Transaction of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 25-26, 2012

NPP Site Selection: A Systems Engineering Approach

Henry Pwani, Florah Kamanja, Zulfakar Zolkaffly, JC Jung
KEPCO International Nuclear Graduate School, Ulsan, S. Korea
Pwanihenry@yahoo.com

1. Introduction

The necessity for improved decision making concerning the siting and licensing of major power facilities has been accelerated in the past decade by the increased environmental consciousness of the public and by the energy crisis. These problems are exceedingly complex due to their multiple objective nature, the many interest groups, the long-range time horizons, and the inherent uncertainties of the potential impacts of any decision. Along with the relatively objective economic and engineering concerns, the more subjective factors involving safety, environmental, and social issues are crucial to the problem. The preferences of the general public, as consumers, the utility companies, as builders and operators of power plant facilities, and environmentalists and the government must be accounted for in analyzing power plant siting and licensing issues. We advocate for a systems engineering approach that articulates stakeholder's requirements, expert judgements, and a systems decision making approach. The appropriateness and application of systems decision making process is illustrated in this paper.

2. Need analysis

The objective is to show that a need for a nuclear power plant site exists and there is a feasible approach to fulfilling the need at an affordable cost and within an acceptable level of risk [1].

2.1. Step 1: Stakeholder identification

The major stakeholders for NPP siting include the Government, public, Regulatory body, Environmental management bodies, Energy utilities and International Atomic Energy Agency among others.

2.2. Step2: Stakeholder needs elicitation

Interviews, Focus groups, and surveys are some of the techniques that can be used to elicit stakeholder needs related to NPP safety, environment, development cost and licensing.

2.3. Step3: Functional and requirements analysis

System functional hierarchy is generated using systems engineering tools including affinity diagrams, IDEF and functional flow diagrams. This hierarchy provides a clear understanding of the functions the system is being designed to perform and serves as the foundation for the assessment of the candidate solutions.

3. Value modelling

Value modelling provides the siting team with an initial methodology for evaluating candidate sites. From the information collected through research and stakeholder analysis and affinity diagramming, functions, objectives and value measures that comprise the value model are derived. Table 1 shows the value hierarchy structure.

Table 1: NPP siting value hierarchy

	Objectives		Attributes
NPP SITING	Public Health & Safety	Maximize public health & safety	Population Density
			Wind Speed
			Distance from the active fault line
			Distance from flight paths.
	Environmental Protection	Maximize environmental protection	No. of protected species
			Air quality index
	Social-Economic Consideration	Minimize no. of people to be relocated	No. of households to be relocated
			Population density
	Construction Cost (Economic & Technical Aspects)	Minimize construction cost	Distance from the power grid
			Distance from the water source
			No. of transportation modes

3.1. Quantitative value model

A sample swing weight matrix is shown in Table 2 and Table 3.

Table 2: Swing weighting matrix for determining measure weight

		Level of importance of the value measure		
		Very Important	Important	Less Important
Variation in measure ranges	High	Distance from cooling water-source (100) Distance from power grid (95)	Distance from fault lines (41)	
	Medium	Wind speed (90) Population density (85)	No of transport modes (78)	No of protected species (30)
	Low	No. of household to be relocated (65)	Distance from flight paths (63)	

Quantitative value model reflects key stakeholder values regarding the systems decision problem. The swing weight matrix analysis is used to determine how well candidate solutions to our system decision problem attain the stakeholder values [2].

Table 3: Global weight of the value measures

Value Measures (x)	Swing Weight	Measures Global Weight
Distance from cooling water source(km)	100	0.154
Distance from power grid (km)	95	0.147
Wind speed	90	0.139
Population density	85	0.131
No of transport mode	78	0.121
No of households to be relocated	65	0.100
Distance from flight paths (km)	63	0.097
Distance from fault lines (km)	41	0.063
No. of protected species	30	0.046
Total	647	1.00

Measure weight for value measures [2], $W_{i,}$ is determined from

$$W = \frac{f_i}{\sum_{i=1}^{m} f_i} \qquad (1)$$

where, f_i = the non-normalized swing weight assigned to the i^{th} value measure, i = 1 to n for the number of value measures and w_i is the corresponding weight.

4. Site selection process

The figure below is an IDEF0 Level 1 showing NPP site selection process [2].

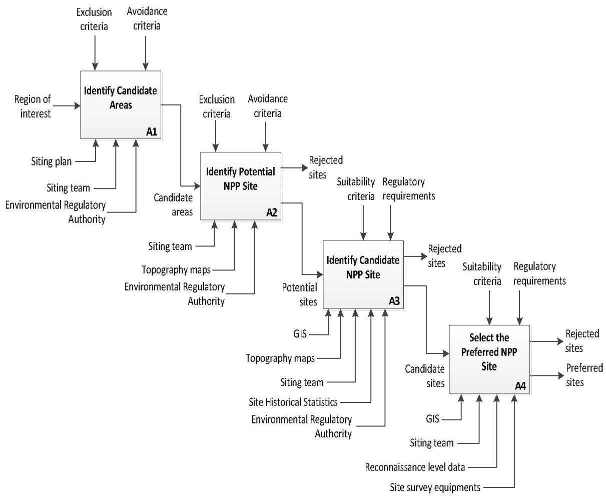

Fig.1. IDEF0 Level 1 for NPP site selection process

Three criteria are used in the site selection process.

i. Exclusion Criteria: Mandatory requirements are regulatory and preliminary plant design requirements [3].

ii. Avoidance: Examples of avoidance include distance from flight paths and distance from population centres [3]

iii. Suitability Criteria: Examples of suitability criteria are local topographic features, access considerations, important species habitat, and impingement or entrainment effects [3].

5. Solution design

Delphi method is to identify alternative sites. In this method, opinions are gathered through formal questionnaires from subject matter experts [2].

5.1. Decision making

Value functions are used to convert candidate solutions scores on the value measures to standard units and are generated based on the views of stakeholders. Value measures scores for the candidate solutions are obtained through expert opinion [2].

An additive value model (MODA) is used to calculate candidate solutions values [2]. The mathematical expression MODA [2] is given by:

$$V_x = \sum_{i=1}^{n} w_i v_i(x_i) \qquad (2)$$

where, $v_i(x_i)$ is the single-dimensional value of the score x_i while the other variables are as defined in equation 1.

Table 4: Solution values for candidate sites

Candidate Sites	A	B	C	D	E	F	G	H	I	Solution value
Site A	65	78	40	80	50	85	70	35	68	**64**
Site B	70	30	35	40	60	50	45	45	72	**48**
Site c	40	63	25	47	44	45	32	50	46	**44**
Weight	0.15	0.15	0.14	0.13	0.12	0.10	0.10	0.06	0.05	

A Distance from cooling water source
B Distance from power grid (km)
C Wind speed (km/h)
D Population density
E No of transport modes
F No of households to be relocated
G Distance from flight paths
H Distance from fault lines (km)
I No of protected species

6. Conclusion

The site with the highest solution value score is selected. Sensitivity studies using different criterion weight sets can be conducted to assess their effect on the selection of a preferred site and thereby lend additional credibility to the decision process [3].

Systems thinking combined with engineering principles focus on creating values for stakeholders and are capable of addressing many of the challenges posed by the growing complexity of the systems.

REFERENCES

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[3] EPRI, Siting Guide: Site Selection and Evaluation Criteria for an Early Site Permit, 2-6, 2-11, 2002