Ex ante Evaluation Framework for R&D Program: Exercises from Korea Government

Sang-Jin Ahn and Yoon Been Lee

***Abstract*—This work includes *ex ante* evaluation framework for R&D program, especially focused on R&D subsidy in Korea. To help implementing the framework, the analytical structure for decision making, recommended range of weights, checklists for analyzing logical linkages and rationales of the examined R&D program, and recommended scope of benefits are described, and brief guidelines for their use are offered. Although it is a kind of examples in public sector, the concept and analytic methods can be applicable in the other field.**

***Index Terms*—*Ex ante* evaluation, R&D program, logic analysis, economic analysis, multi-criteria decision making**

I. Introduction

Preliminary feasibility study (PFS), a specialized version of *ex ante* evaluations in Korea, was introduced in 1999 in an effort to encourage a cautious approach to new large-scale projects, with budgets of over 50 billion Korean won and governmental burden of over 30 billion Korean won, by enhancing the efficiency of fiscal investment. The feasibility of examined program could be demonstrated when the cost-benefit (B/C) ratio is higher than 1 but the concept of such feasibility has limitations.

B/C analysis have a destructive error to reduce what we do to what we can measure, rather than improve the quality of measurement. The whole cost may be underestimated easily, when a program has unclear boundaries of intervention, succumbs to opportunistic encouragement, or plans to be built on existing and available resources.

To overcome these limitations, multi-criteria decision making was introduced in 2001. In this stage, the concept of feasibility was expanded by synthesizing feasibility of economic analysis and policy analysis. Analytical Hierarch Process (AHP) [1], one example of multi-criteria decision making, is useful for helping expert judgment and synthesizing their judgment of each item. The AHP could calculate the degree of feasibility from 0 to 1. The feasibility could be demonstrated, when the estimated degree is higher than 0.5. Nevertheless the B/C ratio remains more essential because cost inclusive evaluations are believed to provide not only important information on program cost but also insight into program goals and effects [2]-[3].

PFS on R&D program was tried in 2006 and mandated in 2008. Before that time, the most part of investigated programs was construction-based project. Contrary to PFS on construction-based project, the result of economic feasibility analysis on R&D program did not include much information on examined program. It was another challenge for the feasibility concept based on cost-benefit analysis. The previous study [4] proposed it as a solution to include technological feasibility analysis into class 1 item of AHP analysis and spillover analysis into economic analysis. It was quite useful but controversial in that the concept of technological feasibility was recognized as vague and spillover analysis usually overestimate real value.

This work includes a step forward concerned with such useful but controversial solutions. The vague concept of technological feasibility is broken by common main issues and checklists, and then logic analysis [5] helps each broken analysis of items to correlate with real value of examined program. It is also discussed whether spillover analysis have an effect on decision-making by simple statistics.

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II. Process of Analysis

The minimum 6 steps are required in PFS as follows.

A. Complete Program Plan

Although the level of concreteness can be diverse in the planning stage of R&D, it is prerequisite for PFS preparing complete program plan. It is believed as common components for completed plan why program should be promoted, what the scope of program is, how program can be effective, and who is responsible for program.

B. Identify Issues

Almost the issues of every investment program could conclude in whether examined program is worthy of investing or not. The general-purpose measures of them are cost-inclusive metrics, such as break-even point, NPV, IRR, and B/C ratio but it can sometimes bring controversy to apply cost-inclusive metrics into R&D program. Therefore it may be right strategy identifying the whole impact of the proposed program and every required resource for it at this stage.

C. Correlate Issues with Analytic Items

Uncovered issues cannot deduce any implication as a sole. To make a correct decision, the identified issues should be correlated with criteria for evaluation. The previous work [4] showed what criteria for evaluation are in PFS on R&D program, but it remained as black box how to correlate the criteria for evaluation with the identified issues. Table 1 and 2 helps to understand how uncovered issues are mapped into

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analytic items and real value on the basis of the 84 cases reported.

D. *Analyze and Evaluate Each Item*

After correlating issues with analytic items, the subject of feasibility has been simplified for each suitable expert. The participated experts make a judgment based on heated discussions and evidences from analysis. The rigorous analysis is needed to prevent personal opinion from distorting a whole decision.

E. *Synthesize Expert Judgment of Each Item*

The whole analytic items are illustrated in Fig. 1. After completing every analytic item analyzed and discussed, scores of each expert judgment are synthesized by AHP.

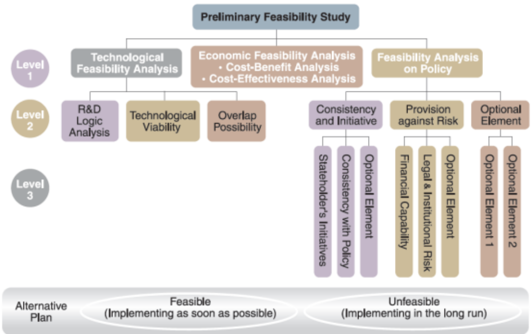

Fig. 1. Hierarchical structure of PFS for R&D program.

F. *Finalize and Report*

When conclusion is reached, the feasibility of examined program can be express as representative scores of AHP. Final version of PFS report should include AHP score, total cost for program, and recommendation for policy. If cost-benefit analysis is possible, B/C ratio is also included.

III. Analytic Framework

Decisions regarding what should be developed as evaluation criteria and how to be weighed is important. The criteria for evaluation were established by feasibility analysis on economic aspects and policy, according to the general guidelines [6]. Technological feasibility analysis is a heritage from trial version of PFS on R&D program [4]. Accordingly hierarchical structure of PFS for R&D program results in Fig. 1 and the identified issues for feasibility study can be correlated to the evaluating criteria by using TABLE I.

The recommended weights have limited ranges between 40% and 50% for economic feasibility analysis, 25% and 35% for feasibility analysis on policy in the conventional investment programs. Weights of other investment programs may have different ranges; between 25% and 50% for economic feasibility analysis; 50% and 75% for feasibility analysis on policy. Accordingly, the weights of evaluation criteria in R&D programs should exist between conventional program and other investment programs. This recommended range of weight can make future decision-makings consistent with the previous ones.

A. *Technological Feasibility Analysis*

Technological feasibility analysis can be understood as a specialized version of policy analysis for science & technology. For implementing PFS, technological feasibility analysis is assumed to consist of *R&D logic analysis* and the occurrence of complementary factors, *technological viability*, and *overlap possibility*.

TABLE I: Correlations Between Issues and the Evaluating Criteria

Main issues in feasibility study	A 1	A 2	A 3	B 1	B 2	C
Are issues clearly addressed in the program?	o					
Will this be the best strategy for the issues?	o					
If it is delayed, can any severe problems emerge?	o	o				
Are participants and their interests investigated beforehand?	o		o			
Are outcomes illustrated in detail and is it possible for them to be controlled?	o					
Is the process of planning comprehensible to taxpayers?	o			o		
Can the proposed activities contribute to attaining the program objective?	o					
Do risks fall within permissible levels?	o	o			o	
What makes the proposed program valid?	o					
Is the program cost estimated economically?	o		o			o
Are additional values identified with certainty?	o					o
Do resources lead to the expected outcome in a way that can be concretely demonstrated?	o					
Is the validity of the program presented in a clearly comprehensible manner?	o					
Is every assessment within the program balanced, objective, and transparent?	o					
Why should the central administrative agency support the program?	o			o		

A : Technology feasibility analysis
1. R&D logic analysis 2. Technological viability
3. Overlap possibility
B : Feasibility analysis on policy
1. Consistency and initiative of program 2. Provision against risk
C : Economic feasibility analysis

R&D logic analysis includes the whole framework for logical linkages and rationales of the examined R&D program; therefore, it is certain that this type of plan contains plentiful information from three areas of technological feasibility. It can explain what proposed program is, why proposed program is valid, how investment results in desired outcome, and who private or public beneficiaries are. Thus concrete plan can be understood as logic analysis on R&D program.

Technological viability, the first of the complementary factors, can sift out non-competitive and immature budget-consuming programs. This factor consists of two elements: trend analysis and technology competitiveness analysis. Trend analysis measures technology maturity for investment and technology competitiveness analysis evaluates the competitive position of principal research agents. Detailed analytical methods for viability rely on scientometrics and expert judgments.

Overlap possibility, the second of the complementary factors, can be useful for identifying delivery systems similar to the examined program, even if the viability of the program is justified. It can be understood as redundancy analysis and focuses on more economical structure on examined programs including do-nothing case.

B. Feasibility Analysis on Policy

Feasibility analysis on policy is identical to general guidelines [6]. The consistency and initiative of program help to understand the position of examined programs in the whole governmental policy, and risk analysis can help to identify risk included in examined program.

C. Economic Feasibility Analysis

The general guideline prescribed that cost-benefit analysis is the sole measure for economic feasibility analysis [6]. This principle needs to be redefined in PFS on R&D program, because of partial permission of spillover effect. The disciplines are that multiple measures of prospective impact analysis cannot be used in economic feasibility analysis and that cost-benefit analysis is the prime methods for economic feasibility analysis. These extended disciplines accommodate spillover analysis in a balanced way and keep consistency in decision-making.

IV. Logic Analysis

Logic analysis is useful for obtaining a clearer understanding of the intervention's strengths and weaknesses, and for analyzing whether the intervention is designed in a way that can logically produce the desired results [7]. Furthermore, this process permits evaluators to assess the strength of the causal link between the intervention and its intended effects.

Logic analysis for PFS on R&D programs starts with identifying potential outcomes of the examined R&D program. Since the most important effects from R&D activities can be understood as technological spillovers, it is useful to distinguish several different mechanisms by which R&D generates spillovers, which are classified desperately into knowledge spillovers, market spillovers, and network spillovers [8].

Knowledge created by one agent can be used by another without compensation, or with compensation less than the value of the knowledge. The spillover beneficiary may use the new knowledge to copy or imitate the commercial products or processes of the innovator, or may use the knowledge as input to a research process leading to other new technologies. This can occur in obvious ways, such as "reverse engineering" of products, and in less obvious ways, such as when one firm's abandonment of a particular research line signals to others that the line is unproductive and hence saves them the expense of learning. The publication of scientific papers is intended to spread new knowledge so that the widest possible audience can use it, and society requires disclosure of new knowledge as quid pro quo for the granting of monopoly rights in the commercial use of an invention. The effect of this disclosure is, in principle, to make the new knowledge available to others for facilitating new and different applications, while at the same time protecting the inventor against imitation. Even if an inventor wishes to prevent the spread of new knowledge, development and use of new knowledge will tend to cause it to spread. Economic exploitation of new knowledge requires the sale of new products or the incorporation of new processes into commercial use. Such commercialization tends, in general, to reveal at least some aspects of the new knowledge to other economic agents. Hence, the very process of economically exploiting the knowledge that research creates tends to pass that knowledge to others. These knowledge spillovers are known to be measurable but not monetized. Accordingly, when the principal outcomes of a program become knowledge spillover, E/C analysis, rather than B/C analysis, should be considered as a measure for economic feasibility analysis of PFS.

Market spillovers result when market operations for a new product or process cause some of the benefits thereby created to flow to market participants other than the innovating firm. It is this "leakage" of benefits through the operation of market forces, rather than the flow of knowledge itself, that distinguishes market spillovers from knowledge spillovers. Any time a firm creates a new product, or reduces the cost of producing an existing product, the natural operation of market forces will tend to cause some of the benefits thereby created to be passed on to buyers. Of course, innovation often results in both higher quality and lower prices; thereby benefiting customers even more. These market spillovers are known to be both measurable and monetized, thus B/C analysis should be considered as a measure for the analysis of the economic feasibility of PFS.

Network spillovers result when the commercial or economic value of a new technology is strongly dependent on the development of a set of related technologies. If the commercial payoff to each of a set of related research projects is dependent on all, or a significant fraction of, the projects being completed successfully, then private firms might hesitate to undertake any one of the projects, for fear that the others will not be undertaken. Conversely, if any one firm decides to undertake such a project, it creates a positive externality for all the other firms, by increasing the probability that the critical mass will be achieved. Where network externalities are important, it is possible that the inability of firms to coordinate their efforts will lead to a misdirection of research effort, away from the activities associated with network externalities, even if firms are, in the aggregate, undertaking a socially efficient level of research effort. Since these network spillovers are acknowledged, they can be considered special considerations for the policy analysis of PFS

Three types of R&D spillovers are summarized in Table 2, with recommendations for their corresponding applications to PFS. Among these, market spillovers warrant further discussion, since baselines for the B/C ratio can usually be emasculated by overestimated benefits from pseudo-market spillovers, unjustifiable wishes, and exaggerated attributions of the examined R&D program. Since some proposed programs, whose B/C ratio is above 1, tend to be acceptable easily, it is not uncommon for applicants to intentionally create knowledge spillovers, network spillovers, or other stimulated effects monetized for the purpose of elevating the B/C ratio. Accordingly, to prevent incredible estimates of program benefit, benefit criteria for B/C analysis are summarized in Table 3. The primary target for logic analysis on R&D program is identifying a suitable category for intrinsic values of the proposed one.

TABLE II: CLASSIFICATION OF R&D SPILLOVERS AND RECOMMENDATIONS*

Category	Definitions and Examples	Recommendations
Knowledge Spillovers	Knowledge created by one agent is used by another without full compensation. 1) Reverse engineering of products 2) Firm abandons R&D effort but related knowledge is accessible to other economic factors 3) Publications 4) Patent disclosures 5) Researcher mobility	Applied to E/C anal ysis, only if it is reas onably calculable an d contributes to prog ram objectives.
Market Spillovers	Market dynamics cause some of the benefits for a product or process to flow to market participants other than the innovating firm. 1) Prices for a new or improved product do not fully capture its superior quality or performance relative to what was available before. 2) Lower production costs lead a company to lower its selling price, benefiting the customer.	Applied to B/C anal ysis, only if it is calc ulable reasonably an d contributes to prog ram objectives.
Network Spillovers	Network spillovers arise if the economic value of a new technology is an increasing function of the development of a set of related technologies. 1) A "coordination problem" is overcome, whereby firms coordinate their efforts for a larger cause. 2) A sufficient fraction of a set of related research projects is completed to create a critical mass necessary for increasing commercial payoff.	Applied to the speci al considerations of policy analysis, not t o economic analysis.

*The classification of R&D spillovers is inherited from reference [8].

TABLE III: BENEFIT CRITERIA FOR B/C ANALYSIS [9]

Category	Include in B/C	Exclude in B/C
Increase in benefits	1. Value added by ado pting new technologi es into new product. 2. Value added by tech nology transfer.	1. Knowledge spillovers 2. Network spillovers 3. Regional development 4. Enhancing market power 5. Enhancing national presti ge 6. Other stimulated effects
Decrease in cost	1. Cost savings in time and resources for production or research 2. Reduction of social cost from natural disa sters, diseases, and e nvironmental polluti on.	

The validity of the examined program can be demonstrated by detailed logical flows of it. *R&D logic analysis* includes the whole information about them and the schematic diagram for logic model is illustrated in Fig. 2. The indispensible components for concrete plan are expressed by (a) to (d), and their practical checklists are summarized in the TABLE IV.

1) proper planning process
2) proper objectives
3) proper logistics
4) proper delivery system

TABLE IV: CHECKLISTS FOR R&D LOGIC ANALYSIS**

Elements	Assessment Questions
(a) Proper Planning Process	1. Did specific experts, criticized as restricted or unsuitable, participate in planning the R&D program?
	2. When the program was planned, was the priority setting suitably applied for technology selection?
	3. Were technological demands investigated as they related to the program subject?
	4. Was planning completed before PFS?
(b) Proper Objectives	1. Is it clear why and how the R&D program was promoted?
	2. Are those who benefit from the R&D program outcome targeted?
	3. Are issues discovered by appropriate surveys or experts' experiences?
	4. Are there clear rationales between program objectives and corresponding issues?
	5. Are the potential improvements offered by the program presented clearly?
	6. Are there any balanced measures for identifying program objectives?
	7. Are proper baselines established for evaluating program performance?
	8. Is there a rational priority decision model for investigating detailed activities in the program?
	※ Optional question 1 (in case of R&D subsidy): Are various strategies reviewed before considering a national R&D program?
	※ Optional question 2 (in case of system development): Are mission and concept designs completed in comprehensive way?
(c) Proper Logistics	1. Can detailed activities contribute to attaining program objectives? (Has a rational WBS been applied to program?)
	※ Optional question 3 (in case of system development): Is WBS composed comprehensively according to core technology?
	※ Optional question 4 (in case of research facilities and equipments): Are research facilities and equipments mission-oriented, effective, and systematic?
	2. Is the WBS dictionary appropriate?
	3. Are there any performance-indexes for detailed activities? Are they specific, measurable, attainable, realistic, and timely?
	4. Is time spent for detailed activities estimated practically?
	5. Are there any logical errors in the schedules?
(d) Proper Delivery System	1. Are central administrative agency's roles delegated by law?
	2. Are balanced standards applied to choose the principal research institute?
	3. Is the program's management system efficient? Does it enable attainment of objectives?

**It has been developed on the basis of reference [10] and [11].

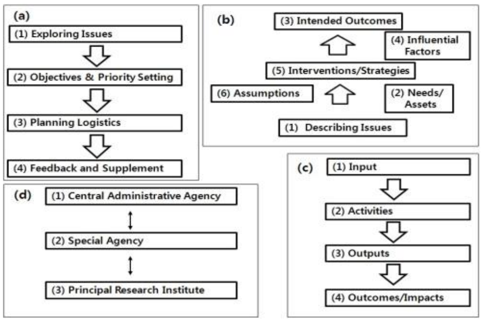

Fig. 2. R&D logic analysis

V. Discussions

A. Premises

AHP can be understood as expert judgments supported by objective and balanced analysis. Accordingly, it is important 'who is participated' and 'what is basis for judgment'. To make a further discussion, we assume economists as major experts participated. When cost-benefit analysis becomes the unique measure for economic feasibility analysis, it is assumed to be judged by major evidence.

B. Statements of Investigation

After the assumptions are conceded, we can study experts' behavior by their backgrounds and basis for judgments. We want to verify two hypotheses.

Hypothesis 1)

The judgment of major experts is identical regardless of background.

Hypothesis 2)

The role of major evidence for judgment is identical to other evidences.

C. Simple Statistics

One way ANOVA analyses are performed at both accepted cases and rejected cases separately. The results are summarized in TABLE V. It implies that major experts tend to behave different from minor ones in accepted cases and that major evidences have a different role in rejected cases. Since only 84 cases are not enough to give a conclusive result, it tends to be robust at the beginning stage.

TABLE V: Checklists for Analyzing Concrete Plan

	Accepted Cases		Rejected Cases	
	F-number	Prob. > F	F-number	Prob. > F
Experts	15.74	0.0002	0.04	0.844
Evidence	0.5	0.4841	6.05	0.0212

VI. Conclusions

We proposed *ex ante* evaluation framework for R&D program, especially focused on R&D subsidy in Korea. The analytical structure for decision making, recommended range of weights, checklists for analyzing logical linkages and rationales of the examined R&D program, and recommended scope of benefits are described and brief guidelines for their use are offered. Simple statistics have revealed some tendency of experts' behavior, which imply the effect of applying the analytic framework, as follows:

1) There is not enough information to determine which expert group or evidence is more suitable.
2) Although there is no difference between expert groups in rejected cases, major expert group exhibit differently in accepted cases.
3) Programs, with B/C ratio lower than 1, can be distinctly recognized as infeasible, but B/C ratio higher than 1 cannot guarantee program's feasibility.

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