METHODOLOGY FOR THE ASSESEMENT OF CONSTRUCTION R&D RESULT

Seung Heon Han[1], Sang Hyuk Park[2], Myung Jin Chae[3], Ha Na Nam[4] and, Hyoungkwan Kim[5]

ABSTRACT

The public research and development (R&D) funds for construction engineering is one of the key elements for the advancement of construction industry. Korean Ministry of Construction and Transportation is currently planning to increase the amount of annual research funds for construction and transportation engineering from 1% to 3% of its annual budget. This can produce approximately US$ 500 millions of research funds every year in Korea from year 2007. Along with the prospect for increasing R&D investment, there is of increasing pressures on the development of quantitative methodologies for assessing the performance of construction R&D results. Although there have been some general R&D project evaluation methods, they are not readily used for construction R&D research assessment due to the distinct characteristics of construction R&D. This paper presents a new methodology that can make quantitative assessments of construction R&D performances. The proposed methodology is expected to assist government officials in objectively evaluating construction R&D performances and identifying the areas that require more R&D investment.

KEY WORDS

Construction R&D, R&D assessment, Analytical hierarchy process

INTRODUCTION

In year 2004, the size of the Korean construction industry is more than US$100 billion per year (Paek 2005). Along with the recognition of the important roles that the construction industry plays, Korean Ministry of Construction and Transportation is currently planning to increase the amount of annual research funds for construction and transportation engineering

[1] Ph.D., Associate Professor, Dept. of Civil Engineering, Yonsei University, 134 Shinchon-dong, Seodaemun-gu, Seoul, 120-749, Korea, Phone82/2-2123-2799, FAX82/2-364-5300, shh6018@yonsei.ac.kr

[2] Research Assistant, Dept. of Civil Engineering, Yonsei University, 134 Shinchon-dong, Seodaemun-gu, Seoul, 120-749, Korea, Phone 82/2-2123-2799, FAX 82/2-364-5300, cm4park@yonsei.ac.kr

[3] Ph.D., P.E., Senior Researcher, Korea Institute of Construction Technology, 2311, Daehwa-dong, Ilsan-gu, Goyang-si, Gyeonggi-do, 411-712, Korea., Phone 82/31-9100-024, FAX 82/31-9100-411, chae@kict.re.kr

[4] Research Assistant, Dept. of Civil Engineering, Yonsei University, 134 Shinchon-dong, Seodaemun-gu, Seoul, 120-749, Korea, Phone 82/2-2123-2799, FAX 82/2-364-5300, hellohana@yonsei.ac.kr

[5] Ph.D., P.Eng., Assistant Professor, Dept. of Civil Engineering, Yonsei University, 134 Shinchon-dong, Seodaemun-gu, Seoul, 120-749, Korea, Phone 82/2-2123-2799, FAX 82/2-364-5300, hyoungkwan@yonsei.ac.kr

from 1 % to 3% of its annual budget. This can result in an unprecedented level of approximately US$ 500 millions of research funds every year in Korea from year 2007 (Cho 2006). This promising prospect for construction and transportation research area, on the other hand, awakens the strong need for methodologies to objectively and systematically assess the results of construction research and development (R&D) efforts. The performance of construction R&D should be quantitatively measured to assist decision makers in strategically identifying and funding important and beneficial research projects. However, R&D assessment in construction, so far, has been made by subjective opinions of a few numbers of so called “experts”, which has resulted in the lack of consistency and objectivity.

This paper presents a new methodology to assess construction R&D performance in an objective, consistent, and quantitative manner. Based on a statistical approach, the proposed methodology produced a list of performance indicators which allows for quantification of R&D results.

LITERATURE REVIEW

In the United States (US), efforts have been made to objectively assess the performance of government funded programs. After Government Performance Result Act (GPRA) was established in 1993, each government organization has produced performance measures to assess its funded programs. However, the Executive Office of the President of the US (2003) indicated that those performance measures were not well defined and did not function well because they were not well aligned with the government budgeting process. In other words, the assessment results were not properly reflected on the next round of decision making process for budgeting. This low level of usefulness formed the basis for the development of the Program Assessment Rating Tool (PART). The PART is a tool designed by Office of Management and Budget of the US to evaluate the performances of federal government supported programs in an objective and consistent manner. The PART consists of 30 questions in four chapters of the survey form. The first to the third chapters have yes/no questions and the fourth chapter has questions that contain four different answers such as “yes,” “large extent,” “small extent,” and “no.” Scores are summed up such that each chapter’s total score is 100%. Each chapter has a predetermined weight to reflect its relative importance on the final total score. Budget decision makers can use the total scores calculated in this way to assess the performances of government programs into five categories: effective, moderately effective, adequate, results not demonstrated, and ineffective.

As an attempting to assess the performance of construction R&D, Korean Institute of Construction Technology (KICT) have used three major evaluation criteria: how much economic benefit is obtained, how well the project results fit into national policy objectives, and how much knowledge is produced (KICT 2005). One of the key characteristics of the KICT method is that the estimated economic benefit is used to derive the impacts of the research against the other two criteria. That is, there exist predetermined portions, determined by a group of experts, for the three criteria. Thus, if the economic benefit is estimated, then the other two benefits can easily be estimated according to the proportion.

The proposed methodology uses a statistical approach based on relative comparisons with other research projects. This approach can assess each research project objectively, reducing the exposure to human experts' subjectivity. In addition, unlike the PART, the proposed methodology has evaluation criteria tailored to satisfy the specific needs of construction industry. The proposed methodology is superior to the KICT method in the sense that the former generates separate indicators for knowledge accumulation and policy fitness criteria, whereas the latter bases the research performance in knowledge accumulation and policy fitness criteria on that of the economic benefit criterion.

PERFORMANCE EVALUATION CRITERIA

The Korean Ministry of Science and Technology (MOST) developed the list of evaluation criteria for assessing national R&D investment results (MOST 2005). Since the list was created based on general science and technology, it cannot address the unique characteristics of the construction industry and technology. The Korean Science and Technology Policy Institute (STEPI) also made an effort to define the categories of construction research project objectives (STEPI 2005). In this paper, the MOST list and the STEPI classifications were used as a basis to develop the list of evaluation criteria for construction R&D performance.

To reflect the inherent uniqueness of construction R&D, the authors held a brainstorming session to identify the MOST evaluation items that are relevant to construction industry and to add construction industry-specific evaluation items that can deal with labour shortage problem, safety issues, etc. The preliminary list of evaluation items determined in this way was distributed to seven experts who have sufficient experiences in construction R&D assessment, including university professors, industry researchers, and a consultant. Their valuable comments were incorporated into the final R&D evaluation list.

PROPOSED METHODOLOGY

In the proposed methodology, the performance evaluation criteria were derived from two main perspectives: research objectives (Table 1) and performance area (Table 2). Research objectives means what the research and development project is intended for, whereas performance area denotes the area on which the research results can have an impact. By combining these two perspectives in a matrix form (Figure 1), the list of evaluation criteria were easily obtained.

As previously mentioned, the STEPI made an effort to classify construction research objectives into the following five categories: product (component technology) development, process development, specification development, standardization, and policy making. Examples of the product (component technology) include the developments of new construction materials, new construction machines, and new computer software tools. Process development means new construction, design, or planning methods. Specifications denote new construction manuals or guidelines that are adopted for regulation purposes, while examples of standardization include the standardization of construction machines parts, construction material size, and construction information data structure for the purpose of effective communication. Policy making category evaluates how much positive impact the research results have on governmental decision making process.

Table 1: Research objectives description (STEPI 2005)

Research objectives	Descriptions
Product (component technology) development	The research aims to develop a certain component construction technology.
Construction process development	The research aims to develop a new design and construction procedure.
Specification development	The research aims to develop a new construction specification.
Construction standardization	The research aims to standardize construction activities and processes.
Governmental policy making	The research aims to assist in developing new governmental policies.

Table 2: Performance area description

Performance area	Descriptions
Productivity	How much productibity increase can be made as a result of the R&D result?
Knowledge	How much new knowledge has been discovered as a result of the R&D result?
Education	How many high-quality construction engineers has been produced?
Public service	How much contributions have been made for the well-being of the general public?

Associated with the research objectives, performance area consists of four categories: productivity, knowledge, education, and public service (Table 2). Productivity is defined in a broad sense such that examples of productivity increase include labor hour savings, cost savings, and time savings. Knowledge discovery or accumulation can be represented by the number of academic papers and patents obtained through the researches. The educational aspect of the research can be evaluated by the number of engineering doctors and masters produced and by the number of lectures or training programs hosted, through the research projects. Public service is a category that is hard to be defined but very important, particularly in the area of construction industry. Examples of public service include whether or not the new product can be reflected in governmental policies and whether or not the new technology can satisfy a nationwide safety specification.

Performance area / Research Objectives	Productivity	Knowledge	Education	Public service
Product	cost savings time savings …	Papers patents …	Field training …	Spec. satisfaction …
Process	cost savings time savings …	Papers patents …	Engineering consulting …	Spec. satisfaction …
Specification	facility life span increase …	Seminars …	PhDs Masters …	Influence on policies …
Standardization		Seminars …	PhDs Masters …	Influence on policies …
Policy		Seminars …		Influence on policies …

Figure 1: Framework for construction R&D

Figure 1 illustrates the matrix form that combines research objectives and performance area. The matrix form is the framework through which a number of evaluation criteria for construction R&D assessment are determined. Currently, the proposed methodology has a total of 37 evaluation criteria. The following paragraphs show how to calculate the quantitative indices for assessing the performance of a construction R& D project.

Step 1: Statistical analysis and scoring

For each evaluation criterion, statistical baselines need to be calculated in order to assess the particular construction R&D project. Mean, maximum, minimum, and standard deviation are first calculated from the population to understand the statistical distribution of R&D projects for the particular evaluation criterion. If the value for the evaluation criterion of the R&D project of interest falls into top 25% of the population, the R&D project obtains score 3 for the particular evaluation item. If the value is between top 25 to 75%, the R&D project obtains score 2. If the value falls into bottom 25%, score 1 is given to the R&D project. Here, the statistical distribution is derived only for those projects that have non-zero values in the particular evaluation criterion. For example, if a certain R&D project produces zero publication for academic publication criterion, then the project is excluded from being used for the statistical distribution estimation of the population. This is to make sure that the project with zero publication obtains zero credit for the evaluation criterion. Total 218 construction research projects, which have been conducted from 1994 to 2005, are being used to test the validity of this statistical approach.

Step 2: Adjusting scores for constant sum scale

The evaluation framework has 20 sectors (5 types of research objectives times 4 performance areas). As illustrated in Figure 1, those sectors can have different numbers of evaluation criteria. However, in this stage, it is difficult to say that one performance area (e.g. productivity) is more important than another (e.g. knowledge). Therefore, it is assumed that each sector has the same amount of total score (100 points), irrespective of the number of evaluation criteria that belong to each sector. To realize this idea, the following equation is applied:

$$k_i = \frac{100}{n} \qquad \text{(eq. 1)}$$

Where k_i is the weight of each evaluation criterion and n is the number of evaluation criteria for the particular sector. Then, the performance index for each sector is calculated by the following equation:

$$S = \sum_{i=1}^{n} k_i \bullet f_i \qquad \text{(eq. 2)}$$

Where f_i is the score that was calculated for each evaluation criterion based on where the particular R&D project is located in the context of the statistical distribution of the population. The performance index S is the sum of k_i times f_i. When the maximum value of the assessment sector is always constant (e.g. 100), it is called “constant sum scale.” Since this methodology uses the constant sum scale, experts’ opinions are later incorporated to reflect relative importances of different performance areas, using the Analytical Hierarchy Process (AHP).

Step 3: Applying AHP on performance area

Finally, weights developed by AHP method are applied to the performance area to consider their relative importance as follows:

$$RPI = \sum_{j=1}^{m} S_j \cdot w_j \qquad \text{(eq. 3)}$$

Where RPI (Research Performance Index) is the total index for the particular R&D project, m is the number of sectors for the particular project (i.e. 4), S_j represents the summation of each sector, and w_j is the weight calculated by the AHP for each sector.

ILLUSTRATIVE EXAMPLE

The proposed methodology was applied to a construction R&D project that has "product development" as the research objective. First, 218 construction R&D efforts were evaluated against the 37 evaluation criteria, which led to the determination of 37 value distributions. Then, using the AHP, three experts in construction R&D assessment came up with the relative weights for the four performance area: productivity (0.615), knowledge (0.126), education (0.207), and public service (0.052). Individual weights of each sector for the four performance area are determined from dividing 100 % by the number of evaluation criteria of each sector: productivity (100/10=0.1), knowledge (100/9=0.11), education (100/7=0.14), and public service (100/6=0.17). The performance of the R&D project was evaluated against the 12 evaluation criteria for which the R&D projects had some performance values. Table 3 shows the Research Performance Index (RPI) calculation example.

Table 3. Research Performance Index Calculation Example

Performance Area (w_j)	Performance Indicators	k_i	Value distribution			Example Results			
			1 (0 – 25%)	2 (25–75%)	3 (75–100%)	Value	f_i	$k_i * f_i$	w_j*(k_i* f_i)*100
Productivity (0.615)	Cost savings	0.10	≤ 3,000	3,001 - 653,107	≥ 653,108	48,000	2	0.20	12.30
Knowledge (0.126)	Domestic conference papers	0.11	≤ 2	3 – 6	≥ 7	6	2	0.22	2.77
	Domestic journal papers		≤ 2	3	≥ 4	4	3	0.33	4.16
	International journal papers		≤ 1	1	≥ 2	2	3	0.33	4.16
	International conference papers		≤ 1	1	≥ 2	2	3	0.33	4.16
	Seminars		≤ 1	2	≥ 3	1	1	0.11	1.39
Education (0.207)	PhDs	0.14	≤ 1	1	≥ 2	2	3	0.42	8.69
	Masters		≤ 1	2 – 8	≥ 9	7	2	0.28	5.80
	Bachelors		≤ 1	2 – 5	≥ 6	8	3	0.42	8.69
	Education		≤ 1	1	≥ 2	1	2	0.28	5.80
	Technology transfer		≤ 1	2 – 3	≥ 4	5	3	0.42	8.69
Public service (0.052)	Influence on policies	0.17	≤ 1	2	≥ 2	5	3	0.51	2.65
Research Performance Index		69.26							

CONCLUSION

So far, construction research performance assessments have too much relied on a few number of experts' qualitative opinions. This often has made it difficult to consider all the important factors of research, often resulting in inaccurate evaluations. To overcome this problem, this paper presents a new methodology that can provide an objective and quantitative evaluations of construction research. First, based on the combination of two major perspectives (research objective type and performance area), the list of evaluation criteria were determined. Then, to provide a reasonable score for each evaluation criterion, the statistical distribution of the population was considered. Currently, this statistical approach is being applied to 218 construction research projects for testing its validity and usefulness. In addition, this methodology has its evaluation criteria tailored to fulfill the specific needs of construction industry.

Further works will concentrate on the following issues. First, the weights for different performance areas or different research objectives need to be refined by more experts using the Analytical Hierarchy Process. This task is essential to represent each performance area's (or research objective types) relative importance. Second, a complete analysis of the 218 research projects, using the proposed methodology, need to be conducted to show which project has highest index and which project needs more research investment. Finally, efforts need to be made to understand how this proposed methodology-based evaluation results can be connected to the governmental research budgeting process.

ACKNOWLEDGEMENTS

The authors wish to thank the Korean Ministry of Construction and Transportation for providing the funding that made this study possible.

REFERENCES

Cho, Dae Yeon (2006) "Prediction and Trends of Construction Research and Development in Korea," 22nd Construction Management Forum, Korea Institute of Construction Engineering and Management, Seoul, Korea, Feb. 2006.

H. A. Bassioni, A. D. F. Price, and T. M. Hassan (2004) "Performance Measurement in Construction," *journal of Management in Engineering*, 20(2)

KICT (2005) *Investigation and Analysis: KICT R&D Performance Assessment*, KICT (Korea Institute of Construction Technology), Korea

Ko, Young Sun, Yun, Hee Suk, and Lee, Chu. Ho (2004) "Performance Management for Non-profit Organization," Korea Development Institute (KDI), pp 207-216

Lee, Bang Rae, Lim, Dae Hyun, Jung, Hye Sun, and Bae, Young Mun(2004), "Study on National Innovation System and R&D Performance Indicators," KISTI (Korea Institute of Science and Technology Information), Seoul, Korea, pp43-48.

Michail Kagioglou, Rachel Cooper, and Ghassan Aouad(2001), “Performance management in construction: a conscptual framework”, *Construction Management and Economics*, 19, 85-95

Ministry of Construction and Transportation (MOCT) (2003) *Construction R&D Performance Assessment*, MOCT, Korea, pp167-176

Ministry of Science and Technology (2005) *Instructions for Assessing National R&D Projects for Year 2006*, Korean Ministry of Science and Technology, Seoul, Korea.

Niven, P. R. (2003) “Balanced Scorecard Step by Step for Government and Nonprofit Agencies,” New York: John Wiley & Sons

Paek, Sung Jun (2005) *Prediction of Korean Construction Market in Year 2005*, Construction and Economy Research Institute of Korea, < http://www.cerik.re.kr/>. Feb. 2006.

Shon, Byung Ho(2004) *Research and Development Program Assessment of U.S. Federal Governments*, Science and Technology Policy Institute, Seoul, Korea.

STEPI (Science and Technology Policy Institute) (2003) *Construction R&D Performance Assessment Methods*, Ministry of Construction and Transportation, Korea, pp 47-48.

STEPI (Science and Technology Policy Institute) (2005) *Construction R&D Performance Assessment by Project Types*, Ministry of Construction and Transportation, Korea, pp 188-190.