

Research Article

Building Site Selection of the Light Industry Plant Using AHP and GIS in NSDL Environment

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Abstract

Building site of the light industry plant should be selected with full consideration of land, electricity, water, transport, raw material supply and environment protection condition of the corresponding area, otherwise it may have a negative effect on the cost of product. Therefore, the optimal selection of building site is very important to the economic revival of enterprise. We have considered a plant building site selection with AHP (Analytic Hierarchy Process) and Geographic Information System (GIS) in NSDL environment. NSDL (Net-oriented System Language) is a complex system modeling tool, which has been developed by combining the advantages of Petri Net with Object-Oriented Programming Language VB (Visual Basic). AHP is a comparative assessment method using human sense, which models the influence of the criteria associated with decision making into a hierarchical structure and allow to choose the best among alternatives to be selected. AHP is widely used in various fields of economy, military, society, management, education, medicine, etc. Also, this method can deal with qualitative or quantitative data. Unlike the other AHP tools, the hierarchical structure models were made by Petri net diagram of NSDL, provides the automatic information link with the AHP module to improve the intuition, flexibility and convenience of decision making tools. In addition, using the object-oriented VB script language of NSDL with powerful integration ability, ArcGIS were combined to perform geographic information analysis to determine the optimal plant building site.

Keywords

Analytic Hierarchy Process, Geographic Information System, Petri Net, Net-oriented System Description Language, Building Site Selection

1. Introduction

It is of great practical significance that develop a convenient and reliable decision making tool.

In the past, AHP tools were mainly developed and used into GUI (graphical user interface) or Excel program with strong spreadsheet capability, such as XLSTAT, AHP Solver,

AHPcalc, AHPDecision and Analytic Hierarchy Process.

These tools have performed Analytic Hierarchy Process by entering the corresponding comparison matrices based on their understanding of the hierarchical structure model previously made with images or drawings [1-8]. In other words,

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there was a lack of automatic and informational link between the hierarchical structure model and the AHP module.

Finally, when the hierarchical structure model has a large number of layers, criteria, alternatives and a complex correlation, the decision making was consumed so much time and laborious and the complexity of users' use is unavoidable.

All over the world, software development tools that combine the advantages of Petri nets and object-oriented programming languages were developed such as Renew, THORNS, SNAKES, etc. [9-16].

We have developed an AHP tool using the Net-oriented System Description Language (NSDL), a complex system modeling tool developed by combining the advantages of Petri net and object-oriented program language.

In this paper, we have intuitively described the hierarchical structural model with Petri nets diagrams of NSDL, have conveniently modeled AHP module with NSDL object-oriented script language, thus enhancing the intuition, flexibility and convenience of AHP tool.

In addition, decision making system of determining the optimal plant building site was designed by combining our AHP and the advanced GIS analysis tool, ArcGIS.

2. Net-Oriented System Description Language NSDL

2.1. Basic Configuration of NSDL

The NSDL (Net-Oriented System Description Language) is an independent software development tool that uses the Petri nets and object-oriented programming language VB based on Microsoft .NET Framework 4.0 libraries.

The formal representation of NSDL is as follows.

$$NSDL = [P, T, A, M, F, \theta, O] \quad (1)$$

Where,

- 1) P is the finite set of places,
- 2) T is the finite set of transitions (includes control transitions),
- 3) A is the finite set of arcs,
- 4) M is the finite set of markings (includes the object tokens),
- 5) F is the finite set of functional code,
- 6) θ is the finite set of attributes (delay time after firing, firing rate, priority, weight, capacity, type of elements, competition extraction setting and color, etc.) and
- 7) is the finite set of standard objects and user defined objects modeled with functional codes.

The NSDL models the system as follows.

In the upper level of system,

- 1) Hierarchical diagram models according to the mutuality and the logical action sequence of system components are constructed.

- 2) Graphical User Interface models can be configured according to the demands of the user. (optional)
- 3) Setting properties of diagrammatic and interface modeling elements.

In the lower level of system,

- 1) Editing Standard and user defined functional code model of upper level diagram elements.
- 2) Dynamic setting properties of diagrammatic and interface elements by functional codes during the simulation.

In NSDL, we introduced elements such as in/out place terminal, equal place and subsystem, functions such as model library management, code debugging and model compiling to further improve its flexibility, convenience, extensibility and productivity.

2.2. Modeling Element

Modeling elements include place, transition, arc, subsystems, controls and functional code.

2.2.1. Place

The place reflects the state of system. It is classified into integer place, variable place (includes object), real number place, stack place, FIFO place and equal place according to the contained information (Figure 1). The integer place, the stack place and the FIFO place have their own capacities.

NSDL may describe the state of continuous or hybrid systems as well as the state of discrete systems using these places.

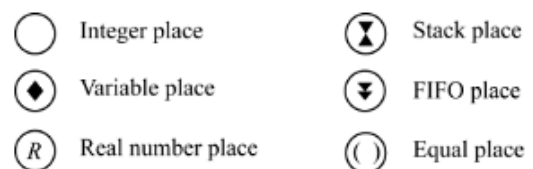


Figure 1. Places.

2.2.2. Transition

Transitions are fired according to the states of input places, input or output arc properties and own condition functions.

The transition is a processing element that executes the corresponding function of a certain event according to the states of input places or inner terminals (variable or simplified input/output place terminal) added to it. (Figure 2)

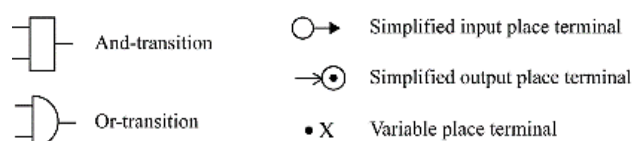


Figure 2. Transition and inner terminal added to it.

For convenience of modeling, And-transition and Or-transition are used and they may be contained simplified input/output or variable place terminal. In these place terminals, data type of token can be contained Boolean, Integer, Real number, String and Object, etc.

Custom controls transition which are widely used in GUI (Graphical User Interface) modeling, such as Graph, Table,

Text Box, Button, Check Box, Combo Box be newly introduced to improve modeling capability in NSDL (Figure 3).

Such Custom controls transitions can execute the action according to the standard transition and itself private function. The attributes of firing time, firing rate, priority and the like can be set in all the transitions.

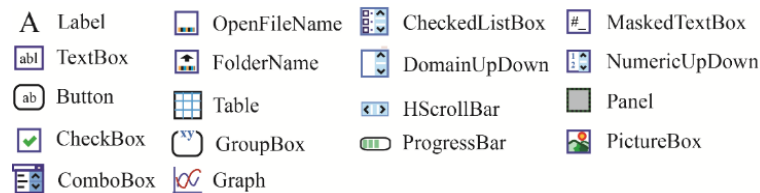


Figure 3. Typical transitions of custom controls.

2.2.3. Arcs

Arc is link element that describes the relationship between places or transitions and has two types: input arc and output arc.

According to the mode of information (token) transmission, input arc can be classified into three types: Flow arc, Reference arc, Inhibitor arc.

Flow arc transfers information of input place into transition connected to it and removes information in the input place. On

the other hand, Reference arc keeps the information in the input place after the relevant transitions are fired. Inhibitor arc transfers information, when there is no information in the input place. Output arc outputs the information of a transition.

Also, arcs may be contained multiplicity, flow quantity and conditional expression, output function can be defined in the output arc (Figure 4).

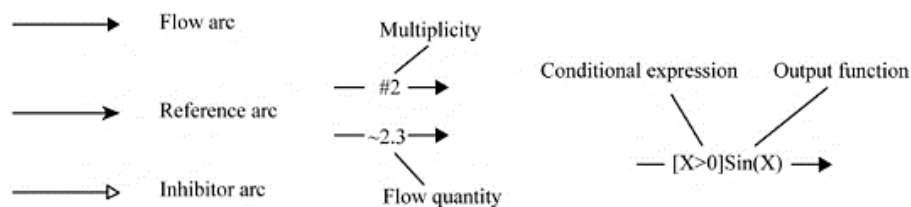


Figure 4. Type of arc.

2.2.4. Subsystem Model Element

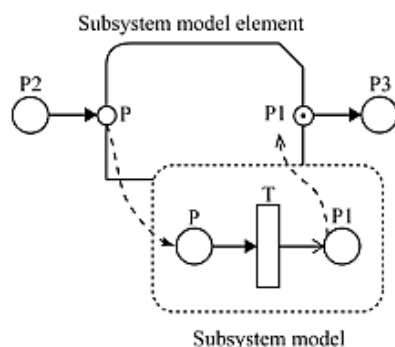


Figure 5. Expression of the input/output terminal of subsystem element.

The hierarchical structure of complex information system can be modeled with subsystem model elements, simplified input and output place terminals (Figure 5).

Input/output place terminals can be only connected to the places in subsystem model.

2.2.5. Functional Code Model

Functional code describes the execution code of diagram model elements created in the upper level of systems.

They can use not only the arbitrary function and procedure that Framework4.0 library supports, but also NSDL's custom functions and procedures as follows.

- 1) Sub Initialize (): a procedure for initialization.
- 2) Sub Terminate (): a procedure occurring when the fire is ended.
- 3) Sub InputValue (): a procedure occurring as the transi-

tion inputs information.

- 4) Sub OutputValue (): a procedure occurring as the transition outputs information.
- 5) Sub Action (): a procedure occurring when the transition is fired.
- 6) Function UserCondition (): a function that processes user defined condition at transition and arc.

The system variables, procedures and functions that NSDL support in default are:

- 1) Systime: Get current running time of model.
- 2) Modelpath: Get current model path.
- 3) Mainform: Display main form windows.
- 4) Resetmodel: Reset the initial condition of the diagram model.

5) Runcount: Set run count of model.

6) Runstyle: Set run style (Debug, Release, Independent).

7) Updatemodel: Redraw the current diagram model.

And so on.

2.3. Firing Rule

The state of the system in NSDL changes by the firing of transition i.e. the occurrence of an event.

The firing of transition follows the standard firing condition of Petri net and the type of transition (And, Or, Custom control action), the kind and attributes of input arcs (conditional expression, multiplicity, flow quantity) (Figure 6).

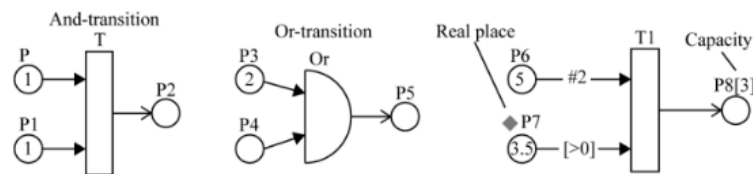


Figure 6. Firing conditions of the transition (firing enable states).

The transitions defined by the function “User Condition ()” can only be fired when the above mentioned conditions and this function value conditions are satisfied.

3. Building Site Selection of the Light Industry Plant

3.1. Algorithm of Tool

The algorithm diagram of the tool is shown in Figure 7.

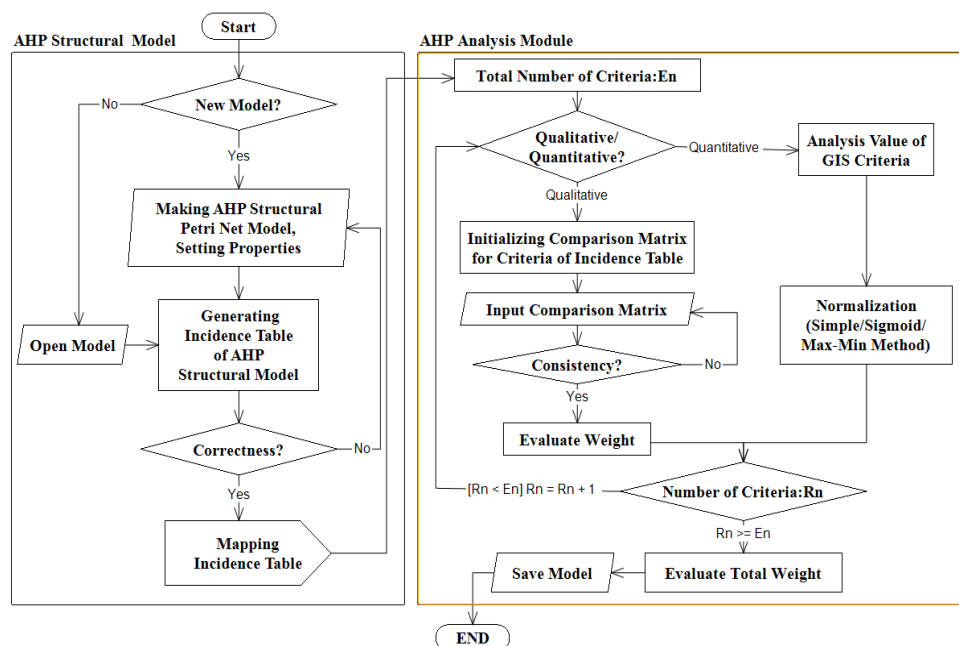


Figure 7. Algorithm Diagram of the tool.

3.2. AHP Tool

3.2.1. Making AHP Structural Model

The process of making AHP structure model in tool is as follows.

1) Hierarchical Structure Modeling Module

- 1) User can use one goal layer element (A1), 17 criteria layer elements (B1- K1), one alternative layer element (S1) and one reference arc element to model hierarchical structure, also one sub-criteria and sub-alternative element by subsystem element. These elements are created and stored in the Hierarchical Analytical Library file “ahp.ndt”.
- 2) Insert the model library file “ahp.ndt” into the toolbox.
- 3) Using the modeling elements in the toolbox, create an AHP structural model that the user needs and add the attributes for the example (Figures 8 and 9).
- 4) For convenience, If there are so many criteria (or alternatives) in one layer can be used as sub-criteria

(alternatives).

2) Generation of incidence table, checking and revising for hierarchical structure model

- 1) Generates incidence table according to the relationship of each element in the hierarchical structure model (Table 1).
- 2) The user checks the consistency of the built-in hierarchical structure model with the generated incidence table and performs modifications and storage of the built-in model.

3) AHP module

- 1) Based on the incidence table obtained from the created AHP structural model, we implement AHP algorithm using the VB script language of NSDL.
- 2) The user can directly input qualitative and quantitative criteria. Also, the NSDL's script language and the best GIS analysis tool ArcGIS were combined to input the analysis results for the relevant criteria.

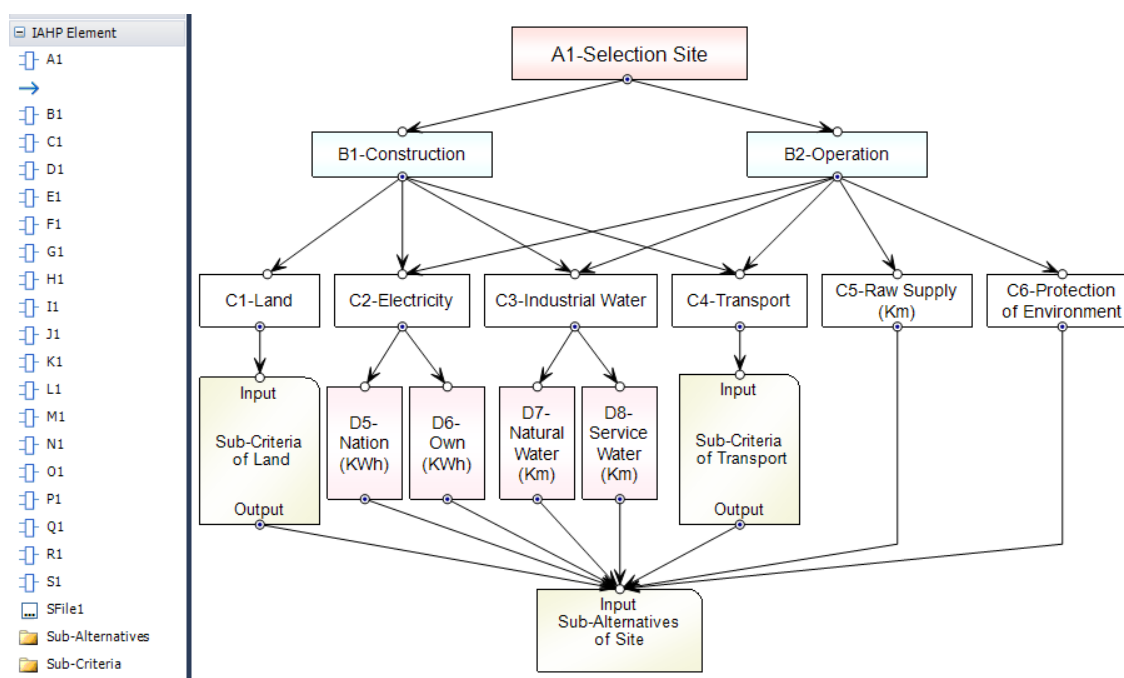


Figure 8. AHP Structural Petri net Model.

The selection of building site should take into account the criteria of electricity, industrial water supply, transportation and, in particular, the convenience.

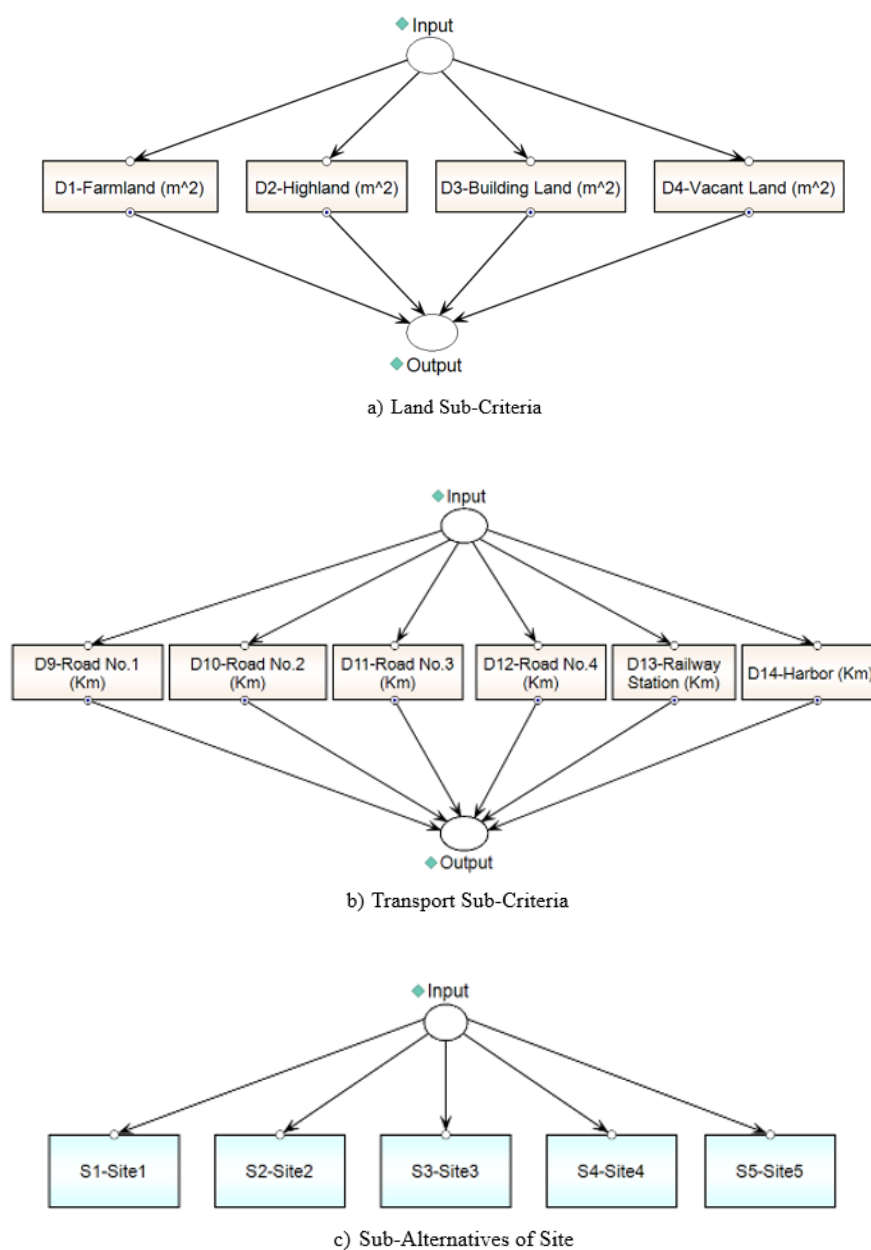


Figure 9. Sub-Criteria and Sub-Alternatives.

The incidence table for AHP structure of example model is as follows.

Table 1. Incidence Table for AHP structure model.

No	A1	B1	B2	C1	C2	C3	C4	C5	C6	D1	...	D13
1	B1	C1	C2	D1	D5	D7	D9	S1	S1	S1	...	S1
2	B2	C2	C3	D2	D6	D8	D10	S2	S2	S2	...	S2
3		C3	C4	D3			D11	S3	S3	S3	...	S3
4		C4	C5	D4			D12	S4	S4	S4	...	S4
5			C6				D13	S5	S5	S5	...	S5
6							D14					

3.2.2. Evaluation of Qualitative Criteria

Based on incidence table, the following AHP algorithm is constructed by VB language of NSDL.

Step 1: Judgment Matrix Construction

When AHP diagram is constructed, judgment matrix to reflect expert's subjective assessment is made. The judgment matrix may be made by comparison table.

Table 2. Meaning of Comparison Values.

Comparison value	Meaning
1	Equally importance
3	Moderately importance
5	Strongly importance
7	Very strongly importance
9	Extreme importance
2, 4, 6, 8	Intermediate values

Step 2: Calculation of the weight by geometric average.

1) Calculate the product $M_i = \prod_{j=1}^n a_{ij}, i = \overline{1, n}$ of the ele-

ments of each row of judgment matrix A.

2) Calculate the n^{th} square root $\bar{w}_i = \sqrt[n]{M_i}$ of M_i .

3) Calculate the weight by normalizing vector $\bar{W} = [\bar{w}_1, \bar{w}_2, \dots, \bar{w}_n]^T$.

$$w_i = \frac{\bar{w}_i}{\sum_{j=1}^n \bar{w}_j} \quad (2)$$

where $W = [w_1, w_2, \dots, w_n]^T$ is an eigenvector.

Step 3: Consistency

The validity of the judgment matrix is determined by the *CI* (Consistency Index).

$$CI = \frac{\lambda_{\max} - n}{n - 1} \quad (3)$$

The consistency of the judgment matrix is determined by the average random consistency ratio.

If *CI* doesn't satisfy the following condition, though it is less than 0.1, must check the judgment matrix again.

$$CR = \frac{CI}{RI} \leq 0.1 \sim 0.15 \quad (4)$$

Table 3. Random Consistency Index.

<i>n</i>	2	3	4	5	6	7	8	9	10	11	12
<i>RI</i>	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.53

Table 4. Judgment matrix of B2.

B2	C2	C3	C4	C5	C6	Weight
C2	1	3	5	9	7	0.5100387
C3	0.3333333	1	3	7	5	0.2638338
C4	0.2	0.3333333	1	5	3	0.1295737
C5	0.1111111	0.1428571	0.2	1	0.3333333	0.0329178
C6	0.1428571	0.2	0.3333333	3	1	0.063636

Comparative judgment matrices for qualitative criteria are made by experts.

3.2.3. Evaluation of Quantitative Criteria

For quantification criteria, normalization can be performed

by Simple, Max-Min and Sigmoid transformation method. The sigmoid transformation method uses the following expression to estimate the importance:

$$\text{Standard deviation } \sigma = \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}} \quad (5)$$

$$\text{Sigmoid transformation } a_i = \frac{x_i - \bar{x}}{\sigma} \quad (6)$$

The larger the value, the better the case:

$$y_i = \frac{1 - e^{-a_i}}{1 + e^{-a_i}} \quad (7)$$

The lower the value, the better the case:

$$y_i = \frac{1 - e^{a_i}}{1 + e^{a_i}} \quad (8)$$

3.2.4. Evaluation Total Weight

For a given problem, let the criteria be K layers and the M_k criteria of the k -th layer denotes separately $W_1^{(k)}, W_2^{(k)}, \dots, W_{M_k}^{(k)}$. The weight of the j -th criterion $W_j^{(k)}$ of the k -th layer is $w_{j(k)}^{(k)}$. Let the estimate of the alternative X_i for j -th criterion $W_j^{(1)}$ of the 1-th layer (lowest layer) is $x_{j(i)}$. The overall estimate $\bar{x}_i$ of the alternative X_i is

$$\bar{x}_i = \sum_{j(k)=1}^{M_k} \dots \sum_{j(2)}^{M_2} \sum_{j(1)}^{M_1} w_{j(k)}^{(k)} \dots w_{j(2)}^{(2)} w_{j(1)}^{(1)} x_{j(1)} \quad (9)$$

Quantitative criteria are inputted by ArcGIS analysis results and normalized by Sigmoid method.

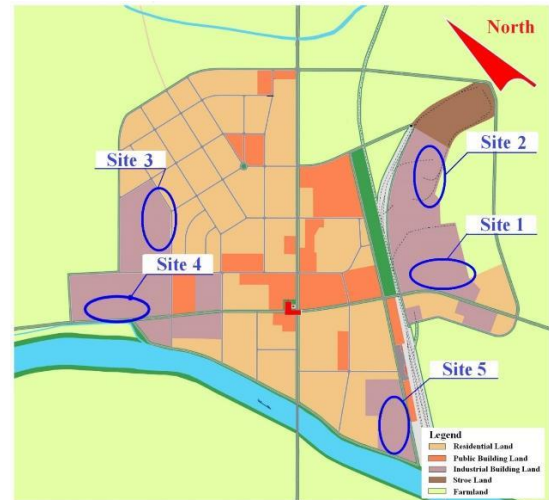


Figure 10. Alternatives of Plant Building site.

The summary of weights is shown in Table 5.

Table 5. Summary of Weights.

A Layer	B Layer	C Layer	D Layer	S Layer	Ranking		
A1-Building Site Selection of the Light Industry Plant	B1- Construction	C1- Land	D1- Farmland	0.0098	S1-Site1	0.3393	3
			D2- Highland	0.0020			
			D3- Building Land	0.0046			
			D4- Vacant Land	0.0010			
		C2- Electricity	D5- Nation supply	0.3796	S2-Site 2	0.1789	5
			D6- Own supply	0.1265			
			D7- Natural Water	0.1765			
	B2-Operation	C3- Industrial Water	D8- Service Water	0.0588	S3-Site 3	0.3491	2
			D9- Road No. 1	0.0518			
			D10- Road No. 2	0.0337			
			D11- Road No. 3	0.0215			
		C4- Transport	D12- Road No. 4	0.0057	S4-Site 4	0.4852	1
			D13- Railway Station	0.0086			
			D14- Harbor	0.0135			
		C5- Raw Supply	0.0417	S5-Site 5	0.2306	4	

A Layer	B Layer	C Layer	D Layer	S Layer	Ranking
		C6- Protection of Environment	0.0656		

As can be seen from the results, it can be seen that building site 4 is the most reasonable site.

Unlike the Simple method, the sum of the total weights is not equal to 1 if the sigmoid transformation method is used.

4. Conclusion

Compared with the previous AHP tools, AHP tool developed by NSDL has been used to build hierarchical structure models with Petri net diagrams to improve the intuition, flexibility and convenience of decision making tool.

Also, the object-oriented VB scripting language of NSDL with powerful integration capabilities and GIS analysis tool ArcGIS were integrated to perform geographic information analysis for building sites.

Abbreviations

AHP	Analytical Hierarchy Process
GIS	Geographic Information System
NSDL	Net-oriented System Description Language
VB	Visual Basic
GUI	Graphical User Interface
FIFO	First-In First-Out

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Conflicts of Interest

The authors declare no conflicts of interest.

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