The Analysis of Measurements and Influence Factors of Mixed Land Use

Shu-Wei Huang and Wan-Jung Tsai

Abstract—Mixed land use is a performance of land-use development that can increase the strength of land-use and arise the vitality of city in the past researches, especially in Asian city. In Taiwan, mixed land-use is a universal city phenomenon. Mixed land-use could be a study case because this kind of land use pattern had long-term development from Taiwans’ historical habits. The policy of mixed land-use could be carried out more efficient. For this reason, this paper considered the concept of landscape ecology and used GIS technique to analyze the influence factors of mixed land use. We measure the degree of mixed land use by calculate diversity indices, and draw on Geographically Weighted Regression to discuss the spatial distribution characteristics of mixed land use. We hope this procedure and results could adjust factors of planning for future urban planners who can control the mixed land-use for the good of the state.

Index Terms—Mixed land use, geographically weighted regression, diversity.

I. INTRODUCTION

Mixed land use is a performance of land-use development that can increase the strength of land-use and arise the vitality of city in the past researches. In Europe and America, mixed land use has been advocated as a way to plane cities and be created different urban pattern in recent years. On the basis of new urbanism, planners start to enhance the important of higher density of mixed land use and the development of T.O.D. To promote the efficiency of land use and quality of life, they integrate urban design, land use and public transportation systems closely [1]–[4].

According to the New Athens Charter, the principle of mixed land use should be known. It can lead more change and vitality into urban patterns especially in the downtown. And it might compact the relationship between temporal and spatial, decrease the demand on trip, save energy and reduce pollution as long as any acceptable use exist within residential and work place [4].

In Taiwan, mixed land-use is a universal city phenomenon. In the past agricultural recreation period, the less transportation development and the surplus labor lead to the mixed land-use grew up gradually. Even though Taiwan takes zoning as the manage strategy in land use, mix land-use still takes place easily because of the non-strict limitation and segmentation on zoning and using category for the reason of elasticity. Consequently, researches of mixed land-use in Taiwan are more important than other countries. Mixed land-use could be a study case because this kind of land use pattern had long-term development from Taiwans’ historical habits. The policy of mixed land-use could be carried out more efficient.

Therefore, the underlying theoretical basis of this study is chiefly the "Landscape Ecology". Through the calculation of diversity indices, measuring the spatial distribution characteristics of the mixed land-use and using the Geographically Weighted Regression discuss factors of affecting the degree of mixed land-use.

II. ANALYZETHETIMIXEDLANDUSE

A. Calculation the Degree of Mixed Land Use

According to the researcher of diversity [5], diversity is a powerful factor for the guidance policy. It’s also a clear policy goal for land use. Therefore, using the diversity be an index and calculate degree of mixing.

The Shannon index has been a popular diversity index in the ecological literature, where it is also known as Shannon's diversity index. With higher value imply higher diversity. It is calculated as follows:

$$H = -\sum_{k=1}^{n} P_k \ln(P_k)$$

where $P_k$ is the proportion of land use belonging to the k type in the space unit. And n simply quantifies how many different types the dataset of interest contains.

B. The Influence Factors of the Mixed Land Use

Based on past researchers, factors affect patterns of mixed land use which include family economic structure, urban planning, building codes, road width and income [5]. Hence, it’s the two parts that factors include block characteristics and socio-economic development.

1) Block characteristics factors

1) Block area: Typically, block area would affect the land’s development. In the other conditions being equal, the larger block area could accommodate more types of land use.

2) Accessibility: In general, there would have more vehicle and user on main roads, and the mixed land use will be complicated. In the other word, the road surrounding block is wider, the land use is more diversity. Therefore, we take maximum road width surrounding block as factor.

2) Socio-economic development factors

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1) Population: Many studies have shown that in the past, the population will affect different activities and produce different land use types. The more population, the higher the complexity of the activities arises. And number of land’s type will also arise.

2) CBD ratio: CBD react to the vibrancy of the region’s economic activity. Different CBD region will affect land to different use. It is calculated as follows:

\[ \text{CBD Ratio} = \sum_{i=1}^{n} B_i \times W_i \]  

where \( B_i \) is the proportion of total floor area to the i type in the Commercial use, and \( W_i \) is the Weight of Commercial degree to the i type.

3) Income: The consumer behavior reflects the income of residents’ daily lives directly. The area where is high-income, the consumption is higher, then the consumption of commercial activity types where it leads will increase, so as the types of land-use. Alonso also mentioned this aspect in Location Theory. To pursue the best standards of utility, the consumer who is under the restriction of income will select different rent of locations which they prefer to. These behaviors of location choices would not only affect the happen and the changes of land-use but also the spatial pattern of mixed land-use. The research by [5] shows that the higher income the areas are, the higher diversity of mixed land-use they use. Therefore, it has positive effects on the mixed land-use.

To explore the influencing factors of spatial distribution, horizontal mixed use be took as the main analysis object and vertical mixed use as auxiliary data. Taking building as an analysis unit could not observe the phenomenon of horizontal mixed use in contrast that is terms of the settlement level or above analysis unit could not observe the phenomenon of vertical mixed use. Then, to fit the researcher topic takes block as analysis unit. Summarized above factors which may affect, the data of population and income can’t be acquire, so we use neighborhood as calculate unit.

III. APPLICATION OF GEOGRAPHICALLY WEIGHTED REGRESSION

Past researchers about mixed land use are nothing more than to probe into the factors of mixed land use by regression method which is lack of variable of spatial features. It’s named Spatial heterogeneity. These would be a point key which cause Spatial non-stationarity. Traditional statistics technology can then be calibrated by ordinary least squares which cause Spatial non-stationarity. Traditional statistics named Spatial heterogeneity. These would be a point key of variable of spatial features. It’s method which is less than to probe into the factors of mixed land use by regression set. Traditional global statistics can’t describe local true circumstance. On the other hand, Geographically Weighted Regression (GWR) can fix above problems.

Consider a global regression model written as:

\[ y_i = \alpha_0 + \sum_{k=1}^{n} \alpha_k x_{ik} + \epsilon_i \]  

GWR extends this traditional regression framework by allowing local rather than global parameters to be estimated so that the model is rewritten as:

\[ y_i = \alpha_0(u_i,v_i) + \sum_{k=1}^{n} \alpha_k(u_i,v_i) x_{ik} + \epsilon_i \]

where \( (u_i,v_i) \) denotes the coordinates of the ith point in space and \( \alpha_k(u_i,v_i) \) is a realization of the continuous function \( \alpha_k(u,v) \) at point i.

IV. CASE STUDY

Base on characteristic of mixed land use, we choose Tainan City as the study area. Tainan City has history of the ancient capital and promotes many related strategies to improve the quality of the living environment in recent year. There would be more diversity in urban pattern. We use the land use data in 2009 to analyze mixed land use (Table I), and Fig. 1 is the spatial distribute of land use type.

**TABLE I: THE PERCENTAGE OF LAND USE AREA IN 2009**

<table>
<thead>
<tr>
<th>Land use class</th>
<th>Area(hectare)</th>
<th>Percentage(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residence use</td>
<td>1334.97</td>
<td>10.87%</td>
</tr>
<tr>
<td>Commerce use</td>
<td>383.17</td>
<td>3.12%</td>
</tr>
<tr>
<td>Industrial land</td>
<td>421.25</td>
<td>3.43%</td>
</tr>
<tr>
<td>Agricultural land</td>
<td>5447.94</td>
<td>44.36%</td>
</tr>
<tr>
<td>Government organization</td>
<td>58.95</td>
<td>0.48%</td>
</tr>
<tr>
<td>School</td>
<td>273.87</td>
<td>2.23%</td>
</tr>
<tr>
<td>Traffic land</td>
<td>1376.72</td>
<td>11.21%</td>
</tr>
<tr>
<td>Communal facility</td>
<td>334.05</td>
<td>2.72%</td>
</tr>
<tr>
<td>Park and green space</td>
<td>101.93</td>
<td>0.83%</td>
</tr>
<tr>
<td>Urban vacant land</td>
<td>837.58</td>
<td>6.82%</td>
</tr>
<tr>
<td>Water</td>
<td>1661.65</td>
<td>13.53%</td>
</tr>
<tr>
<td>Other use</td>
<td>49.1248</td>
<td>0.40%</td>
</tr>
<tr>
<td>Total</td>
<td>12281.2</td>
<td>100%</td>
</tr>
</tbody>
</table>

Fig. 1. The distribution of land use in 2009.
A. The Degree of the Mixed Land Use

In this paper, we adopt the diversity indicators to calculate the degree of mixed land-use. The calculation results of the degree of mixed land-use in Tainan City street block are shown in Table II, the minimum value of mixing degree is 0, and the maximum value is 1.95.

The spatial distribution is shown in Fig. 2. By the figure, the areas with intense mixed land-use are concentrated in the city center. In order to enhance the efficiency of the analysis results and reduce the impact of discrete data, the follow-up analysis scopes adopt the downtown area of Tainan City. (Shown in Fig. 2 dotted lines)

B. The Data of the Influence Factors

From literature review, this research adopts Block area, Accessibility, Population, CBD ratio and Income to be the independent variable, and the analysis amount of street blocks is 4191. The statistics of independent variable are shown in Table II.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Numbers</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>Std</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diversity</td>
<td>4191</td>
<td>0</td>
<td>1.95</td>
<td>0.47</td>
<td>0.42</td>
</tr>
<tr>
<td>Block area(ha)</td>
<td>4191</td>
<td>0.54</td>
<td>139.1</td>
<td>1.31</td>
<td>6.77</td>
</tr>
<tr>
<td>Accessibility(m)</td>
<td>4191</td>
<td>4</td>
<td>40</td>
<td>18.56</td>
<td>4.26</td>
</tr>
<tr>
<td>Population</td>
<td>4191</td>
<td>315</td>
<td>12782</td>
<td>4330.1</td>
<td>2570.1</td>
</tr>
<tr>
<td>CBD ratio(%)</td>
<td>4191</td>
<td>0</td>
<td>6</td>
<td>1.26</td>
<td>1.61</td>
</tr>
<tr>
<td>Income (thousand NT)</td>
<td>4191</td>
<td>562</td>
<td>1104</td>
<td>804.37</td>
<td>146.05</td>
</tr>
</tbody>
</table>

C. GWR Analysis

GWR incorporates the spatial structure of the data into the estimation of the regression model’s parameters and shows how those estimates vary across space. It also provides the researcher with an analytical tool to explore changes in the relationship between variables over space [7].

The summary results of the GWR model are presented (Table III). All the variables are statistically significant in explaining the diversity in the urban mixed land-use in the Tainan City. The Monte-Carlo test shows that all the predictor variables displayed significant non-spatio-narity and indicating spatial variation in the relationship between the diversity of mixed land-use and predictor variables. In the other words, there has spatial variation in the relationship between the diversity of mixed land-use with block area, accessibility, population, CBD ratio and income in this case. Therefore, it should be modify the relationship between mixed land-use and predictor variables by GWR.

Above the analysis, we know there five factors, block area, accessibility, population, CBD ratio and income, are positive effects in the affect factors of the mixed land-use occurrence. Fig. 3- Fig. 8 show the spatial distribution of the Local $R^2$ and all the parameters of the GWR model. All parameters are significant for GWR model and the parameter estimates are mapped to show the spatial variation. All figures show the spatial variation of the parameter estimates that are hypothesized to have influenced the degree of mixed land use in Tainan. Higher parameter estimate means that the effect of the variable is higher in that region as compared to other parts of the region [8]. The darker is the shaded area the higher is the parameter estimates [7].
area of block completely explain the differences in mixed land use around these areas.

Fig. 5 shows the map of GWR coefficients for the main effect of the accessibility variable. The map shows that the high degree of the mixed land use in middle, suggesting that accessibility completely explain the differences in mixed land use around these areas.

Fig. 6 shows the map of GWR coefficients for the main effect of the population variable. The map shows that the high degree of the mixed land use in northwest and southeast, suggesting that population completely explain the differences in mixed land use around these areas.

Fig. 7 shows the map of GWR coefficients for the main effect of the CBD ratio variable. The map shows that the low degree of the mixed land use in center, suggesting that CBD ratio completely explain the differences in mixed land use around these areas.

Fig. 8 shows the map of GWR coefficients for the main effect of the income variable. The map shows that the low degree of the mixed land use in north, suggesting that income completely explain the differences in mixed land use around these areas.

V. CONCLUSION

Some researches compare the Global OLS with GWR model to show that GWR models performed better and provide significant improvement over the global regression models. This is because the GWR method has the advantage of providing local parameters estimates and reveals interesting pattern of spatial variation or nonstationarity of parameters. The spatial distribution of all parameters shows significant spatial variation with higher parameters in some parts of the region. [7]

Using GWR method can effective increase the accuracy of spatial analysis. From sustainable land use development viewpoint, the present study is particularly important because the spatial characteristics of mixed land use are useful for understanding various impacts of human activity on the urban environment.

The spatial information of urban mixed land use is very important for Asian city especially Taiwan. In this study, to analyze the connection between the degree of the mixed land-use and the factors of environment and socio-economic development factors, we can examine the suitability about the land usage again.

This study analyzes the relationship between the degree of mixed land use and influence factors for further research. We established a assessment structure of planning with GIS technique, spatial analysis of GWR method and the diversity of landscape ecology to delineate the correlation of spatial distribution. The main objective of this paper is to provide an assessable process of mixed land use planning for further research and hope that the results will be referred to the modification of urban land use plan.

REFERENCES


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