USING AHP TO ANALYZE THE PRIORITY OF PERFORMANCE CRITERIA IN NATIONAL ENERGY PROJECTS

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Abstract: Numerous studies of performance measurement have been done centralize in exploring performance measurement by input and outcome of original data in past research. The examiners usually evaluate the project performance by using the equal weights of performance criteria. Most studies do not consider the importance degree of performance criteria. In fact, each project should be evaluated by applying the unique weights of performance criteria on evaluating project performance. However, there has a little research focus on investigating importance of performance criteria by means of reviewing related literature. In order to examine the project performance accurately and precisely, the purpose of this study is to understand the importance and priority of performance criteria of national energy projects. Based on reviewing previous studies and expert interview, related impact factors have been examined were inducted to establish a hierarchy table which was sequentially designed into the comparison format of analytic hierarchy process (AHP) questionnaires. The sample is surveyed from energy experts who are experienced in the fields of reviewing and conducting national energy projects. The results of data analysis indicate that, although the performance criteria have significant difference among various fields of energy experts, the finding of this study can provide a valuable reference to evaluate energy project performance for government organization in the future.

Keywords: Performance measurement, performance criteria, energy projects, analytic hierarchy process (AHP)

INTRODUCTION

Facing the short of global energy and the trend of energy conversion, the policy of energy technology has been played a vital competition index for developed country in twenty-one century. Regarding the energy situation in Taiwan, over 98% of energy supply is imported (Ministry of Economic Affairs, 2007). Therefore, in recently years the government invests a lot of human resource and government annual budget to develop and advance energy technology in Taiwan.

Although the governmental organization made a great effort to advance the energy research and development (R&D) projects, the project performance is still hard to evaluate in reality. In order to reinforce the core competition in global environment, the more precise and accurate in performance measurement of energy project have been emphasized by executives in Bureau of Energy around the world. The meaning of performance measurement is to evaluate the meeting of the objectives of project budget, project schedule and an acceptable level of outcome (Pinto and Slevin, 1988). Therefore, project managers are facing with the decision-making environment and real-world problems in selecting and carrying out the appropriate weights of performance measurement for project management.

In previous research, numerous studies of project performance have been worked on investigating performance measurement by the original of input resource and output data. In particular, the examiners usually evaluate the project performance by using the equal weights of performance criteria. Most studies, unfortunately, do not consider the importance degree of performance criteria. It should be noted that the weights of performance criteria will be changed in different field of energy projects. That is, each project should be measured by applying the various weights of performance criteria on performance evaluation. On the other hand, there is little research focus on investigating performance measurement through the literature review, especially in the priority and weight of each performance criterion. In order to create an efficient use of limited national energy resources and energy budget, the purpose of this study, therefore, is applying analytic hierarchy process (AHP) to understand the importance and priority of performance criteria in national energy projects. The results of this study would further provide a useful reference for decision-makers who need an effective performance evaluation and resource allocation of national energy projects in the future.

LITERATURE REVIEW

Energy research and development is necessary for governmental organization to facilitate the core competition capability in global dynamic environment, as well as lead the development of local economical industry simultaneously. Shin et al. (2007) stated that it is important to examine the performance of energy project for the national research and development of government organization. The governmental organizations around the world are facing the issue of implementation and applicability for performance measurement of project management (Melkers and Willoughby, 1998). The importance of performance criteria has significantly played a vital role in examining project performance.

The criteria of performance measurement are usually used to evaluate the project performance which is measured by appropriate performance criteria to reflect realistic outcomes, as well as is included of examining whether the project outcome which meeting with the original objectives and expected benefits of a project. Therefore, the basis for the validity for performance measurement should be established critical performance criteria (Luu et al., 2008).

The key performance criteria success is to establish the criteria which include a comprehensible, objective, as well as reasonable. The success of optimal performance criteria will not only facilitate the benefit of energy project but examine precisely in project performance (Chan and Chan, 2004). Through determining on the priority of performance criteria, participants of energy project can examine the fulfillment of project ante-objective and the implementation of project performance (Chan and Chan, 2007), which facilitate the government organization in allocating optimal resources. Therefore, the benefit of determining appropriate performance criteria is valuable for executants and project' reviewer to inspect the performance measurement of energy project (Bryde, 2005).

Most previous studies have aimed at using comparative method (Pessemier and Baker, 1971), scoring method (Bedell, 1983; Pinto and Slevin, 1989), economic analysis (Graves and Ringuest, 1991), cost-benefit analysis (Kuwahara, and Takeda, 1990), and decision tree analysis (Faulkner, 1996). Although these research methods which have been applied to examine the performance measurement, it is still not clear for a decision-maker to select the appropriate criteria for performance measurement of the energy projects when confronted with realistic issues.

On the other hand, it should be worth noted that each performance criterion, in fact, should have unique importance of performance criteria in process of performance measurement. However, there are few researches have been worked in performance criteria of energy project, especially such as the importance and priority of impact factors. Therefore, it is so far still not clear that how to evaluate the project performance by applying appropriate performance criteria.

Therefore, the major purpose of present study is to investigate the importance of performance criteria in national energy projects. This study applies the analytic hierarchy process (AHP) to analyze the importance of performance criteria for national energy promotion projects. AHP is suitable for solving the following 12 decision-making problems: (i) setting priorities; (ii) generating a set of alternatives; (iii) choosing a best alternative/policy; (iv) determining requirements; (v) allocating resources; (vi) predicting outcomes/risk assessment; (vii) measuring performance; (viii) designing systems; (ix) ensuring the stability of a system; (x) optimization; (xi) planning; and (xii) resolving conflict (Saaty, 1980). According to the objective of this study, the weights of performance criteria is the issues of setting priorities and resources allocation, which are expected to realize more precisely for decision-maker to allocate national limited resource. Therefore, this study apply AHP to analyze would provide more accurate information for decision maker, as well as the findings of this study would have significant implications for future national energy projects.

METHODOLOGY

This study examines the priority of performance measurement criteria which is a multi-criteria decision making (MCDM) problem. The analytic hierarchy process (AHP), a well-known approach, was applied to solve MCDM problems (Saaty, 1980). The complicated problems can be organized systematically by using AHP, which display the problems in a hierarchy context. The paired comparison questionnaires were designed to calculate the relative weights of each criterion based on the hierarchy structure.

Poh et al. (2001) stated that the advantage of AHP, a qualitative and quantitative approach, was to determine the priority and weight of each performance criteria through paired comparison of attributes. The weights of the performance criteria, therefore, should be considered and further provide priorities for decision-makers to measure project performance and allot limited resources more precisely. Therefore, the AHP approach is applied in this study and the methodology of detailed process is described as following seven steps:

(1) Describe of the evaluation issues

The research issues are the key points of the research discussion and the objective of final evaluation. Therefore, the research issues should be defined specifically to avoid the deviation as much as possible.

(2) Identify all criteria which affect the issues

The related performance criteria should be discussed and selected based on the process of reviewing the relevant literature and interviewing experts. These criteria should also be separated in accordance with the level of internal relevance and individual independence.

(3) Construct the hierarchy structure

A hierarchy structure, in general, can be established from the top through the intermediate levels to the lowest level which usually contains the list of alternatives. In order to lessen the complexity of the consistency, the criteria for each alternative should contain no more than seven elements, and keep independence individually.

(4) Establish the paired matrices for comparison

The criteria within each hierarchy should be evaluated against their corresponding criteria in the level above, and then compared in pairs between themselves. If there are “n” criteria in one hierarchy, decision-makers must conduct paired comparisons by n(n-1)/2. The establishment of paired matrices A lead to determining the weights of the criteria within each hierarchy.

(5) Calculate eigenvectors

The establishment of paired matrixes is used to obtain the maximum eigenvalues which should correspond with eigenvectors.

(6) Consistency test

The purpose of consistency tests is to ensure whether the calculation fit the condition of transitivity in priority. Consistency ratio (CR) is used to verify the credibility and reasonability of evaluation, and to check whether there is inconsistent causality or conflicts in subjective judgments. The CR is acceptable if it does not exceed 0.1 (Saaty, 1980). The definition of consistency index showed as follows:

$$CI = (\lambda_{\max} - n)/(n-1) \text{ , and } CR = \left(CI/RI_n\right) \quad (1)$$

The positive reciprocal matrix generated by valuation yields different consistency index (CI) values at each level. These CI values are called random indexes. The $\lambda_{\max}$ is the maximized eigenvector of a pair-wise comparison matrix. The n is an attribute of the matrix, and RI_n is a random index as shown in Table 1 (Saaty, 1980).

Table 1: Random index

N	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R.I.	0	0.58	0.90	1.12	1.25	1.32	1.41	1.45	1.49	1.54	1.48	1.56	1.57	1.59

(7) Normalization

This study normalized the weight of the interval level and connected the local weight to acquire the global weights of the criteria in each hierarchy after calculating the weights of all criteria.

DATA ANALYSIS

Description analysis

The data collection of this study was worked on the processes of AHP described above. First, the hierarchy structure of this study is made attempt to display research theme itemized through the related literature and experts’ interview. Therefore, hierarchy structure of energy performance measurement can be established into the criteria level and sub-criteria level which are showed in Table 2.

Table 2: Performance criteria of national energy projects

Criteria	Sub-criteria	Description
Research effect	Academic research published	Amount of academic research published
	Patent invention	Amount of patent invention
Industry effect	Firm participation	Number of firm participation
	Firm investment	Amount of Firm Investment
Technology transfer effect	Technology transfer benefit	Number of transfer technology piece
	Technology transfer to Firm	Number of technology transfer to firm
	Technology transfer Income	Amount of technology transfer income
Spillover effect	Energy benefits	Economized energy and creating new energy product application benefit
	Environmental protection benefits	Decrease the degree of CO2 emissions

	Economic benefits	Sum of spillover investment and additional effects
	Creating occupation benefits	Creating occupation opportunity

Subsequently, the AHP questionnaire was transformed into a pairwise comparisons form based on the hierarchy structure of the criteria. The respondents ticked the desired answers from a scale of 1 to 9 for a total of eighteen questions.

The aim of this study is to analyze the performance criteria of national energy projects. Each performance criterion, however, should have unique importance in the performance measurement. Therefore, this study surveyed various experts from distinct fields, such as energy experts who had much experience reviewing energy projects, project leaders who are authorized to execute the energy projects, and public sector's energy experts who had worked for many years in Bureau of Energy, to determine realistic difference weights and priority of performance criteria. As the processes mentioned above, we collected 32 valid questionnaires, response rate was 46.38%, which was showed in Table 3.

In this paper, it should be noted that logical examinations were performed to avoid related errors from the returned questionnaires while we conducted the data analysis. In addition, the consistency ratio was calculated to test the condition of consistency in the data analysis. Finally, none of the results of the consistency ratio exceeded 0.1, which is acceptable. After conducting the consistency test, all the performance criteria were normalized the weight of interval level, which further connected the local weight to acquire each hierarchy of global weights as shown in Table 4 and Table 5.

Table 3: Sampling and data collection

Subject	Initial questionnaires	Usable questionnaires	Response rate
Energy experts	9	9	100%
Project leaders	45	15	33.3%
Public sector's energy experts	15	8	53.3%
Total	69	32	46.38%

Table 4: The weights and ranking of criteria level in energy innovative projects

Subject	Criteria level	Weights	Ranking
Energy experts	Research effect	0.330146	1
	Technology transfer effect	0.278699	2
	Industry effect	0.267081	3
	Spillover effect	0.124074	4
Project leaders	Research effect	0.382336	1
	Technology transfer effect	0.275355	2
	Industrial participation effect	0.244589	3
	Spillover effect	0.09772	4
Public sector's energy experts	Research effect	0.383263	1
	Technology transfer effect	0.250698	2
	Industrial participation effect	0.240628	3
	Spillover effect	0.125412	4
Total	Research effect	0.368321	1
	Technology transfer effect	0.270362	2
	Industrial participation effect	0.251200	3
	Spillover effect	0.110118	4

The Hierarchy Structure Analysis

First of all, this study was conducted to collect information from various groups of respondents as described above. The questionnaires were integrated into depict the importance of each hierarchy criterion. However, the key performance criteria will be changed in different kind of national energy projects, such as energy innovative projects and energy technological R&D projects. Therefore, the hierarchy structure of national energy project can be analyzed as follows:

(1) Criteria Level

Table 4 illustrates a summary of top five criteria form, the initial weights of the criteria of energy innovative projects which were calculated and ranked. As we can observe all of the respondents, the research effect (36.83%) is the most important of performance criteria than technology transfer effect (27.03%), industrial effect (25.12%) and spillover effect (11.01%).

These results implicate that the academic research and patent invention of energy projects are considered as key indicator of national core competition capability. That is, energy technology should focus on the outcome of academic research published and technological patent invention. Therefore, related government organization should pay greater attention to the importance of performance criteria and incorporate this in the content of future energy innovative projects. On the other hand, we also calculated and ranked the initial weights of performance criteria of energy technology research and development (R&D) projects which was showed in Table 5.

Table 5: The weights and ranking of criteria level in energy technological R&D projects

Subject	Criteria level	Weights	Ranking
Energy experts	Technology transfer effect	0.351230	1
	Industrial participation effect	0.268547	2
	Research effect	0.255299	3
	Spillover effect	0.124924	4
Project leaders	Research effect	0.332543	1
	Technology transfer effect	0.319354	2
	Industrial participation effect	0.245748	3
	Spillover effect	0.102355	4
Public sector’s energy experts	Technology transfer effect	0.298692	1
	Research effect	0.290863	2
	Industrial participation effect	0.219380	3
	Spillover effect	0.191064	4
Total	Technology transfer effect	0.323134	1
	Research effect	0.303163	2
	Industrial participation effect	0.251416	3
	Spillover effect	0.122286	4

The finding is that project leaders and public sector’s energy experts highlight the importance of technology transfer effect (29.86%) and research effect (29.08%), rather than industrial participative effect (21.93%) and spillover effect (19.10%). In addition, all respondents consider the spillover effect is little impacts and slight weighs to energy technological R&D projects. The results indicate that governmental organization should encourage the large enterprise transfer internal know-how and unique technique to small and medium enterprises (SMEs), that lack of research and development capability.

(2) Sub-criteria Level

In the hierarchy structure, the nature of sub-criteria is not only simple to realizing but effortless for judging. Similarly, we presented the top five sub-criteria as shown in Table 6 and Table 7.

First, as the Table 6 showed, the accumulated weights of top five sub-criteria are over 72%, that is these sub-criteria should be more stressed than other factors in energy innovative projects. Second, all respondents emphasize on the patent invention of sub-criteria for performance measurement. Overall, the crucial ranking of the performance criteria were patent invention (22.2%), firm participation (15.5%), academic research published (14.5%), technology transfer benefit (10.8%), and firm investment (9.5%).

This results show that in energy innovate projects, all respondents consider the main task is patent invention. The weight of patent invention is higher importance than other criteria. Therefore, the governmental organization should highlight the priority of patent invention to facilitate the benefit of energy innovative projects. Finally, the weights of the top five criteria accumulated over 72.81%. Therefore, the results of top five criteria would have significant representativeness in energy innovative projects.

Table 6: The top five ranking of sub-criteria level in energy innovative projects

Subject	Sub-criteria level	Weights	Ranking	Accumulated weights

Energy experts	Patent invention	0.262484	1	0.723005
	Firm participation	0.152501	2	
	Firm Investment	0.114580	3	
	Transfer technology benefit	0.101052	4	
	Technology transfer to firm	0.092388	5	
Project leaders	Patent invention	0.212831	1	0.734395
	Academic research published	0.169505	2	
	Firm participation	0.128709	3	
	Firm investment	0.115880	4	
	Technology transfer benefit	0.107470	5	
Public sector's energy experts	Patent invention	0.198589	1	0.760582
	Academic research published	0.184674	2	
	Firm participation	0.181526	3	
	Technology transfer benefit	0.115853	4	
	Technology transfer to firm	0.079940	5	
Total	Patent invention	0.222844	1	0.728111
	Firm participation	0.155486	2	
	Academic research published	0.145476	3	
	Technology transfer benefit	0.108591	4	
	Firm investment	0.095713	5	

As the Table 7 illustrated that, energy experts almost pay more attention on the performance criteria of firm participation, patent invention, as well as academic research published in energy technological R&D projects. In addition, the priority of academic research published is more important than the firm investment and technology transfer to firm.

Form the project leaders and public sector's energy experts perspectives, they focus on the priority of patent invention is more significant than other criteria, such as firm participation, technology transfer benefit, academic research published and technology transfer to firm.

Furthermore, the interesting and significant finding is that public sector's energy experts stated the energy efficiency, such as the benefits of energy technology facilitate implementation of economized energy and publicity of energy conservation policy, which have been considered as a critical performance criteria.

In whole, the weights of the top five criteria accumulated over 69.11%, that is, those five criteria should be accented its importance in energy technological R&D projects.

Table 7: The top five ranking of sub-criteria level in energy technological R&D projects

Subject	Sub-criteria level	Weights	Ranking	Accumulated weights
Energy experts	Firm participation	0.153456	1	0.662711
	Patent invention	0.138864	2	
	Academic research published	0.133084	3	
	Firm investment	0.122215	4	
	Technology transfer to firm	0.115092	5	
Project leaders	Patent invention	0.221947	1	0.730515
	Firm participation	0.155784	2	
	Technology transfer benefit	0.134301	3	
	Academic research published	0.110596	4	
	Technology transfer to firm	0.107887	5	

Public sector’s energy experts	Amount of patent invention	0.178600	1	0.665076
	Technology transfer benefit	0.148598	2	
	Firm participation	0.131377	3	
	Academic research published	0.112263	4	
	Energy efficiency	0.094238	5	
Total	Patent invention	0.182276	1	0.691195
	Firm participation	0.152792	2	
	Technology transfer benefit	0.131516	3	
	Academic research published	0.120887	4	
	Technology transfer to firm	0.103724	5	

CONCLUSION

National energy projects play an influential role in national economic development in Taiwan. The purpose of this study is to identity the priority of performance measurement criteria for national energy projects. The key performance criteria are useful for decision-makers to adjust policy, control projects, as well as allocate resources. Therefore, this study applies AHP approach to understand the weights of performance criteria and realize more precisely information for decision-maker to allocate national limited resource in national energy projects.

The empirical findings of this study indicate that performance criteria have significant difference among various experts, as well as the critical performance criteria will be changed in various kinds of energy projects. The most important criterion was research effect in energy innovative projects, as well as technology transfer was highlighted in energy technological R&D projects. These results suggest that the decision-makers in the public sector of government organization should pay greater attention to the priority of performance criteria which have significant difference. On the other hand, the innovative activities, such as implementation of economized energy education and publicity of energy conservation policy, should be considered critical performance criteria of energy projects in the future.

In addition, performance measurement should emphasize the importance of sub-criteria, such as patent invention, firm participation, technology transfer benefits, as well as academic research published. The innovation of energy technology could be considered as a conception of national competitive capability index, which requires the government organization devote a lot of human resource and capital investment to connect related industry realize it exists and gradually helps them to authorize the technology transfer. The scope of energy application should be expanded to general enterprises. Therefore, the concrete energy innovative indexes, such as the benefits of patent invention and critical technology transfer, should be stressed as much as possible.

Finally, for public sector of government organization perspectives, this study provides the priority of performance criteria to help decision-maker to allocate limited resources and national budget in Taiwan. The performance criteria of this study can offer useful reference for evaluating national energy projects, measuring project performance, and enhancing the contribution of efficiency and effectiveness in the whole energy industry.

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