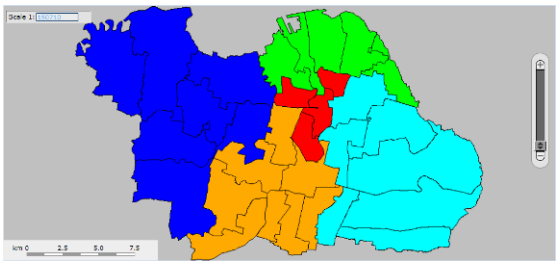


Figure 6. Political Map of Surabaya

This picture shows political geography of Surabaya. Surabaya is divided by 5 district namely Surabaya Tengah (Central of Surabaya), Surabaya Timur (East Surabaya), Surabaya Barat(West Surabaya), Surabaya Utara(North Surabaya) and Surabaya Selatan(South Surabaya). Each district consist of group area called Kecamatan, Every district have different number of kecamatan. Kecamatan itself cover a numbers of area called Kelurahan. Every kecamatan has different numbers of kelurahan. Figure 1 shows all kecamatan in Surabaya.

To meet GIS and fuzzy, one technique in GIS, grid system, is employed. All map is divided in square, in this case 2km by 2 km, and every grid has specific database include geographical data and data for fuzzy input. Figure 6 shows result of Surabaya after gridded

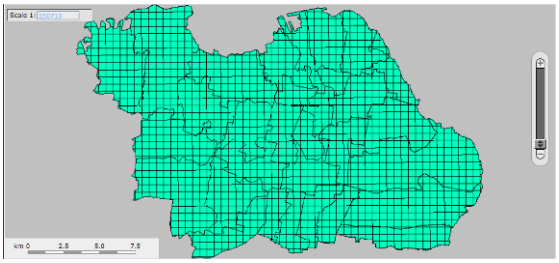


Figure 6. Political Map of Surabaya

Then, all data in grid is proceed in fuzzy system to produce result in term of Very Low, Low, Low Enough, Medium, High Enough, High, Very High development. Last, this result is analyzed in GIS software and visualized in different color.

4. Result And Discussion

Socio economic factor is chalenge because it is dynamic and complex. In a big city, where infrastructure is establish, this factor play significant role in urban development. From the statistical correlation test, 4 independent variable is decided, that is hospital, school, manufacture, and shopping centre while independent variable is population. The result is shown in figure 6.

Correlations

		Kepadatan 2009	rs
Kepadatan 2009	Pearson Correlation	1	.686**
	Sig. (2-tailed)		.000
	Sum of Squares and Cross-products	3.146E9	165078.468
	Covariance	1.049E8	5502.616
	N	31	31
rs	Pearson Correlation	.686**	1
	Sig. (2-tailed)	.000	
	Sum of Squares and Cross-products	165078.468	18.387
	Covariance	5502.616	.613
	N	31	31

**. Correlation is significant at the 0.01 level (2-tailed).

(a)

Correlations

		Kepadatan 2009	sekolah
Kepadatan 2009	Pearson Correlation	1	.583**
	Sig. (2-tailed)		.001
	Sum of Squares and Cross-products	3.146E9	1662032.401
	Covariance	1.049E8	55401.080
	N	31	31
sekolah	Pearson Correlation	.583**	1
	Sig. (2-tailed)	.001	
	Sum of Squares and Cross-products	1662032.401	2587.484
	Covariance	55401.080	86.249
	N	31	31

**. Correlation is significant at the 0.01 level (2-tailed).

(b)

Figure 7. Correlation factor
(a) Hospital to population
(b) School to population

Figure 6 explain negative and positive correlation factor. For school, correlation is negative. School in this case consist of elementary, junior high school and high school, privat and public school.. When it is checked in spatial data, school is spread in group randomly. Private school in Surabaya is growing up, compete public school.Their market are middle to high class whose has personal car. Private school usually located in real estate, in which land price is relatively expensive. This is the explanation why this variable decrease urban development.

In contrast, hospital means public service. When hospital is build, the environment change. It attract people to live surround for economic reason, such as trading, rent a room and so on. This is the reason why correlation is positive. Another result shown in table 2.

Table 2. Correlation between manufacture and population

Kecamatan	Kepadatan 2009	Industri
Tegalsari	26655.94	12
Genteng	14498.71	6
Bubutan	30442.67	19
Simokerto	35728.67	26
Pabean Cantikan	20251.88	26
Semampir	23503.39	18
Krembangan	26759.83	31
Kenjeran	16918.26	59
Bulak	5460.746	20
Tambak Sari	24924.62	78
Gubeng	20463.5	26
Rungkut	4649.382	26
Tenggilis Mejoyo	10133.94	45
Gunung Anyar	5169.643	24
Sukolilo	4456.722	42
Mulyorejo	6460.476	22
Sawahan	32210.39	37
Wonokromo	27116.87	22

Table 2 shows the correlation between manufacture and population. From all kecamatan, manufacture shows the negative correlation. Different reason with school, it because manufacture need a big area. It means only a few people live in there, and causing the development stagnant. Period 2004-2009 was used in order to extract a knowledge base which was applied in the 2010 to 2014. The fifth period is chosen because usually policy for city planning is revised in 4 year Figure 6 shows the result after all process from preparation to data training occur.

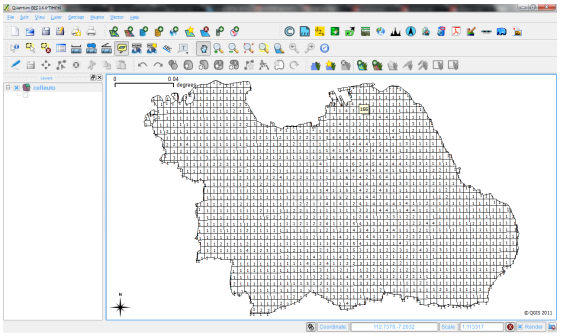


Figure 8 fuzzy for every grid

In figure 6 all of grid contain value of fuzzy result that is translated in linguistic. The result in term of word is shown in table 3

Table 3. Result for Surabaya Pusat

Kecamatan	Result
Surabaya Pusat	
Tegalsari	Cepat
Genteng	Sedang
Bubutan	Cepat
Simokerto	Cepat

The weighting value can be determined by the knowledgebase operation of fuzzy models. A decision-maker can analyze the suitability for each space and any fuzzy degree. The function of computing weighting in Mamdani fuzzy models can be coded to be a part of system model. The combination of Mamdani fuzzy model and GIS would be effective for GIS database and enforce the ability of special decision-making. Then the result is visualized in GIS, as shown in figure 9

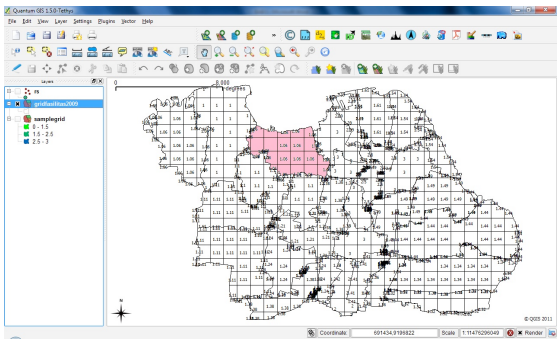
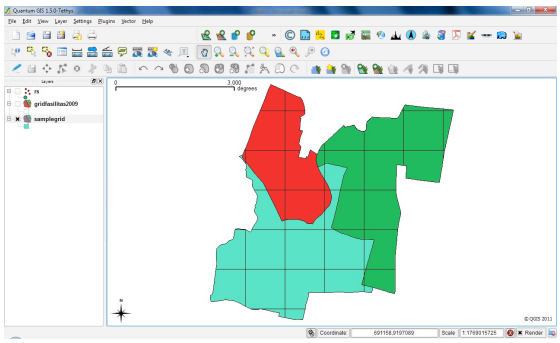
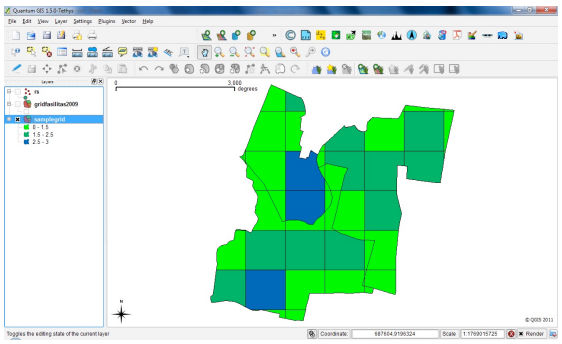


Figure 9 Fuzzy for every grid in one kecamatan

From figure 9, it is clear that there some grid has same value (see the color). That because the grid lied on the same Kecamatan. Actually, it is not so accurate . For example, one kecamatan consist of 20 grid, a hospital lied on grid 18 while 19 others kecamatan has no hospital. Of course weighting in grid 18 different with others grid even though they are lied on the same kecamatan. Nowadays, monitoring of urban development is done for every kecamatan, even though it is not accurate. If the stakeholder want to get more accurate data, it is suggested to observe by segmentation like a grid. Figure 10 illustrate an example for showing the urban development of three kecamatan intersect



(a)



(b)

Figure 10. Thematic Map
(a) Political Map
(b) Socio economic Map

Figure 9 explain how to change thematic map from political to socio economic map. This picture is capture of three kecamatan,namely Tegalsari, Bubutan, Genteng, all are located in Surabaya Pusat. The darkest color is Kecamatan Tegalsari, Medium color is Bubutan and The light color is Genteng. From figure 10, it is clear that urban development across the kecamatan border, so it is running to closest neighborhoods which has similar or less similarity in variable. Political geography thematic map should is not suitable to applied when socio economic variable is used for. Unfortunately, this result can not express how fast the development is. To know, we need another adding method that suitable for handling flow of changes in urban development caused by time (year) and spatial data.

The method is using cellular automata. And figure 11 is the implementation about cellular automata.

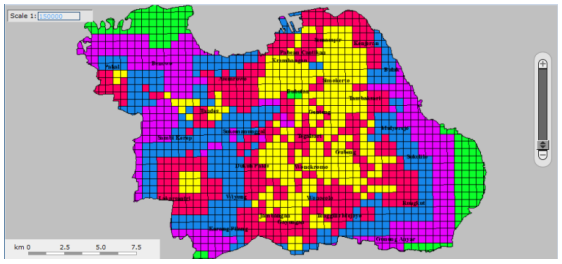


Figure 11. Prediction with Cellular Automata

From the visualization of results of the first test that leads to the prediction of the development of the District of Central Surabaya in the past, it seems that an adequate infrastructure in the Centre of Surabaya, such as hospitals, schools, and much less self-serving, due to the city centre. Then, the prediction of the direction of the development of the city to go north, South, and part to the East in North Surabaya, South of Surabaya, Surabaya, Surabaya and East near the central which

have the infrastructure that menmadai but has a small land area, so many residents who moved to North Surabaya, Surabaya, East and South and some began to develop in some areas because the area of West Surabaya District Sukomanunggal there are many supermarkets such as malls and hence estimate the direction of the legendary moves in there. For most of the sub-region of West Surabaya do not experience the predicted development, because in areas where infrastructure is still not too many that are available. In the following years the direction perkermbangan moving toward the East Surabaya and West Surabaya in Surabaya to Central, North and South not likely be occupied as a place of settlement, which is full. In the final stage there is no more empty land because all the land in the city of Surabaya is already in use.

5. Conclusion

This paper has combine a fuzzy and GIS automata urban growth modelfor simulating the complex dynamics of urban growth in urabaya, Indonesia. The use of these methods provided a more efficient and accurate means of calibrating the model, The inclusion of fuzzy logic allowed for the formulation of more realistic transition rules. The model was rigorously validated through the application of quantitative and qualitative methods. These methods were selected based on their capability to assess changes in spatial structure over time. The model was tested by simulating the spatial patterns of urban growth over several different development stages using the calibrated values. empirical spatial patterns of Surabaya's urban growth which had occurred in reality. And the conclusion is prediction of human settlements development by using cellular automata method can help for analysis and decision-making on macroeconomic development Surabaya city. Also Development with a focus on Surabaya city centre where the movement of population flows from the city centre to the suburbs.

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