URBAN LAND VALUATION USING GEO-SPATIAL SUPPORT SYSTEM

Florence GALEON[a] *and Karlo PORNASDORO*[b]

[a] *Assistant Professor, Department of Geodetic Engineering,*
Rm 324 Melchor Hall, University of the Philippines, Diliman, Quezon City 1101, Philippines;
Tel: +63(2) -981-8500 local 3148; Fax. +63(2) -920-8924
E-mail: mighty.renz@gmail.com, florence.galeon@up.edu.ph

[b] *Senior Science Research Specialist, Disaster Risk Exposure, Assessment and Mitigation (DREAM) Project,*
National Engineering Center, University of the Philippines, Diliman, Quezon City 1101, Philippines;
Tel: +63(2) -981-8500 local 3147
Lecturer/Member, Institute of Philippine Real Estate Appraisers (IPREA)
Center for Appraisal Studies, Magsaysay Avenue, UP Diliman, Quezon City 1101, Philippines;
Tel: +63(2) -927-4608
E-mail: karlopornasdoro@yahoo..com

KEY WORDS: Land valuation, GIS, Analytic Hierarchy Process, Direct Market Comparison Approach, QuickBird satellite image

Abstract: Professional valuers until now perform land valuation based on their intuitions and experiences. This makes land values provided by valuers very subjective and less accurate. The main objective of this paper is to introduce a technique of valuing land more logically, quantitatively and rapidly reducing the subjectivity and standardizing valuation process. This paper envisions the development of a geo-spatial support system to enhance and hasten the ferreting out of land values using a mathematical model developed employing a multicriteria decision-making technique called the Analytic Hierarchy Process (AHP). Numerous land value determinants extracted from surveys of valuation specialists are grouped and reduced to six most significant parameters by statistical analysis. The relative weights and importance of these land value factors and their sub-categories are likewise determined. The required spatial data for each parameter are gathered and incorporated in a Geographic Information Systems (GIS) which serves as the technical support platform. This valuation support system is tested in the University of the Philippines Visayas Cebu Campus (UPVCC) in determining the land values of the 13 hectares informal settlement areas. A base map of the study area is generated from a high resolution QuickBird satellite image and updated through ocular inspections. Since no technical descriptions of the untitled informal settlement areas exist, analysis tools in GIS are used to simulate parcels. The digitized structures are used to create Thiessen polygons approximating the shapes of land parcels. Samples lots are identified to test the validity of the method by determining land values using the Direct Market Comparison Approach. Land values derived from the geo-spatial model and from the valuation specialists using their traditional method are compared and analyzed. Initial validation showed promising results that, at 95% CI, there is no significant difference between the system-generated values and the expert-generated values.

INTRODUCTION

Land valuation uses three approaches to determine values namely Direct Market or Sales Comparison, Income Capitalization and Cost (IVS, 2007). To make direct market comparisons between the comparable property and the subject property, a valuer shall consider possible adjustments based on differences in the elements of comparison as stated in Section 5.11.5 of the International Valuation Standards 2007.

According to Yomralioglu and Nisanci (2004), professional valuers until now perform land valuation based on their intuition and experiences. A technique of valuing land more logically and quantitatively is introduced to reduce this subjectivity and standardize the present valuation methods practiced in the Philippines. This paper envisions the development of a spatial-based support system to enhance and hasten the ferreting out of land values using the fundamental approach Direct Market Comparison. A mathematical model created using one of the most extended multicriteria decision-making technique called Analytic Hierarchy Process (AHP) is used for calculation and tested in this study. This support system is not intended to replace the work of a valuer but designed to improve and facilitate the ferreting out of values using the Direct Market Comparison Approach only.

LITERATURE REVIEW

The Analytic Hierarchy Process (AHP) by Thomas Saaty which deals with qualitative data may be considered as the most popular Multiple Criteria Decision Making (MCDM) technique that have been used in recent years (Ho, 2007). Many previous studies emphasized the use of spatial factors on land valuation. Nisanci et al (2006) optimized the number of valuation factors from twenty initial factors by factor analysis utilizing the Statistical Package for the Social Sciences (SPSS) statistical software now known as Predictive Analytics Software (PASW). It is a computer application that provides statistical analysis of data allowing for in-depth data access, data preparation, analytical reporting, graphics and modeling. The AHP is used to measure the intangible aspects of the problem and GP incorporate the scarce information which make the whole concept very applicable in valuation.

Geographic Information Systems (GIS) in simple terms may be defined as a set of computer-based systems for managing geographic data and using these data to solve real-world spatial problems. One of the main advantage of GIS lies in its powerful processing ability which makes the integrated management of spatial information and attribute information very much achievable. It does not only search data but also can create an application based on analysis of patterns of various analytical processing, evaluation and decision-making. The GIS support platform such as ArcGIS provides a huge stage for the development of GIS applications (Wu Lun, 2002).

STUDY AREA AND DATASETS

The study area is a portion of the University of the Philippines Visayas Cebu Campus. It is located in Gorordo Avenue, Brgy. Camputhaw, Lahug District, Cebu City. It occupies an 18 hectare site which was donated by the Cebu Provincial Government in 1929. This is one of the university campuses occupied by informal settlers which, based on Commission on Audit (COA) report dated May 30, 2008, have never been valued. These informal settlement areas are used to test the validity of the generated model and the spatial-based support system.

The satellite data available and suitable for this research is QuickBird Satellite Image dated 2011 from Google Earth courtesy of DigitalGlobe with sub-meter effective ground resolution of 0.61 meters. A location map and satellite image indicating the location and extent of the study area respectively is shown in Figure 1 below. Three 1:5,000 Topographic Maps from National Mapping and Resource Information Authority (NAMRIA) with index numbers 3721-I 18A, 18B and 18C covering the entire university campus were acquired and utilized. The UPVCC administration provided the Boundary and Topographic Survey Data in CAD File Format.

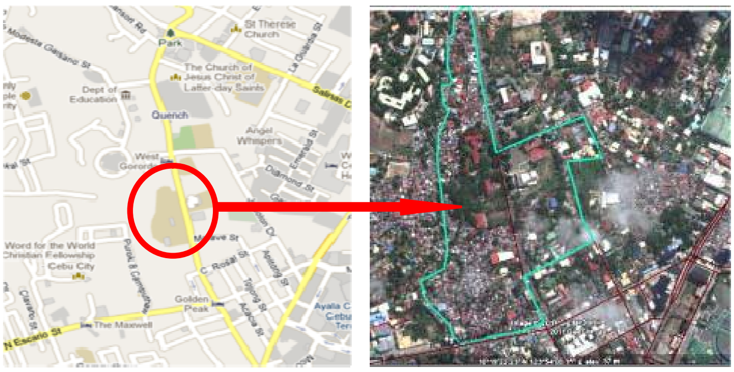


Figure 1. The UP Visayas Cebu Campus

METHODOLOGY

Eight major steps are needed to accomplish this study. The general process flow of the research work is shown in Figure 2

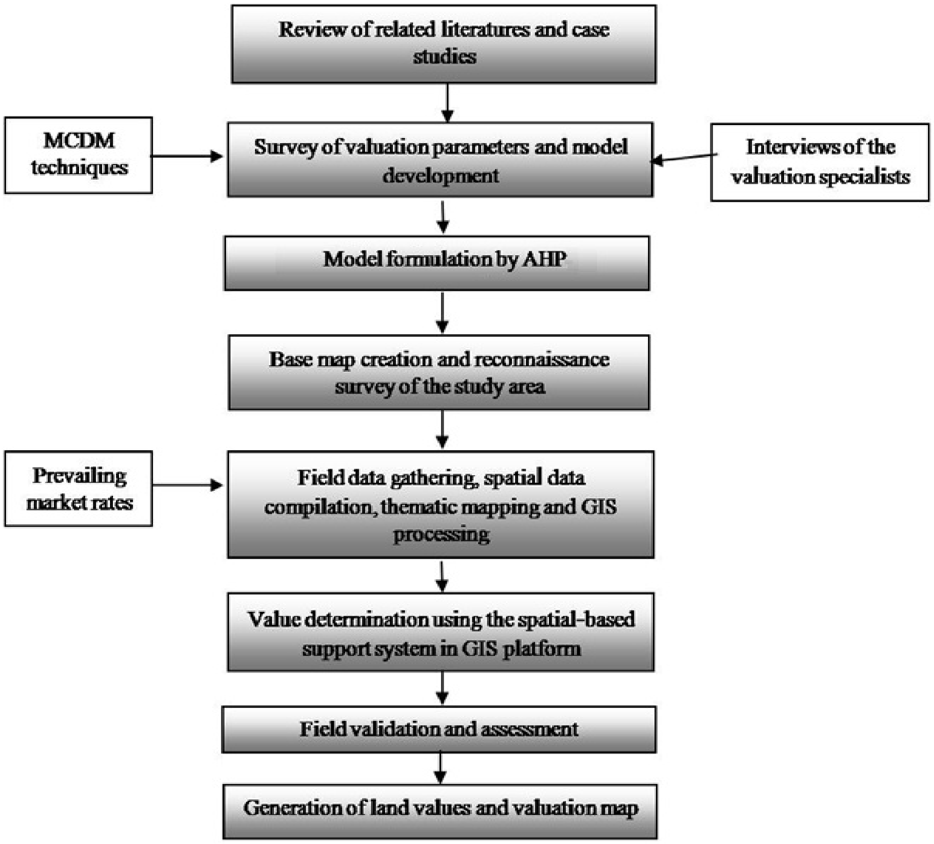


Figure 2. General process flow of the study

A summary of the process flow is described in this paragraph. The first work to be done is an extensive review of related literature and case studies providing insights on the initial valuation parameters to be considered. This lead to the design of a relevant set of questionnaires intended for the interviews of the valuation specialists. The result of the interviews determines the parameters of the model including their individual significance in the model equation using the AHP technique. Variation in the subcategories of the different parameters are likewise extracted in the interviews. After the formulation of the model, a base map is created and boundary lines are overlaid to define precisely the extent of the study area. Reconnaissance survey followed to obtain a general perspective and produce the required information to plan the logistics in conducting the necessary field data gathering activities. Archives and field data are compiled in a GIS platform for spatial analysis and attribute indexing of the subject areas. This GIS platform now serve as the spatial-based support system for the succeeding automated calculations of individual property land values to be implemented using the direct market comparison approach. These system generated land values are then validated using the conventional method from valuation specialists for performance and accuracy assessment. The initial result determines the current reliability of the support system and can be used to introduce further refinements and improvements in implementation.

Survey of Valuation Parameters

This particular step of the methodology is critical in the success of the study. The information provided by the professional valuers serves as the basis for the formulation of the valuation model. There are two sets of surveys conducted with the valuation specialists. The first is intended to extract objectively all the factors that affect land values. Statistical tests are then performed for the assessment of sampling sufficiency, consistency and transformation of relational data structures into independent and reduced but more sensible new data sets. These fewer number of significant parameters becomes the coefficients of the valuation equation. The second interview is meant to produce the hierarchy tree of the valuation factors employing pairwise comparisons adapted from Saaty's fundamental scale as shown in Table 1 below.

Table 1. The comparison scale for the importance of factors

Verbal Judgment	Numerical Rating[1]
Equal Importance	1
Moderate Importance	3
Strong Importance	5
Very Strong Importance	7
Extreme Importance	9

[1]Intensities of 2, 4, 6 and 8 are can be used to express intermediate values

All the extracted major factors are paired with each other and the relative importance in valuation is determined by indicating the mentioned numerical rating. AHP technique is used to determine the weights of these significant parameters. Also incorporated in the second interview is another set of questionnaires designed to evaluate the subcategories within the major parameters.

Model Formulation

After the rigorous task of requesting and in some instances practically begging valuation experts to answer the questionnaires and share their knowledge, the next big step is to process the relevant information contained in the interview materials. This involves the undertaking of a series of statistical tools and analysis needed to formulate the equation for land value calculations. The numerous land value factors determined from the interviews need to be analyzed and reduced to a more meaningful quantity. One test to be conducted is Factor Analysis (FA) which is a method to transform relational data structures into independent and less new data sets for making new sense. One of the many methods for factor extractions is principal component which is used in this study. Figure 3 below shows the flow of the FA technique using the SPSS software.

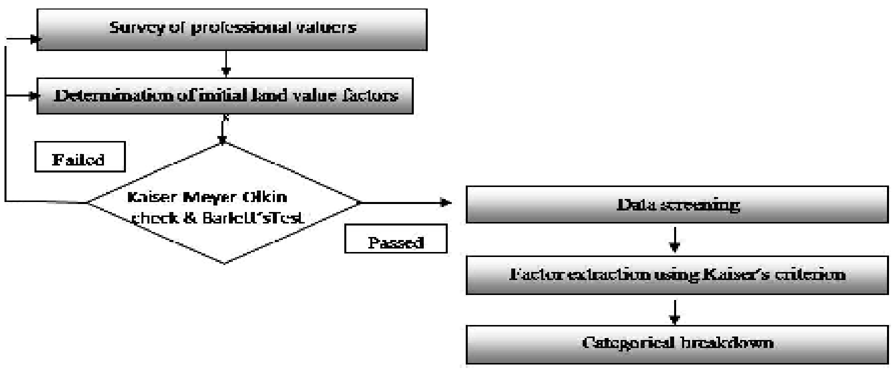


Figure 3. Process flow of valuation factors optimization by Factor Analysis (FA)

The reliability of factor analysis is also dependent on sample size. The Kaiser-Meyer-Olkin measure of sampling adequacy is a test statistic varying from 0 to 1. A value of 0 indicates that the sum of partial correlations is large relative to the sum of the correlations, indicating diffusion in the pattern of correlations making factor analysis likely to be inappropriate. A value close to 1 indicates that the patterns of correlations are relatively compact and that factor analysis should yield distinct and reliable factors. Kaiser (1974) recommends accepting values greater than 0.5 because values below suggest either collecting more data or rethink the variables to be included. According to Field (2005) values between 0.5 and 0.7 are mediocre, between 0.7 and 0.8 are good, between 0.8 and 0.9 are great and values above 0.9 are superb.

The Barlett's test for sphericity (BTS) evaluates if the original correlation matrix is an identity matrix because if the R-matrix turns out to be an identity matrix, then all correlation coefficients would be zero. We need desirable inter-correlation between the variables for the factor analysis to work. A significance test tells us that the R-matrix is not an identity matrix with a significance value of less than 0.05. The Consistency Ratio (CR) is used to evaluate the consistency of each respondent's pairwise judgments. Determining CR starts with the construction of the pairwise comparison matrix and goes all the way to the computation of the consistency index. When the CR is less than 0.10, the matrix is considered to be consistent.

In the valuation model proposed here the computation of the individual land value M is intended. Eq. 1 illustrates the customized model for computing the adjusted market rate M with *n* AHP parameters. The objective function incorporates the AHP-based relative importance weights W_i and the prevailing market rate in the vicinity H.

$$\mathbf{M} = \mathbf{H} \sum_{i=1}^{n} (W_i c_i) \qquad \textbf{(Eq. 1)}$$

Spatial data compilation and GIS processing

The first primary work in the data compilation procedure is the creation and establishment of the base map. This is accomplished using a 2011 high resolution QuickBird satellite image from Google Earth and geo-referenced accurately using ground control points (GCP) from 1:5,000 NAMRIA topographic maps. Boundaries are plotted using CAD software and overlaid on the base map in order to define the extent of area covered by this study.

The spatial data layers required for the support system are digitized from the satellite base map image which is supplemented by information from the topographic maps and by ocular inspections in the field. Land use map, neighborhood classification map, corner effect map, easement condition map, proximity to points of interest (PPOI) map, and proximity to main road map are the geo-spatial support data needed.

The study area is informal so there are no existing legal technical descriptions of the individual lots. The area of the lots are estimated by digitizing existing structures and generate Thiessen polygons to represent individual parcels. Prevailing market rates are gathered through online sites, valuation expert's inputs and validation through phone calls or site inspection. Spatial data gathered from maps and fieldworks are digitized in ArcGIS v9.3 software.

Validation

Values generated from the GIS-assisted model are validated with respect to the expert-generated values using statistical hypothesis testing. Several sample parcels are selected in the different parts of the study area attempting to get representation of the varied characteristics of the land affecting land values. The two comparable generated values are independent of one another. A 95% confidence interval (CI) at 0.05 test of significance is implemented to test the difference between the two means.

RESULTS AND DISCUSSION

Factor extraction and computed factor weights

The KMO value of 0.723 for the data falls in the range of good enough. The BTS showed that $\rho < 0.001$ which is highly significant indicates that factor analysis is appropriate. SPSS extracted all factors with eigen values greater than 1 resulting in six significant factors. Table 2 below shows the computed weights of the factors by the AHP technique. Table 3 shows the sub-categorical weights of the four (4) non-proximity related factors. The remaining sub-categorical weights were determined using analysis tools in ArcGIS.

Table 2. Computed weights of major value factors

Major Value factor	Weight
Land Use Type	0.212690077
Neighborhood Classification	0.203810838
Accessibility to Main Roads	0.158937710
Proximity to Points of Interest	0.146293958
Easement Condition	0.139296530
Corner Influence	0.138970887

Table 3: Sub-categorical weights of the non-proximity related factors

Major Factor	Sub-category	Sub-categorical Weight (%)
Neighborhood Classification	Formal	100.00
	Informal	45.00
Land Use	Commercial	100.00
	Residential	75.00
	Industrial	50.00
	Parks/Open space	40.00
	Institutional	40.00
Corner Influence	Corner lot	100.00
	Interior lot	77.50
Easement Condition	Developed	100.00
	Partially developed	55.50
	Depreciated	38.75

Model Formulated by AHP

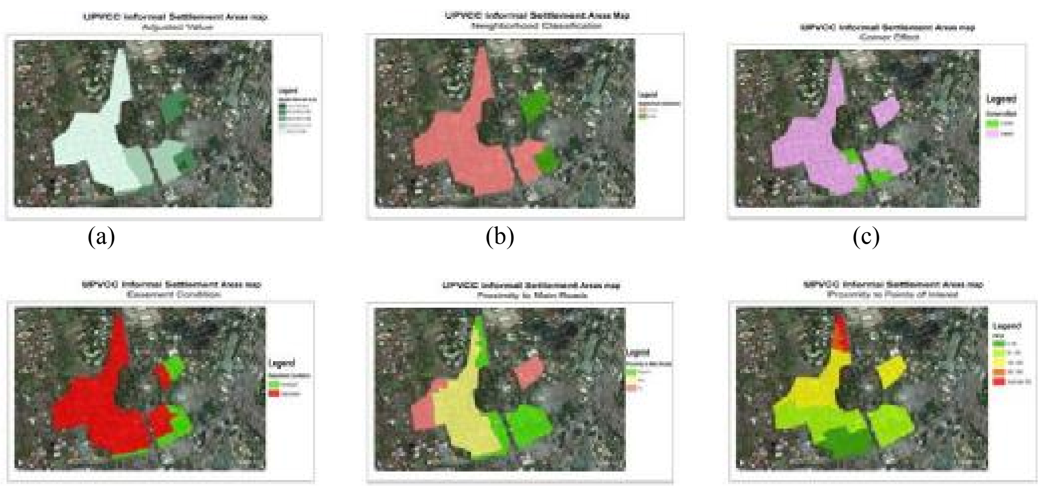
Incorporating the AHP weights of the major valuation to the customized model in Eq.1, the resulting equation is formed,

$$\mathbf{Mv/a} = H * [0.203810838nc + 0.212690077lu + 0.138970887ce + 0.13929653ec + 0.146293958ppoi + 0.15893771amr] \qquad \textbf{(Eq.2)}$$

where Mv/a is the adjusted market value of the parcel per square meter, *H* is the prevailing market rate in the vicinity, *nc, lu, ce, ec, ppoi,* and *amr* are the sub-categorical weights.

Compilation of Spatial Data in GIS Platform

Six thematic maps of the informal settlement areas are produced based on the major parameters and sub-categories. Figure 4a to 4f shows these different classification maps.



(a) (b) (c)

(d) (e) (f)

Figure 4. Thematic maps for the Geo-spatial Support System: (a) Land use map, (b) Neighborhood classification map, (c) Corner effect map, (d) Easement condition map, (e) AMr map, (f) PPOI map

Model validation

A number of samples were randomly selected from different areas of the study area and gathered for comparison of the expert-generated values and the model-generated values. The difference and percentage of the land values are computed and shown in Table 4 below. The summary of the statistics for the expert and model values are likewise tabulated in Table 5.

Table 4: Validation Data

Sample	Expert	Model	Absolute Diff	% Difference
1	22000	24,410.91	2410.91	11
2	9000	9720.99	720.99	8
3	9000	9727.07	727.07	8
4	22500	20622.42	1877.58	8
5	12500	14345.99	1845.99	15
6	20000	23364.11	3364.11	17
7	25000	24393.63	606.37	2

Table 5: Summary of the Statistics

Land Values	Mean (Php/sq m)	Standard Deviation (Php/sq m)
Expert	17,142.86	6,786.72
Model	18,083.59	6,682.25

Applying the statistics for hypothesis testing in Table 5, it is concluded that there is no significant difference between the expert-generated values and the model-generated values. The criteria for the test is shown below. Table 6 further shows the acceptability of the values generated.

Ho: $\mu\_expert - \mu\_model = 0$ (no significant difference)

Ha: $\mu\_expert - \mu\_model \neq 0$

Reject Ho if $|z| > 2.447$

Table 6. Hypothesis Testing: Difference Between the Two Means

Ho (null hypothesis)	Test Statistic	Conclusion
No significant difference	$|z| = 0.26$	Do not reject Ho

A map of the land values of the informal settlement areas in UPVCC using the valuation model is shown below.

UPVCC Informal Settlements Areas
Land Value Map

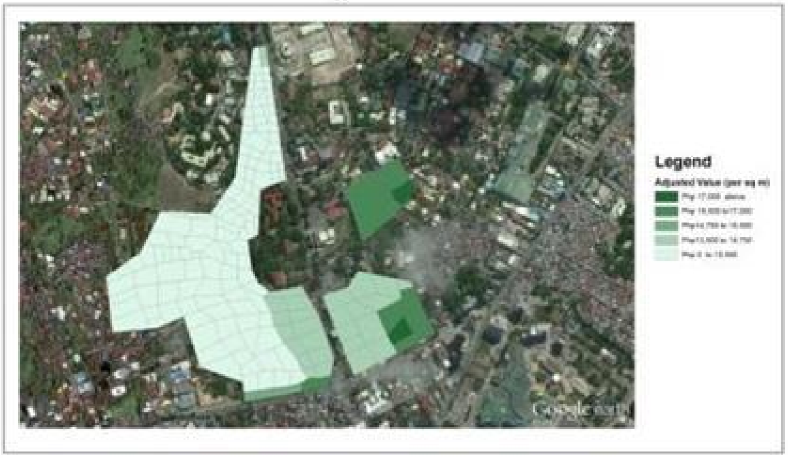


Figure 5. Land Value Map of the Informal Settlement Areas in UPVCC

This model provides an indication of value for the simulated individual lots and the whole informal settlement areas in UPVCC. The higher valued lots are located along the main roads and value decreases towards the interior portions of the study area. The highest value calculated is PhP 27,500 or US 655 for lots located at the northern and eastern sides. The total value estimate of the informal settlement area is Php 2,734,554,790.53 or around 2.73 Billion Pesos or 65.11 Million US Dollars.

CONCLUSIONS & RECOMMENDATIONS

This study proved that a geo-spatial support system in a GIS platform can enhance and hasten the ferreting out of land values employing the sales comparison approach in land valuation. The model-generated values and the values generated through the expert valuer showed no significant difference at 95% CI using statistical tests for hypothesis.

The latest outputs are just the initial results in a continuing study to further validate and improve this model and support system. It is recommended that more data from expert valuers are gathered and incorporated in the model for possible refinement then tested again in other study areas for evaluation. It is the wish of the authors that this study will be extended to include goal programming in order to appreciate more the capability of GIS in this particular field. Other research topics include the effect of environmental risks like flood vulnerability and proximity to fault lines in the land valuation of Philippine metropolitan cities.

ACKNOWLEDGEMENT

The authors would like to express gratitude to Mr. Meneleo P. Albano and Mr. Javier P. Bondoc, both of the Institute of Philippine Real Estate Appraisers (IPREA), for their unselfish sharing of expert ideas in land valuation which helped much in the success of this study.

REFERENCES:

Aznar, J., Guijarro, F. and Moreno-Jimenez, J.M., Mixed valuation methods: a combined AHP-GP procedure for individual and group multicriteria agricultural valuation, Annals of Operations Research, Chang, C., A modified goal programming approach for the mean-absolute deviation portfolio optimization model, Applied Mathematics and Computation, Volume 171 Issue 1 2005, pp. 567-572

Coyle, G., 2004, The Analytic Hierarchy Process (AHP), Practical Strategy. Open Access Material. AHP 1 © Pearson Education Limited

Field, A. P., 2005, Discovering Statistics using SPSS 2nd Edition. London: Sage

Ho, W., 2007, Combining Analytic Hierarchy Process and Goal Programming for Logistics Distribution Network Design, Systems, Man and Cybernetics, ISIC. IEEE International Conference, October 2007, pp. 714-719

International Valuation Standards Eighth Edition, 2007.

Kaiser HF. Little Jiffy, Mark IV. Educational and Psychological Measurement. 1974;34:111-7.

Nisanci, R. et al, Optimization of Land Valuation Factors by GIS & SPSS, XXIII FIG Congress Munich, Germany, October 8-13, 2006.

Wu Lun, 2002, Geographical Information System- Principles, methods, applications, 1nd Ed., Science Press, Beijing, China, pp.7-12

Yomralioglu, T. and Nisanci, R., Nominal Asset Land Valuation Technique by GIS, Valuation Techniques and Applications, May 2004.