ORIGINAL ARTICLE

Development of criterion weights for preliminary site selection: A pilot project of Supanburi industrial estate

Pichaya Rachdawong[1] and Sunee Apawootichai[2]

Abstract

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A generalized framework for criterion weights development was proposed for a pilot project of Supanburi industrial estate for light industries. It encompassed selection of criteria, questionnaire design, data collection, and data analysis. Relative or comparative importance matrix of the six factors was created from the summary of the data from expert survey. Pairwise comparison matrix was subsequently computed to reduce the data dimension and to highlight the relative importance of each factor prior to weight extraction. The highest weight was the distance to water bodies, which emphasized the importance given to natural features by experts. The framework should ease and enable adoption of multi-criteria decision-making technique for other cases of preliminary industrial estate site selection. Care must also be exercised to ensure the adequacy of quantities and quality of survey made as well as of data analysis protocol.

Key words : comparative importance matrix, pairwise comparison matrix, multi-criteria decision-making technique, preliminary industrial estate site selection

[1]Ph.D.(Environmental Engineering), Department of Environmental Engineering, Faculty of Engineering, Chulalongkorn University, Pathum Wan, Bangkok 10330, Thailand. [2]M.Phil.(Environment), Technical Officer 7, Strategy and Strategic Planning Devision, Industrial Estate Authority of Thailand, Nikom Makkasan Road, Ratchathewi, Bangkok, 10400 Thailand
Corresponding e-mail: fenprw@kankrow.eng.chula.ac.th, asunee62@hotmail.com
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บทคัดย่อ

พิชญ รัชฎาวงศ์[1] และ สุนีย์ อาภาวุฒิชัย[2]

แนวทางการหาน้ำหนักของปัจจัยที่ใช้ในการเลือกพื้นที่เบื้องต้นในโครงการนำร่อง: นิคมอุตสาหกรรมสุพรรณบุรี

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การศึกษานี้มีวัตถุประสงค์เพื่อพัฒนาแนวทางการสร้างน้ำหนักความสำคัญแก่ปัจจัยที่ใช้ในการเลือกพื้นที่เบื้องต้นในโครงการนำร่อง เพื่อหาพื้นที่ให้กับนิคมอุตสาหกรรมสุพรรณบุรีซึ่งเน้นอุตสาหกรรมเบาหรืออุตสาหกรรมที่ก่อให้เกิดมลภาวะน้อย โดยเริ่มต้นจากการเลือกปัจจัยที่เป็นตัวก่อให้เกิดผลกระทบทางด้านสิ่งแวดล้อม 6 ปัจจัย คือ ระดับความสูงของพื้นที่ ความชัน ระยะห่างจากแหล่งน้ำ คุณสมบัติของดิน ระยะห่างจากถนน และระยะห่างจากชุมชน นำมาหาน้ำหนักความสำคัญเชิงเปรียบเทียบของแต่ละคู่ความสัมพันธ์ของปัจจัยจากการสรุปผลการสอบถามความคิดเห็นของนักวิชาการ และแปลงเป็นค่าความสัมพันธ์ของปัจจัยเป็นคู่ในรูปเมทริกซ์ เมื่อคำนวณหาค่าน้ำหนักของแต่ละปัจจัยออกมาพบว่า ปัจจัยของระยะห่างจากแหล่งน้ำเป็นปัจจัยที่นักวิชาการเห็นว่ามีน้ำหนักหรือความสำคัญสูงที่สุด เนื่องจากแหล่งน้ำเป็นแหล่งสภาพแวดล้อมทางธรรมชาติที่ถูกกระทบได้ง่าย แนวทางการหาน้ำหนักนี้สามารถนำไปใช้ในการเลือกพื้นที่เบื้องต้นของนิคมอุตสาหกรรมประเภทอื่นหรืออยู่ที่อื่นได้โดยการปรับปรุงวิธีของการได้มาซึ่งข้อมูลและการวิเคราะห์ข้อมูลได้เหมาะสมกับประเภทของอุตสาหกรรมในนิคมอุตสาหกรรมนั้น ๆ

[1]ภาควิชาวิศวกรรมสิ่งแวดล้อม คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย เขตปทุมวัน กรุงเทพฯ 10330 [2]กองยุทธศาสตร์และแผนกลยุทธ์ การนิคมอุตสาหกรรมแห่งประเทศไทย ถนนนิคมมักกะสัน เขตราชเทวี กรุงเทพฯ 10400

Selection of an industrial estate site has not been an easy task for all parties involved. In a number of cases, conflicts between groups with different points of view arose and ended up in violence. This was partly due to the fact that local people and groups of NGOs did not believe in the decisions made by government officials or industrial estate developers. Many times, the decisions made were not justified. Important factors were neglected and were not taken into account.

In Thailand, the Industrial Estate Authority of Thailand (IEAT) is in charge of site selection, planning, and management of industrial estates around the country. Traditionally, there were two major concerns for initial industrial estate site selection. One was a huge number of candidate project sites being proposed. This required, as a result, a lot of effort for feasibility studies and environmental impact assessment (EIA) preparation before the most suitable sites were determined. Another concern was how the criteria or factors for evaluation of the sites were chosen and quantitatively defined.

To address the above concerns, a method was created to locate the most appropriate areas quantitatively for the Supanburi industrial estate using the selected sets of criteria with different weights. Criteria with appropriate ranges were chosen based on literature reviews and expert survey. Later, attribute values of the criteria and corresponding weights were fed into a multi-criteria decision-making scheme aided by geographical information system (GIS). A suitability map was constructed to indicate the sites with the highest scores. Subsequently, planners can use the screened information for final decision-making and for presentation to the public and other concerned parties.

However, not all the criteria selected are equally important. In fact, their perceived importances are dependent on numerous factors such as types of industries, characteristics of areas, risk perception of people surveyed, compositions and quantities of pollutants emitted, degrees of resource consumption, etc. In this study, we try to develop a criterion weight framework for a pilot project

of Supanburi industrial estate. Starting from (1) selection of criteria, (2) questionnaire design, (3) data collection, and finally (4) data analysis, this framework should, hopefully, ease and enable the adoption of the multi-criteria decision-making technique for preliminary site selection purpose.

Objectives

The major purposes of this study were

1) To create a framework for computing criterion weights for a pilot project of Supanburi industrial estate site selection.

2) To compute the weight of each criterion by using GIS software.

Study Area

Supanburi province was the target area in this study. It is located in the central plain region of Thailand between latitude 14º 4′ to 15º 5′ north and longitude 99º 17′ to 100º 16′ east (DEQP, 1999), and is in the Tha Chin Basin. The province is subdivided into ten districts with the total area of 5,354.4 km^2. Topography of the province can be classified into three broad groups, namely the mountain and hill in the west, the rolling plains in the middle immediately adjacent to the hill, and the plain in the east. Approximately, eight (8), twenty (20), and seventy-two (72) percent of Supanburi belong to the above classification, respectively.

Supanburi industrial estate project was launched in 1995. The proposed area was 2,000 rai in Tambon Hua Na, Doembang Nangbuat District, Supanburi Province (IEAT, 1999a). Presently, the Office of Environmental Policy and Planning has postponed the project proposal under review according to environmental impact assessment recommendation.

Proposed industrial types

Criteria selection for assessment of industrial estate impact on surroundings inevitably depended on types of industries to be situated in the project. According to the initial study by the IEAT, the industrial estate was to contain four major groups of industries namely: (1) agricultural processing and canning; (2) electronics, car assembly, machinery and equipment; (3) ceramics; and (4) pharmaceutical and medical-related industries. These industries were estimated to produce approximately 8,500 m^3 per day of organic wastewater and 850 m^3 per day of chemical wastewater during operation. Solid and hazardous wastes productions were estimated to be on an average of 156 and 8 m^3 per day, respectively (IEAT, 1999a).

Methodology

The ultimate goal of this study was to compute the suitability scores for plots of land. The whole process started from (1) criteria selection, (2) attribute value selection, (3) computation of weights for each criterion, and finally (4) combination of weight and attribute value of criteria in the GIS application so as to yield the suitability scores (Figure 1). More details on the process of attribute value selection, treatment of data range and incorporation into the GIS applications can be found in Apawootichai (2001). The process of criterion weight development included criteria selection, questionnaire design, data collection, and data analysis. It is quite new in the environmental planning application for industrial estate and is elaborated in this article. Details for each step are

1. Criteria Selection

Types of criteria were obtained from the literature relating to industrial estate siting of the aforementioned groups of factories. These selected criteria and their attribute values were further confirmed and modified by expert opinion for their suitability.

2. Questionaire Design

Basically, the questionnaire was designed to gather information on the relative importance of factors. There were two parts in the questionnaire addressing two different aspects of perceived relative importances. The first one was for the relative importance of factors regardless of the types of industries to be located. The second part was for the relative importance of factors con-

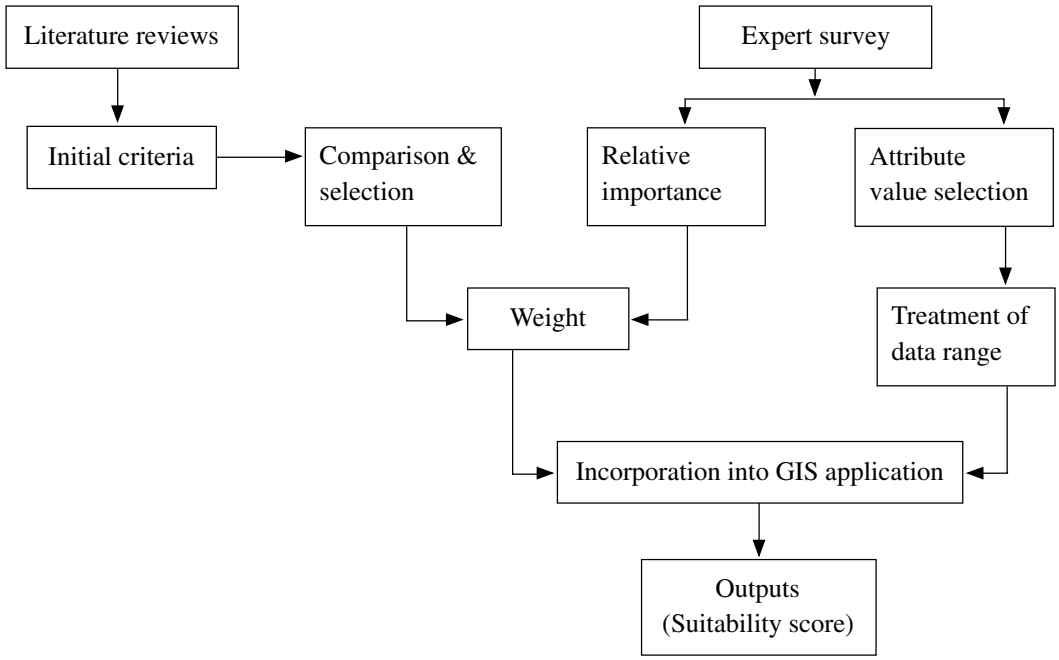

Figure 1. A process of the Supanburi industrial estate site selection.

sidering the effect of four different types of industries, namely, (1) agricultural processing and canning; (2) electronics, car assembly, machinery, and equipment; (3) ceramics; and (4) pharmaceutical and medical-related industries. There were fifteen rows representing the six factors and nine columns representing relative importance; ranging from extremely less important (1/9), very strongly less important (1/7), strongly less important (1/5), moderately less important (1/3), equally important (1), moderately more important (3), strongly more important (5), very strongly more important (7), and extremely more important (9). The numbers in the parentheses were discrete values numerically assigned to indicate the degree of relative importance for factors.

Along with the questionnaire, questions were also asked relating to the necessity of having two parts for the questionnaire and the information of the respondents.

3. Data Collection

The questionnaires were distributed to environmental/industrial experts and follow-up interviews were conducted in all cases, during November 15, 2000 to December 8, 2000, to ensure that the respondents understood contents of the questionnaire. Altogether, there were twenty-four experts from six central and one local government departments surveyed. The sample number was limited due to time and budget constraints. Nevertheless, it was considered sufficient for the purpose of this framework. These experts were selected based on the experience on site selection and availability of time to answer the questionnaire. Distribution of sources and numbers of experts surveyed is shown in Table 1.

4. Data Analysis

To account for the six factors' comparative importance, the summarized matrix of six factors with nine-point comparative importance scale (15×9) was created using the information from the expert survey questionnaires. After creation of the comparative importance matrix, calculation of pairwise comparison was conducted to reduce the dimension of information involved.

Table 1. Distribution of sources and numbers of experts surveyed

Department	Sample size
Department of Environmental Quality Promotion	3
Department of Pollution Control	3
Office of Environmental Policy and Planning	3
Department of Town and Country Planning	3
Department of Industrial Works	3
Industrial Estate Authority of Thailand	3
Government Officers in Supanburi Province	6
Total	**24**

Results and Discussions

1. Criteria Selection

There were eight criteria selected. Of the eight, there were two constraints with values of allowed or not allowed to use (reserved forest and watershed class) and six factors with numerical ranges (elevation, slope gradient, distance to water bodies, soil properties, distance from roads, and distance from communities). Types, attribute values, and references for criteria selection are given in Table 2.

2. Expert opinion

Ninety one percent of experts indicated that their jobs were related to environmental issues including planning aspects. Their backgrounds were environmentalists, scientists, urban planners, and engineers. A majority of them (74%) stated that the data from only the part one (with no consideration of the effect of industrial types) was adequate. Only twenty-six percent of the respondents agreed with the importance of having four separate evaluations for four different industrial types. More details of the opinion and attribute

Table 2. Types, attribute values, and references for criteria selection

Type	Acceptable range for industrial estate application	Reference
1. Reserved forest	Not permitted	IEAT regulation (1999b)
2. Watershed class 1 & 2	Not permitted	IEAT regulation (1999b)
3. Elevation	100-700 meters above sea level	Jensen & Christensen (1986) Hendrix & Duckley (1992)
4. Slope gradient	0-10 %	Stans *et al*. (1969)
5. Distance to water bodies	50-1,000 meters	Expert survey Apawootichai (2001)
6. Soil properties	clay texture moderately slow permeability moderately deep	Anderson & Greenberg (1982) Hendrix & Duckley (1992) Sloan (1999)
7. Distance from roads	10-1,000 meters	Expert survey Apawootichai (2001)
8. Distance from communities	800-5,000 meters	Expert survey Apawootichai (2001)

Table 3. Summarized comparative importance matrix for all factors

Column Factor	extremely less import. (1/9)	very strongly less import. (1/7)	Strongly less import. (1/5)	moderately less import. (1/3)	equally important 1	moderately more import. 3	strongly more import. 5	very strongly more import. 7	extremely more import. 9	Row Factor
elevation	0.00	5.88	17.65	11.76	41.19	5.88	5.88	5.88	5.88	slope
elevation	11.76	11.76	29.42	5.88	11.77	11.76	5.89	5.88	5.88	water body
elevation	0.00	0.00	11.76	11.76	29.42	5.88	23.53	17.65	0.00	soil properties
elevation	0.00	17.65	17.65	5.88	29.42	5.88	5.88	11.76	5.88	road
elevation	17.65	5.88	23.54	17.65	11.76	5.88	0.00	5.88	11.76	community
slope	5.88	17.66	5.88	5.88	35.30	11.76	0.00	11.76	5.88	water body
slope	5.88	0.00	0.00	0.00	41.18	5.88	17.65	29.41	0.00	soil properties
slope	5.88	5.88	5.88	5.88	35.30	5.88	17.66	11.76	5.88	road
slope	0.00	11.76	5.88	5.88	29.42	11.76	17.66	11.76	5.88	community
water body	5.88	5.88	0.00	5.88	17.66	11.76	5.88	23.53	23.53	soil properties
water body	5.88	5.88	0.00	5.88	41.19	5.88	11.76	17.65	5.88	road
water body	5.88	0.00	0.00	0.00	23.53	23.53	17.65	17.65	11.76	community
soil properties	5.88	17.66	11.76	11.76	35.30	5.88	5.88	0.00	5.88	road
soil properties	0.00	29.42	11.76	23.54	11.76	11.76	0.00	5.88	5.88	community
road	0.00	5.88	0.00	23.54	29.42	11.76	11.76	11.76	5.88	community

value selection can be found in Apawootichai (2001). Therefore, only the information from part one of the questionnaire was employed for further analysis.

3. Data Analysis

3.1 Comparative importance

The idea of comparative or relative importance was to compare the relative preference of any two factors at a time. Higher score would be assigned to a factor with higher importance than the other (Banai, 1993). These importance scores corresponding to the median values of expert opinion voted of each factor pair were entered into pairwise comparison matrix. The summarized comparative importance for six factors in this study is given in Table 3. In order to select score of importance for each combination, statistical measures of central tendency were used. The middle value of frequency or median was accepted as the all-important scale of combinations instead of mean or mode (Triola and Franklin, 1994) because the sample size of experts was small and the frequency of surveyed opinion could not be considered a normal distribution. If mode was chosen for this case, it might create a biased estimate. To avoid the effect of extreme value, the mean was not also used in this study. From Table 3, the median value of relative importance of elevation and distance from communities criteria (the fifth row) indicated that elevation was moderately less important than distance from communities and it was supported by approximately 18% of the experts surveyed. On the other hand, it could be said that distance from communities was moderately more important than elevation. Most of the median values were quite similar to the mode while a few were different.

3.2 Pairwise comparison

Each entry of the summarized matrix is the percent of respondents who agreed with the score of importance for each pair of factors (Banai, 1993; Malczewski, 1999 and Saaty, 1994). According to this study, dimension of the pairwise comparison matrix were six by six (Table 4). The most important factor was distance to water bodies, which was considerably strongly more important than soil and elevation factors and was moderately more important than distance from communities factor. There were two-second most important factors. First was slope, which was moderately more important than the soil factor. The second was distance from communities, which was moderately more important than the elevation and soil factors. Distance from roads was equally important to all factors whereas the least important factors were soil and elevation factors. Most experts gave higher weight to natural features than public facilities. This was similar to those concerned with the siting of a landfill (Banai, 1993).

Eigenvectors of weights for each of the six factors were extracted from the pairwise comparison matrix using protocol prescribed by GIS application (Malczewski, 1999 and Saaty, 1994). More details on the process of weight computation can be found in Apawootichai (2001). The weights were later assigned to criteria map

Table 4. Pairwise comparison matrix for all factors

Column / Row	Elevation	Slope	Water body	Soil	Road	Community
Elevation	1	1	1/5	1	1	1/3
Slope	1	1	1	3	1	1
Water body	5	1	1	5	1	3
Soil	1	1/3	1/5	1	1	1/3
Road	1	1	1	1	1	1
Community	3	1	1/3	3	1	1

Table 5. Final weights extracted for all factors

Factor	The eigenvector of weights
Elevation	0.0970
Slope gradient	0.1783
Distance to water bodies	0.3164
Soil properties	0.0787
Distance from roads	0.1540
Distance from communities	0.1757

layers. (Malczewski, 1999 and Eastman, 1999).

Weights in Table 5 indicated that the distance to water bodies factor had the highest weight of 0.3164. Whereas the weights of slope and distance from communities factors were quite the same (0.1783 and 0.1757, respectively). The lowest weights were the elevation and soil factors with the scores of 0.0970 and 0.0787, respectively. The distance from roads factor with a weight of 0.1540, was moderate compared to the others.

3.3 Incorporation of weights to map layers for site selection

Standardize scale was used to transform the attribute values of each factor into the same unit of summation (0-255 in GIS application). Attribute scores for each map layer were obtained by multiplication of the weight with the standardized values from the criteria map. Then, the weighted linear combination technique was used to summarize the total suitability score of

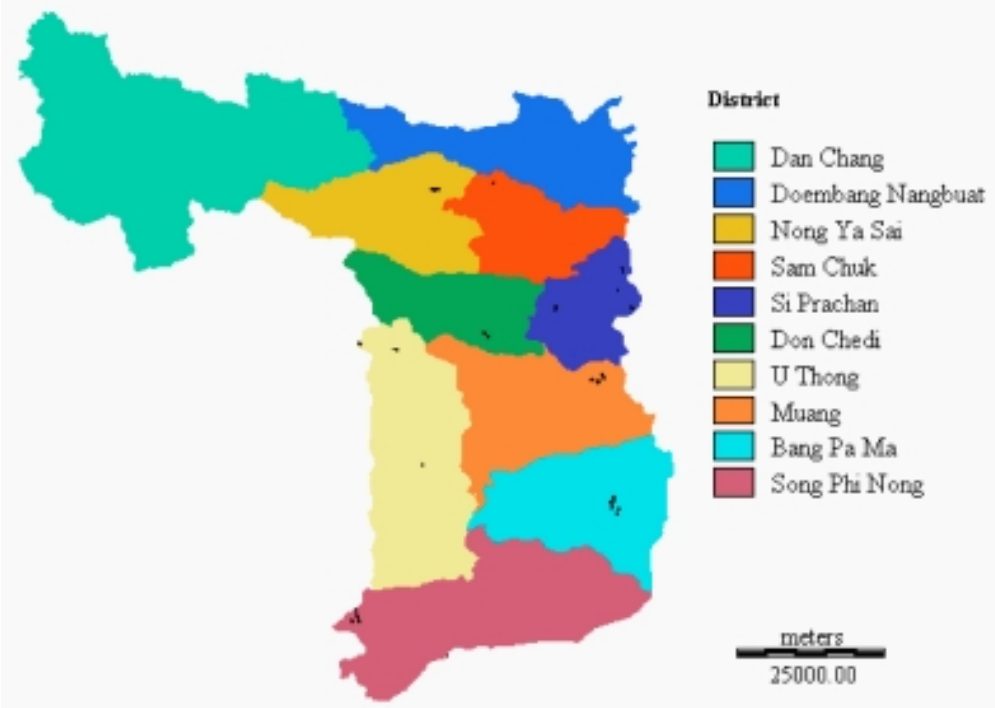

Figure 2. Suitable areas for establishing an industrial estate.

attributes from all layers for a particular area. Finally, a suitability map was created as in Figure 2. There were twenty four sites that met the specified criteria with the total area of 218.41 hectares (1,365.09 rais).

Conclusion and Recommendations

Six factors with attribute values namely, elevation, slope gradient, distance from water bodies, soil properties, distance from roads, and distance from communities factors, were identified and quantified to create the criterion weights framework for preliminary industrial estate site selection. A relative or comparative importance matrix of the six factors was created from the summarized data from twenty-four expert surveys. Pairwise comparison matrix was later computed to reduce the data dimension from fifteen by nine to six by six and to highlight the relative importance of each factor prior to the weight extraction. The highest weight extracted was the distance to water bodies, which emphasized the importance of natural features perceived by the experts. The weights were later input into map layers for site selection.

This study highlighted the importance of necessary steps required to create weights for GIS application. Important steps that could be followed by others were criteria selection, questionnaire design, data collection, and data analysis. Care must be exercised to ensure the adequacy of quantities and quality of the survey made as well as of the data analysis protocol. Differences in site locations, selected factors, and types of industries to be situated must also be addressed in any applications.

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