Journal of Engineering and Applied Sciences 13 (19): 7933-7939, 2018
ISSN: 1816-949X

Combining GIS with AHP for Facility Site Selection: A Case Study in Cheongju, South Korea

[1]H.Y. Kim and [2]J.H. Hwang
[1]Institute of Regional Regeneration, Chungbuk Natl' University 3-606, 209-40 Yeulbong-ro, Cheongwongu, Cheongju, 28626 Chungbuk, Korea
[2]Department of Urban Engineering,Chungbuk Natl' University, Cheongju, Chungbuk, 3-606, 209-40 Yeullong-ro, Cheongju, 28626 Chungbuk, Korea

Abstract: The aim of this study is to provide a methodology for the facility site selection, applying spatial and multi-criteria analysis and to suggest an optimal location in study area for a sustainable large-scale facility. The 5 candidate sites of study area are evaluated and compared under both quantitative and qualitative factors from the analysis results of Geographic Information Systems (GIS) and Analytical Hierarchy Process (AHP) to identify suitability of facility location. The public survey is conducted for experts and residents on preference of site location in order to endorse the proposed site. This site selection model can be useful to planners and designers seeking to choose locations where new public facility will best integrate into the surrounding environment.

Key words: Facility site location, sports facility, Geographical Information System (GIS), Analytical Hierarchy Process (AHP), methodology, facilit

INTRODUCTION

The implementation of new public facilities for the urban welfare by governments may cause changes in the lifestyles of existing members and the changes in local economies. Therefore, effort have been made on local governments seeking to enhance the competitiveness of various perspective such as local economy, city image and culture to meet demand for cultural activities (Seo and Kwak, 2016). But the public facilitie's planning often involves the application of the urban planning standards (Yeh and Hong, 1996). Such planning process often causes problems before and after the execution because it only specifies the area required. However, facility location decision process encompasses the identification, analysis, evaluation and selection among alternatives (Kim and Chung, 2001). The decision-makers can no longer ignore the influence of highly judgmental and sensitive factors such as the political situation, government regulations and economic factors related to the region (Badri, 1999). For the long-term operation of public facilities the site selection needs to be systematically carried out by selecting the appropriate location factors for the purpose of use and then selecting the location that satisfies the most. The increased attractiveness to locate region and the impact of new technologies on facility location consideration made the facility location selection become more strategically important and the location decision process become more complex (Yang and Huei, 1997).

There are various research methods for site location analysis for site selection but few researches classify the GIS location allocation tool and Hierarchical Analysis Process (AHP) into quantitative and qualitative analysis method. The AHP is applied to each factor considering the regional characteristics of the candidate sites and the amount of contribution to facility operation.

This study consists of five sections. The next section presents findings from literature on the analysis and evaluation methods of site selection. There then follows a description of the study area and methodology in this study and an illustration of the solution procedure through a study area. Finally research findings are discussed.

Literature review: A chosen literature is reviewed in this section. Two subjects are discussed which are location decision models and location factors.

Site selection process and decision models: Since, the late 1950s, extensive efforts have been devoted to developing models for analyzing the phenomenon occurring in space. Such models are for example, the isolated state model by Waentig and Thunen (1990) the location-allocation

Corresponding Author: J.H. Hwang, Department of Urban Engineering, Chungbuk Natl' University, 103-606 Youseung-han-nae-dl, 109 Dukkeobi-ro, Sewongu, 28623 Cheongju, Chunbuk, Korea

model (Park, 2016) which developed the concept of Weber in industrial location facilities a gravity model for measuring interregional interactions and a diffusion model for describing the phenomenon spreading in space and time. The reason for using modeling is to simplify and generalize the complex real world multi-criteria problems. The most common method for the suitability of the land is the cartographic modeling by superimposing the drawings. Since, McHarg (1969) has first introduced the method of superimposing analysis drawings for ecological landscape planning this method has been used widely in various fields by using GIS (Geographical Information System). Various techniques such as Janssen and Rietveld (1990) Carver (1991) has been proposed for solving various problems and solutions and it became a more rational decision-making tool.

Because the site selection has a process of selecting and comparing several sites rather than a single site it is important to compromise the matters considering the pros and cons of each candidate. The AHP (Analytical Hierarchical Process) enables the site selection process to structure complex matters and to evaluate a large number of factors. AHP is a decision technique first introduced by Asakereh *et al.* (2014) which is used for selecting the best on among several alternatives based on multiple criteria. Carlsson and Walden (1995) have used the AHP for locating hockey stadium that brought policy clashes. And a politically compromised third choice came out as a result rather than the best location. The AHP method is a procedure for constructing a hierarchy of problems and setting weights through binary comparison of each layer to synthesize the priority of the lowest layer.

Location factors: The adequacy of the site for the proposed facility would take into account the potential impact of the function and future operational objectives as well as the evaluation criteria and factors (Hwang, 2003). Therefore, the first priority in site selection is to identify and eliminate factors that will not significantly affect the location selection. Park and Kim (2009) demonstrated the location determination factors of public facilities, including public accessibility, parking lots, cultural sites and historical sites, tourist attractions, cultural sites and amenities. Park and Kim (2010) analyzed economic factors, social factors, social factors, proximity of residential areas (road accessibility, public transportation) and natural environment factors for urban facility location. The collection of site data on candidate sties and location factors can be a huge labor on a researchers resources (Choimeun *et al.*, 2011). The location factors that have been widely used in industrial location research generally can be grouped into the following categories: Market, transportation, labor, site considerations, raw materials and services, utilities, governmental regulations and community environment (Yang and Huei, 1997).

The composition of location factors can be adjusted based on the specificities of industry and facility type. In order to select the final location, the analysis and evaluation process is performed under the multiple criteria. The hierarchy of importance is changed according to the decision process stage (Dhaya and Zayaraz, 2012). In the initial stage of analysis a few key factors such as employment and market proximity are considered focusing on the geographical location conditions of the candidate sites and the candidate sites are sought through factors such as land price and road accessibility. In the final stage is then selected through qualitative factors associated with the community of culled candidates as the final stage of the evaluation.

Location factors based on quantification can be divided into quantitative and qualitative categories (Park, 2017). The quantitative form refers to the data measured by numerical values such as land price or geographical accessibility and the qualitative form is the resident satisfaction and preference and the quality of life which appear in the specific area. Although these qualitative forms are difficult to express and evaluate with numerical values, the issue of site selection has become complex and the importance of qualitative factors in which subjective judgement has converged has been emphasized. In this study, Location factors, based on the measurability, can be addressed from 6 factors and 18 sub factors and presented in (Table 1 and Fig. 1).

Study area: The study area is the urban area of Korea with a population of 0.8 million living in an area of about 94, 300 ha. It is divided into 4 administrative districts. In the 2030 City Comprehensive Plan the lack of sports

Table 1: Location factors and sub-factors

Factors	Sub factors
A: Access factor	A1 : Inward system
	A2 : Outward system
	A3 : Share of easement
B: Environmental factor	B1 : Average slope
	B2 : Conservation area
	B3 : DGN
C: Land use factor	C1 : Rate of usable area
	C2 : National and public land
	C3 : Land use
D Community factors	D1 : Public facilities
	D2 : Local market
	D3 : Schools
E Economic factors	E1 : Development cost
	E2 : Effect on local property
	E3 : Operation cost
F Balanced growth	F1 : Development status
	F2 : Regional policy
	F3 : Public participation

Fig. 1: Location of candidate sites

facility was pointed out and five potential sites within city were specified. In this study, 5 potential sites (Site 1-5) as mentioned have been proposed for location consideration to illustrate the site selection model.

MATERIALS AND METHODS

The overall procedure of site selection is illustrated in Fig. 2. First, A GIS was integrated with a location-allocation model to analyze the quantitative factors which were classified into six categories and 23 sub-factors through the literature review. We produced the database in ArcMap 10.2 using raster pixel size of 30×30 m grid. Secondly, quantitative and qualitative evaluation is made using the set of site factors and criteria. Thirdly, the AHP is applied for constructing a hierarchy of problems, setting weights through binary comparison of each location facto and synthesizing the priorities of the lowest hierarchy. Finally, the final location is selected by assigning a weight to each decision makers in comprehensive evaluation.

The quantitative analysis is performed by applying the weights obtained through the overlay and hierarchical methods of the GIS. The calculation of GIS analysis score was by the following linear combination.

$$S-\sum_{i=1}^{n} V_i W_i$$

Where:

S = Score of suitability
n = Number of criterion factors
V = Standized score of cell value on each criteron factors
W = Importance of each critcrion factors $(\Sigma W = 1)$

As the date representation units and scales of each location factors are different the score of each factors are standardized so, that they can be compared with each other. When the score of the standardized quantitative factors is calculated, the final score is calculated based on the opinion weight among the decision makers in the following general form.

$$SS(\text{Site Score}) = \alpha Sa+\beta Sb+\gamma Sc+\delta Sd$$

Where:

$\alpha, \beta, \gamma, \delta$ = Weighted score (decision makers)
Sa = Resident's prefrence
Sb = Government's preference
Sc = Local experts preference
Sd = Result of quantitative/qualitative analysis

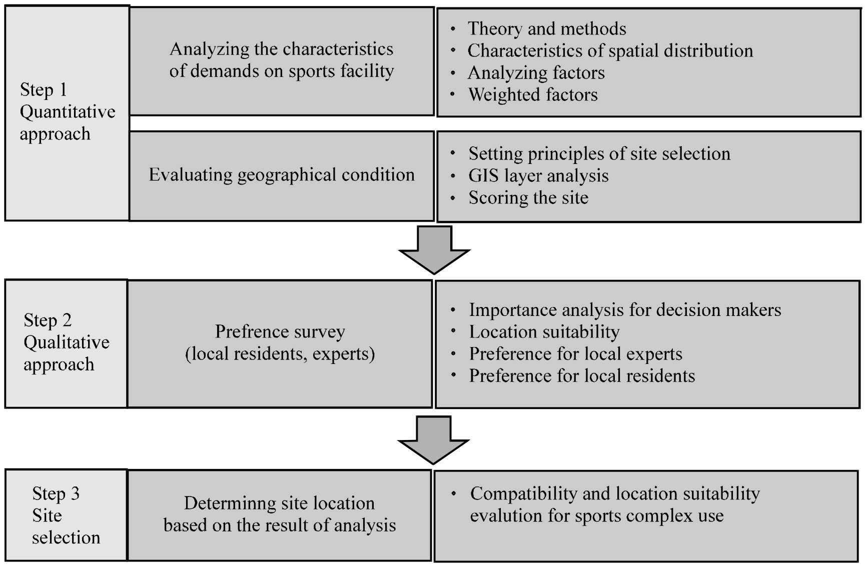

Fig. 2: Framework of site-selection procedure

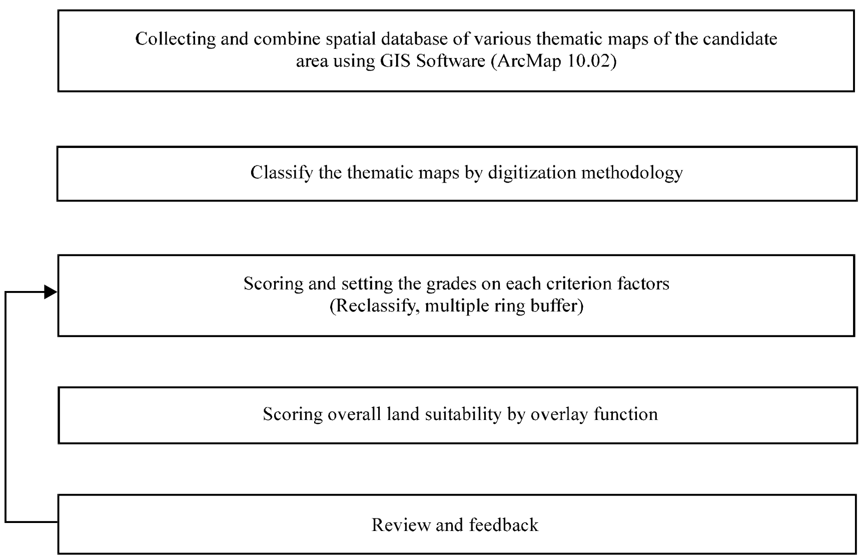

Fig. 3: Solution process of GIS Model

Application

Quantitative approach: For the application of quantitative evaluation, GIS map overlay method is used. Based on the determined hierarchical method, the data set of five candidate sites was constructed in the GIS Model. The data set consists of various maps such as topographic, geology, population, land cost, land use and traffic. Data is combined with graphic data and attribute data, rasterizing the subject map and standardizing it on the same scale. Each factor was evaluated according to the evaluation index used in the analysis, standardizing the location fitness through the overlay function and scoring it. The process of quantitative approach is illustrated in Fig. 3 and 4.

The final score of each candidate sites was calculated based on the scores of the sub factors. In addition, the weight of each site selection criteria was derived through the AHP and the result of questionnaire of experts. The importance of each factors was as follows. Access (0.199), environmental (0.117), land-use (0.106) and urban infrastructure (0.132) as shown in Table 2.

Fig. 4: Example result of GIS Model for site 2

Table 2: Resulting priority values for each criterion (AHP)

Criterion	AHP weighting
Access	0.199
Environmental	0.117
Land-use	0.106
Urban infrastructure	0.132
Local resources	0.129

Qualitative approach: The public opinion was reflected to the selection process to secure the validity of the final location. The questionnaire survey was conducted from June 14 and 30, 2016. It was distributed to a total of 1, 200 residents in proportion to the number of administrative districts in each province. It was asked to choose from 1st-3rd preference site for 5 sites. As a result, the preference of each candidate site is as shown in Table 3 and 4. The most favored candidate site is the site 3 which is located nearest to the city center and the 2nd choice is divided into the site1 and site 2. This result shows that participants have a tendency to choose the site close to their home.

In order to reflect the results of the public opinion, the total score is given to the public opinion in three grade the 1st (1-5 point), 2nd (6-10 point) and 3rd(11-15 point) as shown in Table 5.

Table 3: Resulting priority values for each candidate sites (GIS analysis)

Factors	Site 1	Site 2	Site 3	Site 4	Site 5
Access factors					
A1	8.040	7.000	8.510	8.020	7.000
A2	3.000	1.000	3.000	2.110	2.080
A3	2.900	0.500	6.400	4.900	0.400
Sub sum	13.940	8.500	17.910	15.030	9.480
Weighting	0.199	0.199	0.199	0.199	0.199
Total	2.770	1.690	3.560	2.990	1.890
Environmental factors					
E1	3.920	3.200	3.810	3.250	3.470
E2	5.000	5.000	5.000	5.000	3.820
E3	5.000	4.350	5.000	4.780	3.950
E4	1.000	3.000	2.000	5.000	4.000
Sub sum	14.920	15.550	15.810	18.030	15.240
Weighting	0.117	0.117	0.117	0.117	0.117
Total	1.750	1.820	1.850	2.110	1.780
Landuse factors					
L1	1.000	1.000	1.000	1.000	0.980
L2	1.940	2.200	1.260	1.730	1.200
L3	2.250	2.060	2.240	4.990	2.850
Sub sum	5.190	5.260	4.500	7.720	5.030
Weighting	0.106	0.106	0.106	0.106	0.106
Total	0.550	0.560	0.480	0.820	0.530
Community factors					
C1	2.000	2.000	4.670	2.330	2.000
C2	1.940	2.200	1.260	1.730	1.200
C3	1.330	1.670	3.670	2.330	1.670
Sub sum	5.270	5.870	9.600	6.390	4.870
Weighting	0.261	0.261	0.261	0.261	0.261
Total	1.380	1.530	2.510	1.670	1.270
Total	6.450	5.600	8.400	7.59	5.470

Table 4: Preference survey of the five candidate sites (residents)

Preference/Location	Number	Percentage	Ranking
First choice			
Site 1	161	15.3	3
Site 2	153	14.6	4
Site 3	324	30.8	1
Site 4	241	22.9	2
Site 5	153	14.6	4
Second choice			
Site 1	243	23.1	2
Site 2	252	24.0	1
Site 3	144	13.7	5
Site 4	167	15.9	4
Site 5	184	17.5	3
Third choice			
Site 1	219	20.8	1
Site 2	197	18.7	2
Site 3	179	17.0	3
Site 4	171	16.3	4
Site 5	165	15.7	5

Table 5: Preference of the five candidate sites (residents)

Variables	Site 1	Site 2	Site 3	Site 4	Site 5
First choice	13	12	15	14	12
Second choice	9	10	6	7	8
Third choice	5	4	3	2	1
Score	27	26	24	23	21

Table 6: Preference ranking of the five candidate sites

Preference/Location	Number	Percentage	Ranking
First choice			
Site 1	10	15.9	3
Site 2	14	22.2	4
Site 3	25	39.7	1
Site 4	12	19.0	2
Site 5	2	03.2	4
Second choice			
Site 1	15	23.8	2
Site 2	15	23.8	1
Site 3	13	20.6	5
Site 4	16	25.4	4
Site 5	4	06.3	3
Third choice			
Site 1	22	34.9	1
Site 2	12	19.0	2
Site 3	8	12.7	3
Site 4	13	20.6	4
Site 5	8	12.7	5

Table 7: Preference of the five candidate sites (Expert)

Variables	Site 1	Site 2	Site 3	Site 4	Site5
First choice	12	14	15	13	11
Second choice	9	9	7	10	6
Third choice	5	3	2	4	1
Score	26	26	24	27	18

Table 8: Overall score of the five candidate sites

Models	Site 1	Site 2	Site 3	Site 4	Site 5
GIS analysis	06.45	05.60	08.40	07.59	05.47
Preference by locals	09.00	08.67	08.00	07.67	07.00
Preference by experts	08.67	08.67	08.00	09.00	06.00
Overall score	24.12	22.94	24.40	24.26	18.47

The expert survey of preference was also conducted among 63 local expert and it also shows similar preference to the public as shown Table 6. And it is scored in the same method as presented in Table 7.

The final result of scoring quantitative and qualitative results is shown in Table 8. As a result, the optimal site was determined as site 3 with a total score of 24.40. Among the five candidate sites, the chosen site has the highest official land cost but it has the highest area of available land and gentle slope of land. It will be favorable for construction. There is also an advantage that accessibility is good and infrastructure around the site is well maintained in current. The score and weights of each evaluation index depend on the factors that the investor puts on and the GIS analysis results can also be weighted differently (Park and Kim, 2009). Determining how much of these weights are very crucial and it needs to decide carefully.

RESULTS AND DISCUSSION

The motivation of this study is to develop a decision model that will normally complex and various location factors into a hierarchy and help decision makers concentrate on key areas.

This study offered the methodology for the site selection for public facility reflecting the importance of hierarchical structure in performing quantitative and qualitative evaluation. The paper reviewed the site selection model and location factors through literature review and previous research. The solution procedure presented on a study area for large-scale sports facilities. The result of the study area shows that the proposed model can provide a framework to assist decision makers in making final location selections. The site selection procedures of study area and findings are summarized.

First, the expert AHP is used to prioritize the 6 categories of location factors as a ranking scheme with the framework of site selection analysis. As a result, community factor (0.261) was the most prioritized and accessibility factor (0.199), land-use factor (0.177) and natural environmental factor (0.106) were followed.

Second, the quantitative analysis of five candidate sites generated by GIS overlapping layers based on the data of the characteristics of accessibility, environment, land-use, socioeconomic and balanced development for five candidate sites for siting large sports facility. As a result, the candidate with good accessibility to city center and urban infrastructure was higher than those of other candidates. Third, the preference survey was executed in order to collect opinions of residents and experts. As a result of analyzing the preference of residents and experts it is found that respondents prefer to be located in their residential area or nearby due to high expectation effect on larger facilities.

Lastly, this study found that the site selection for public facilities could be derived from rational and objective methods which can be utilized effectively in determining the optimal location of the urban public facilities as a result of selection the city's planning facilities.

CONCULSION

To improve the quality of urban life through utilization of public facilities, the planning of public facilities should account for differentiated preferences and perception of private facilities, especially for residents form different socio-economic backgrounds. Given that this case study was limited to five candidate sites within a single city in South Korea, future studies should determine the applicability of the expanded model to other urban area with different location settings.

REFERENCES

Asakereh, A., M. Omid, R. Alimardani and F. Sarmadian, 2014. Developing a GIS-based fuzzy AHP model for selecting solar energy sites in Shodirwan region in Iran. Intl. J. Adv. Sci. Technol., 68: 37-48.

Badri, M.A., 1999. Combining the analytic hierarchy process and goal programming for global facility location-allocation problem. Int. J. Prod. Econ., 62: 237-248.

Carlsson, C. and P. Walden, 1995. AHP in political group decisions: A study in the art of possibilities. Interfaces, 25: 14-29.

Carver, S.J., 1991. Integrating multi-criteria evaluation with geographical information systems. Int. J. Geogr. Inform. Syst., 5: 321-339.

Choimeun, S., N. Phumejaya, S. Pomnakchim and C. Chantrapornchai, 2011. Using GIS tool for presenting spatial data: Case study Nakorn Pathom Province. Intl. J. U. E. Serv. Sci. Technol., 4: 53-68.

Dhaya, C. and G. Zayaraz, 2012. Fuzzy based quantitative evaluation of architectures using architectural knowledge. Intl. J. Adv. Sci. Technol., 49: 137-154.

Haigh, R., 1990. Selecting a US plant location: The management decision process in foreign companies. Columbia J. World Bus., 25: 22-32.

Hwang, K.W., 2003. A study on the application of land resource evaluation using GIS and analytic hierarchy process. J. Korean Assoc. Geographic Inf. Stud., 6: 16-23.

Janssen, R. and P. Rietveld, 1990. Multicriteria Analysis and Geographical Information Systems: An Application to Agricultural Land Use in the Netherlands. In: Geographical Information Systems for Urban and Regional Planning, Scholten, H.J. and J.C.H. Stillwell (Eds.). Kluwer Academic Publishers, Dordrecht, pp: 129-139.

Kim, C.H., 2010. A study on the optimal location decision of public service facilities: Focused on Paju City. Korea Res. Inst. Hum. Settlements, 66: 149-168.

Kim, J.I. and H.W. Chung, 2001. GIS applications for optimum site selection of public facility. J. Korean Assoc. Geographic Inf. Stud., 4: 8-20.

McHarg, I.L., 1969. Design with Nature. Natural History Press, Garden City, New York, pp: 75-77.

Park, H., 2016. [The study of design strategy of large-scale development project centering on industrial complex (In Korean)]. Asia Pac. J. Multimedia Serv. Convergent Art Humanities Sociology, 6: 439-449.

Park, H., 2017. [A study on the place representation of urban planning facilities centering on parks and squares (In Korean)]. Asia Pac. J. Multimedia Serv. Convergent Art Humanities Sociology, 7: 187-200.

Park, H.J. and C.H. Kim, 2009. [A study on locational factors of complex public cultural facilities: Focusing on urban-rural complex cities in the metropolitan area (In Korean)]. J. Korean Urban Manage. Assoc., 22: 211-224.

Seo, W. and J.H. Kwak, 2016. Comparing factors of urban characteristics according to location of large professional sports facilities. J. Korea Contents Assoc., 16: 712-721.

Waentig, H. and J.H.V. Thunen, 1990. [The Isolated State in Relation to Agriculture and Economics]. 5th Edn., Scientia Publisher, Germany, ISBN-13:978-3511092184, Pages: 694 (In German).

Yang, J. and L. Huei, 1997. An AHP decision model for facility location selection. J. Facil., 15: 241-254.

Yeh, A.G. and C.M. Hong, 1996. An integrated GIS and location-allocation approach.. Environ. Urban Syst., 20: 339-350.