Development of a GIS Tool for Automatic Assigning of Land Price to Land Parcel

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Abstract
Setting a state price to each land parcel is a frequent and yet important task in the state management of land parcels. Land price for four location levels belong to each main street is issued by the state and is changed in average every five years or less. Thus before being assigned price, parcels in area have to be assigned to one of four location levels depending on its walking distance to nearest street, and related alley's width. To ease this burden for government staff, a step by step processing model is developed to automatically determine the location level of a particular parcel based on its spatial relationship with the street and alley that it belongs to. The steps in the model are then converted into corresponding functions in a GIS application and used to automatically assign location levels for land parcels. The classified parcels are compared with corresponding parcels in legal price map implemented and issued by state government. Comparison result shows that approximately 93.23% of parcels at all location levels are classified with the same location level. The experiment demonstrates the effectiveness and correctness of the proposed model in automatically determining location levels and corresponding prices of land parcels.

1. Introduction

Land is a special commodity, and establishing and issuing land price is an activity prescribed by Vietnamese Land Law 2003. Normally every five years or less, a provincial/municipal government will issue land price for location levels belonging to main streets within the respective province. The regulation specifies how many location levels there are, and which location level a land parcel should be assigned to. For each particular land parcel which street and what location level it is assigned to will depend on its spatial relationships with its surrounding streets and alleys. The task of assigning location level to land parcels is confronted with difficulties such as a large number of land parcels that need to be evaluated in an administration unit, and the struggle in determining complex spatial relationships between each land parcel with its surrounding network of streets and alleys. Since GIS software has been adopted in current practice of land information management, some steps in the process of land valuation can be done quickly using the tools available within ArcGIS, for example identifying parcels that are on streets. However, a number of steps still have to be carried out with lot of staff's involvement, such as determining minimum alley width along walking route from a parcel through alleys to street. These steps are not only time consuming but also tiresome to the staffs involved.

To tackle the issue, Trung (2012) described in general functions of the software that provide the tools to restore, update and analyze information for mapping land price, but do not provide details on how to calculate land price. Duc and Bach (2011) described step by step procedure to automatically determine location level for each parcel. At that time, steps of processing model is developed based on Dong Nai People's Committee's Decree No. 79/2010/QĐ-UBND (2010). A parcel is assigned location level based mainly on walking distance from parcel to street with highest street price ….. The latest Dong Nai People's Committee's Decree No. 64/2014/QĐ-UBND (2014) has modifications on how to determine location level for land parcels. In particular, a land parcel is assigned location level based on shortest walking distance from parcel to street.

This paper describes new processing model to automatically assign land parcel to location level following guide of Decree No. 64/2014/QĐ-UBND. The processing model is implemented based on ArcGIS Engine Developer Kit and VB.NET programming language and is tested for land parcels of Tam Hiep ward, Bien Hoa city of Vietnam.

2. The Processing Model to Determine Location Level and Price of Land Parcels

2.1 Rules of Assigning Location Level for a Land Parcel

For the study area, location levels of land parcels are determined based on Decree No. 64 of Đong Nai province issued on December 22, 2014 as follows:

- *Location level 1*: applied to land parcels which are located in the front of a street.
- *Location level 2*: applied to any of the following cases:
  + A land parcel whose walking distance is less than or equal to 600m from the street, located on an alley and the alley's width is equal and greater than 5m.
  + A land parcel whose walking distance is less than or equal to 400m from the street, located on an alley and the alley's width is equal and greater than 3m but less than 5m.
- *Location level 3*: applied to any of the following cases :
  + A land parcel whose walking distance from the street is more than 600m, located on an alley and the alley's width is equal and greater than 5m
  + A land parcel whose walking distance is more than 400m and less than or equal to 600m from the street, located on alley and the alley's width is equal and greater than 3m but less than 5m.
  + A land parcel whose walking distance is less than or equal to 200m from the street, located on an alley and the alley's width is less than 3m.
- *Location level 4*: applied to all land parcels not belonging to any of the above cases

The above described locations of land parcels and their corresponding location levels are summarized and illustrated in Figure 1. List of streets and corresponding price of four location levels are attached with the Decree.

2.2 Develop a processing model for calculating location level and price of a land parcel

The proposed processing model has nine following steps:

Step 1: *Identify Isolated Alleys*

If there is any isolated alley, walking route from parcel belonging to this isolated alley to street is not generated and location level of land parcel is not assigned correctly. To avoid this problem, isolated alleys need to be identified and corrected. The process to identify isolated alleys is as follows: starting with one of the street which has price tag. The geometric relation *Intersection* is then used to find out all alleys connecting to that street, assigning them to level 1. Repeat the process again, with another street in street list to determine all alleys of level 1. Applying the similar processing method through level 1 alleys to identify all level 2 alleys (alleys connected to level 1 alleys) and so on. The process is carried out until *alley level* is assigned for each and every connected alley in the studied area. Any alley not assigned alley level is considered as isolated alley. Staff can either modify isolated alleys by connecting them to the rest of the alley network or delete them.

Step 2: *Build Network Dataset*

To be able to solve question of nearest street from parcel, ArcGIS tool such as *closest facility solver* in *Network Analysis* in ArcGIS can be used. The same procedure later is applied in this research, but function is developed based on API in ArcGIS Engine. Network dataset is needed for this kind of problem. Therefore, a network dataset is created based on network of streets and alleys in the study area. Result of this step is network dataset composed of nodes where lines intersect and edges.

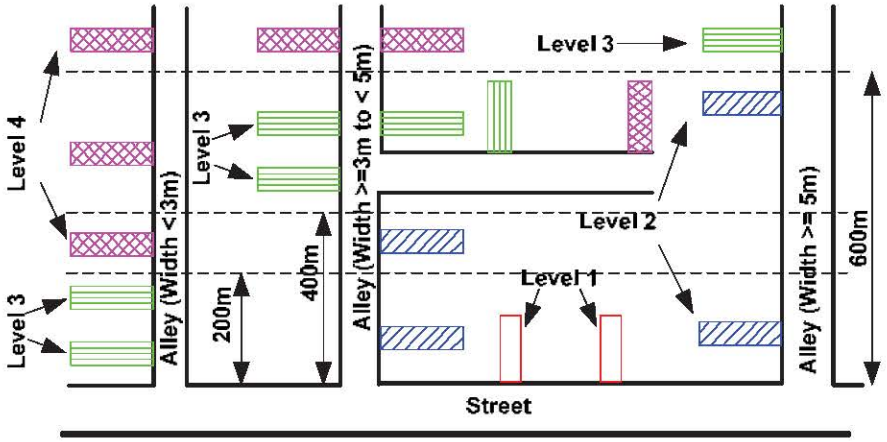

Figure 1: Location of land parcels and its corresponding location level

Step 3: *Assign Location Level 1 and Corresponding Price to Each Land Parcel on Street*

Start the process by browsing through each street from highest to lowest price. When browsing a street, search for all parcels that *intersect with* the street *buffer* (buffer is equal to half of the street width plus a tolerance), then transfer street-id to each of these land parcels and assign location level 1 to these parcels. This process ensures land parcels situated at street corner has been assigned price based on the street with highest price. Look into non-spatial street price table to search for a record with the street-id, get price of location level and then assign price to these parcels.

Step 4: *Create Facilities*

ArcGIS *closest facility solver* measures the cost of traveling between incidents and facilities and determines which are nearest to one another. In our problem, incidents are land parcel and facilities are alley-street intersections. The facilities are found by searching for nodes obtained from step 2 that *intersect* with streets. These nodes are then assigned corresponding street-id and are exported to create facility layer.

Step 5: *Create Incidents*

Start the process by browsing through each alley. When browsing an alley, search for all parcels (except parcels that already assigned location level 1) that *intersect with* the alley *buffer* (buffer is equal to half of the alley width plus a tolerance). For each found parcel, find two parcel corners - polygon locations assumed to have sharp angle (approximately 90 degree ± tolerance) - nearest to the alley. Then generate two incidents corresponding with these two corners. Assign parcel-id to these incidents. Parcels located at alley's intersection are found more than once when browsing through all alleys, so number of incidents generated for these parcels are more than two. Result of this step is an incident layer.

Step 6: *Calculate Walking Route and Corresponding Walking Distance*

Use ArcGIS Network library, especially *closest facility solver* to find walking route and walking distance from each incident (parcel corners) to nearest facility (alley-street intersection).

Each generated walking route contains shape and attribute information such as parcel-id, street-id, walking distance. Different walking distances of the same parcel are compared to find out the shortest one when move from parcel to nearest street. Result of this step is a walking route layer.

Step 7: *Calculate Minimum Alley Width*

Start the process by browsing through each walking route. For each walking route, find all alleys that walking route shape contains alley's shape. Compare alley's width of the found alleys to find the alley's minimum width and assign this attribute value to walking route.

Step 8: *Assign location level 2, level 3 and corresponding price to land parcels*

In this step, browsing each walking route, and for each walking route, determine *location level* based on route's attribute values such as *walking distance*, *minimum alley width* and based on the decision rule described in Table 1. Search for parcel which has the same walking route's parcel-id, and assigns location level and street-id for found parcel. Look into non-spatial street price table to search for record with the street-id, get price of location level and then assign price to the parcel.

Step 9: *Assign Location Level 4 and Price for the Other Land Parcels*

The other land parcels are parcels that are not adjacent to streets or alleys. In other words, owners of these land parcels access to street or alley through another land parcels. Based on guide of Decree No. 64/2014/QĐ-UBND, these parcels are assigned location level 4 based on nearest alley. In this step, the process starts by browsing through each parcel that is not assigned location level yet. For each parcel, search for nearest street or nearest alley. If nearest street is found, parcel is assigned location level 4 and corresponding street-id that this parcel belongs to.

Table 1: Location levels of land parcels in relation to alley

Walking distance from land parcel to nearest street	**Land parcels belong to alley with width**		
	≥5m (Width level = 1)	**≥3m to <5m (Width level = 2)**	**<3m (Width level = 3)**
≤200m	2	2	3
>200m to ≤400m	2	2	4
>400m to ≤600m	2	3	4
>600m	3	4	4

If nearest alley is found then find the nearest point on alley to generate corresponding incident for the parcel and assign parcel-id to the incident. Implement similarly as step 6, walking route from parcel to street is generated. The walking route contains appropriate street-id. Assigns location level 4 and street-id, and corresponding price for the parcel as implemented in step 3 and step 8.

3. Develop the GIS Application

3.1 *Database Design*

For calculating location level and price of land parcels, the following spatial and attribute data are used:

- *Parcel layer* (polygon type) contains all parcels of land in the studied area. Its attributes include: parcel-id, street-id, location level, price, …
- *Street layer* (polyline type) contains all streets and alleys in the studied area. Its attributes include street-id, street name, type ('street' or 'alley'), width
- *Non-spatial Street attribute table* contains unit prices for streets. It has the following attributes: street-id, price of location level 1, price of location level 2, price of location level 3, and price of location level 4
- *Non-spatial attribute table* contains decision rules as described in Table 1. It has the following attributes: minimum distance, maximum distance, alley width, location level

Data in the system is built based on ESRI Geodatabase model (Zeiler, 1999) and stored in SQL Server 2008 and accessed through ArcSDE.

3.2 *Functional Design*

Besides normal navigation tools and other functions usually included in a GIS software, a special module is designed to calculate location level and unit price of land parcel. Functions in the module are shown in Figure 2. The use of functions in this module is as follows:

- *Update Basic Data*: use to edit basic data served for calculating location levels and prices of land parcels. It allows staff to edit street price list, decision data in table 1 …. It also allows staff to erase old calculation results before recalculating location level and unit price of land parcel.
- *Calculate Parcel Price*: use to calculate location level and price of land parcel based on the basic data. It involves nine sub functions corresponding to the above nine steps of the processing model.
- *Land parcel Query*: this function enables both query land parcel attribute information and displays walking route from land parcel to nearest street.

4. The Experiment

The application module is developed based on VB.Net programming language and ArcGIS Engine 10.2.2. ArcGIS Engine interfaces (Zeiler, 2001) that used to build the module include *IWork space Edit, IBuffer Construction, ISpatial Filter, IProximity Operator, ITopological Operator, INA Context, INetwork Dataset* … (ESRI, 2004). For testing purpose, the module is used to assign location level and unit price for land parcels of Tam Hiep ward, Bien Hoa city of Vietnam. The studied area has a total of 157 street segments, 980 alley segments, and 5839 evaluated land parcels. Figure 2 illustrates graphical user interface of the GIS application with special module and sample data of the studied area. The experiment records average time spent to run each step in the model as follows:

- Step 1 - identify isolated alleys: 1 minute 31 seconds.
- Step 2 - build network dataset: 7 seconds.
- Step 3 - Assign location level 1 and corresponding price to each land parcel on street: 18 seconds.
- Step 4 - create Facilities (street nodes): 6 seconds.
- Step 5 - create incidents (parcel nodes): 28 seconds.
- Step 6 - calculate walking distance and walking route: 49 seconds.
- Step 7 - calculate minimum alley width: 4 minutes and 46 seconds.
- Step 8 - assign location level 2, level 3 and price to land parcels: 16 minutes and 21 seconds.
- Step 9 - assign location level 4 and price for the other land parcels: 38 seconds.

Omit necessary time to prepare or edit data and set up system parameters, total running time is approximate 25 minutes. In order to evaluate quality of the designed process model, classified parcels obtained from the experiments are compared with classified parcels issued from state government. Comparison result is summarized in a confusion matrix Table 2. Overall matching equals (954+2352+1524+614) * 100 / 5839 = 93.23%.

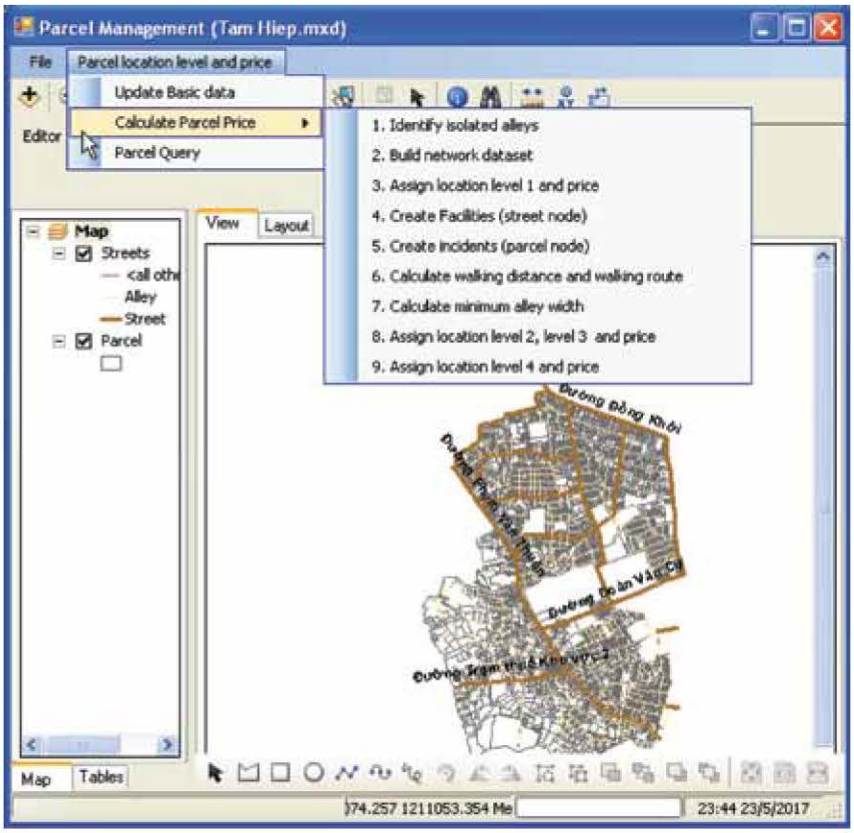

Figure 2: Graphical User Interface of the GIS application and sample data of Tam Hiep ward, Bien Hoa City of Vietnam

Table 2: Confusion matrix of classification results

		Classified Parcels Obtained from the Process Model			
		Location level 1	Location level 2	**Location level 3**	**Location level 4**
State's classified parcels	Location level 1	954	4	1	0
	Location level 2	0	2352	71	23
	Location level 3	1	145	1524	3
	Location level 4	4	59	84	614

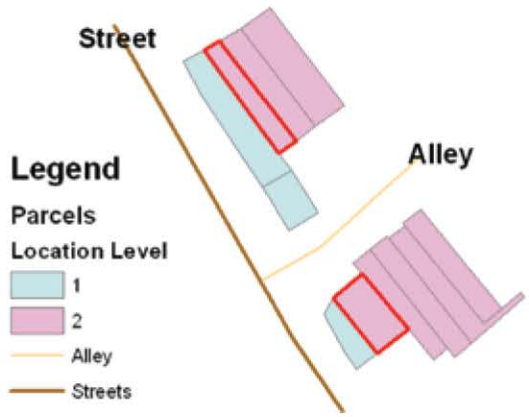

Figure 3: Case 1 of difference of classified results

Figure 4: Case 2 of difference of classified results

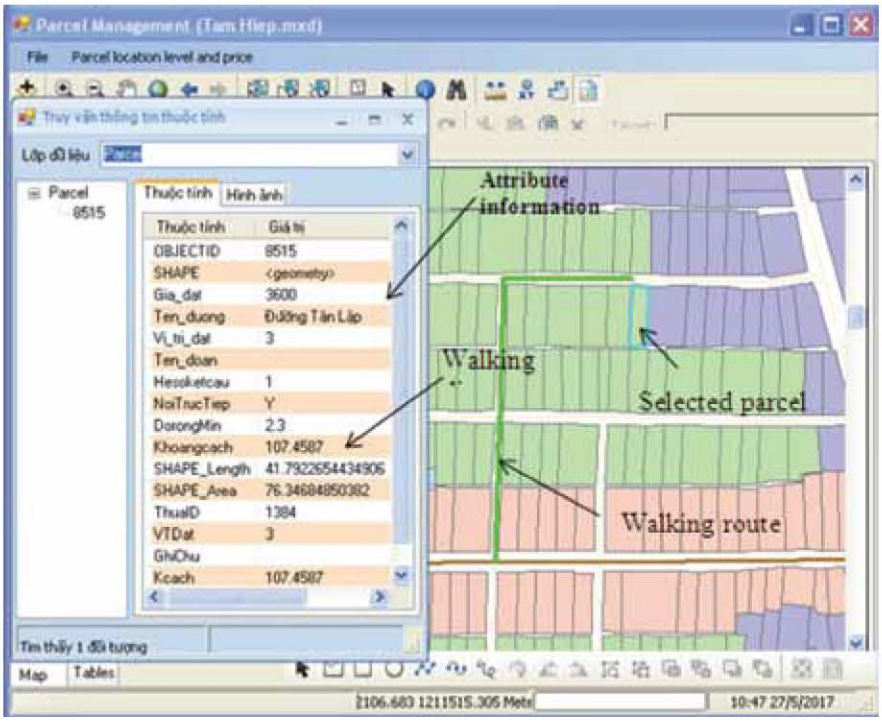

Figure 5: Query Parcel information

Some of reasons lead to the difference of classification results are found as follows:

- *Case 1*: visual check the difference of classification occurred as in Figure 3. The two parcels with boundary marked by red lines are classified as location level 2, while these are classified by state as location level 1. According to decision rule, the process model produces correct classified results. Reason for state classifying these parcels as location level 1 may be these parcels have same owner with adjacent parcel labeled as location level 1.
- *Case 2*: visual check the difference of classification occurred in Figure 4. The parcel with boundary marked by red lines is classified as location level 4, while this parcel is classified by state as location level 2. The process model found two shortest walking routes (205m and 209m) from the parcel to street moving through narrow alley with (0.7m width). So, according to the decision rule, the process model produces correct result. Reason for state classifying these parcels as location level 2 is to use walking route (215m) move through 5m alley width.

- There are also cases that the classified parcels from two methods have the same walking distance, but state classifies those parcels to wrong position level.

In order to allow users of the system inspect result of classifying location level, an interactive tool is developed. By simply clicking a parcel on map window, a normal dialog shows detail attribute information of land parcel, plus walking route from land parcel to the nearest street shown in Figure 5. To enable staffs to incorporate changes in state regulations concerning the parameters in decision rules such as alley width, distance from land parcel to street, etc. These parameters are stored in a separate, non-spatial attribute tables. Whenever there is a change in regulations, these tables can be easily updated accordingly. When the application package is run, these updated parameters will be fed into the program.

5. Summary

The task of assigning location levels and corresponding prices to large number of land parcels in an administrative unit is a time consuming task with high possibility of errors. This research proposes a processing model and transforms this model into sequence of functions in special module in the GIS application. The experiment is carried out to validate the correctness of the process model as well as the GIS application by using GIS road and parcel layers provided by state. The state's parcel layer contains parcel shapes and important attribute information as location level and corresponding price. These attribute information are then used to compare with location levels and prices of corresponding parcel produced by the processing model. 93.23% of parcels with same classified location levels and prices show high potential application of the model. There are still differences in classified results with possible reasons as illustrated above. To find out the real reasons for difference, need to contact government staffs involved in creating the classified parcel layer. But this seems very difficult in Vietnam condition. Using the proposed GIS application in approximately 25 minutes, a user could determine, fully in accordance with government land pricing regulation, prices for 5839 land parcels. Considering the amount of time a staff has to spend if carrying out this pricing workload by employing the use of available functions in a general GIS software and his manual effort, one could see a very clear benefit the staff could enjoy when using this proposed GIS application. Beside of main task of evaluating location level, a special parcel query tool is also developed to allow user not only to check attribute information on location level but also to view walking route, walking distance, to get confidence on correctness of assigned location level.

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