Ex-ante Evaluation System of Government R&D Programs in Korea

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Abstract

Since 2008, the Korean government has employed the preliminary feasibility study (PFS), an ex-ante evaluation, to enhance the efficiency of fiscal management in large-scale government research and development (R&D) programs and to determine whether to invest in each R&D program. Most PFS results are directly reflected in budget formulations, making the PFS an important step in budgetary decisions. The PFS has been developed and improved as a comprehensive evaluation system of R&D program proposals in terms of technology, policy and economics. Over the past 10 years, 66.2% of R&D programs and 37.4% of program budgets have passed the PFS. The PFS has contributed to enhanced fiscal efficiency in public investment by preventing non-feasible programs from being launched. This paper explains the framework, methodologies, results, and issues of the PFS on R&D programs in Korea.

Keywords: ex-ante evaluation, preliminary feasibility study, government R&D program, logic model, R&D budget

1. Introduction

It isn't easy to predict the results or effects of any work. Prediction is even more difficult if this is the first time the work is being attempted. Not being easy, however, will not stop the continuing attempts to forecast the future. The ex-ante evaluation is part of this effort to predict what will happen as the result of any intended work.

In the second half of 1997, South Korea suffered a financial crisis and received bailouts from the International Monetary Fund (IMF) (Kim, 2000; Chopra et al., 2001). In the wake of the financial crisis, the issue of fiscal soundness became an important policy agenda. To enhance the efficiency of public investment management (PIM), in 1999 the Korean government adopted the preliminary feasibility study (PFS), an ex-ante evaluation, for newly proposed large-scale projects with budgets of more than 50 billion Korean won (KRW) (about 45 million USD), including more than 30 billion KRW in central government expenditures. The National Finance Act of 2006 provides the legal basis of PFS. The PFS aims at improving the efficiency of fiscal management and preventing budgetary waste through a careful decision on whether a large-scale fiscal project will be implemented (MoSF, 2014). Initially, the PFS focused on economic infrastructure and has expanded to social infrastructure and non-infrastructure (e.g. R&D, welfare) programs.

Korea has become the world's most research-intensive country. In 1999, Korea's investment in research and development (R&D) totaled 2.07% of its gross domestic product (GDP), just below the average for

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nations in the Organization for Economic Co-operation and Development (OECD) (Zastrow, 2016). In 2015, however, that figure had increased to 4.23%, which was ranked first in the world (MSIP and KISTEP, 2017). The Korean government has more than tripled the R&D budget from 5.7 trillion KRW in 2001 to 19.6 trillion KRW (about 17.8 billion dollars) in 2017. From the middle of 2000, the Korean government began to take an interest in raising the efficiency of government R&D investment.

In 2008, the PFS was introduced to newly proposed large-scaled, long-term R&D programs also (Lee and Park, 2011; Ahn, 2017), making 2017 the 10th year since the PFS was employed in government R&D programs in Korea. The fundamental purpose of PFS is to provide important information to help the Ministry of Strategy and Finance (MoSF), the government fiscal authority, to decide whether to implement R&D programs proposed by government ministries. MoSF can make an informed decision based on results of the PFS for each R&D program proposal. Only the programs that pass the PFS qualify for a budget investment. In addition, the PFS also improves an R&D program proposal by complementing small drawbacks of the program during the PFS process (Kang, 2012). Korea Institute of Science & Technology Evaluation and Planning (KISTEP) has played the key role of PFS of R&D programs.

The PFS of R&D programs is an ex-ante evaluation performing in points of views of technology, policy, and economics. In general, the ex-post evaluation focuses on measuring the final outcomes and performance of a project, whereas the ex-ante evaluation is used to evaluate mainly why the project should be implemented and what the project aims to do (Bulathsinhala, 2015). Because the PFS is applied to R&D programs before the programs begin, it is more difficult to evaluate the future performance in an ex-ante evaluation than the actual performance in an ex-post evaluation.

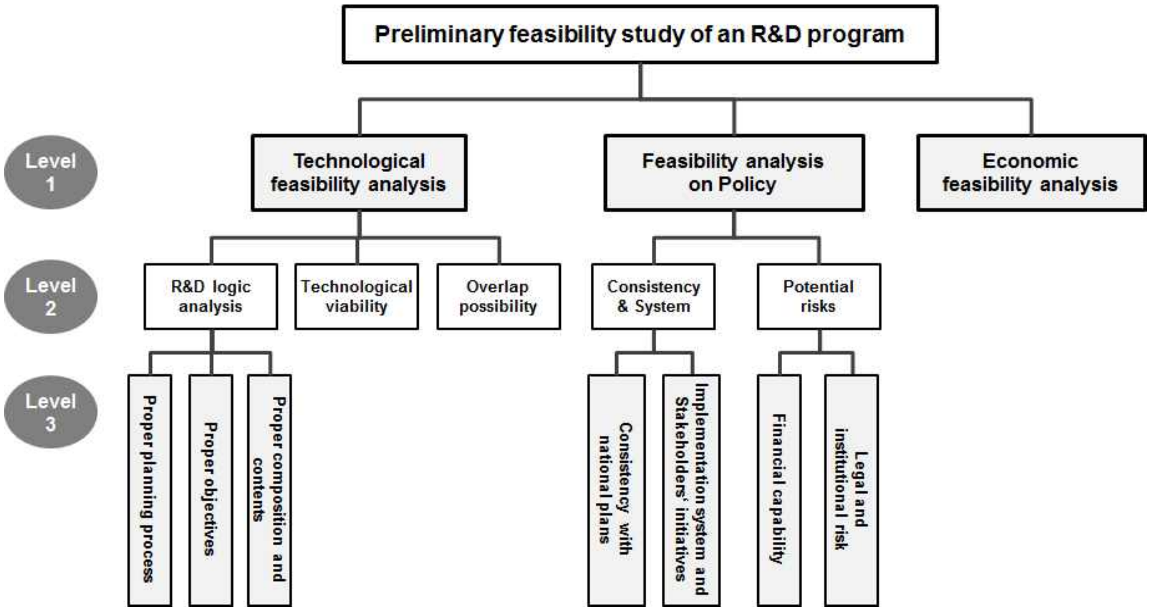
In this paper, on the 10th anniversary of the PFS on R&D programs, the framework of the PFS currently conducted in Korea is presented and the achievements and issues are discussed. In section two, the analysis structure of PFS is explained. In sections three to five, the three major criteria, technological analysis, policy analysis, and economic analysis, are presented. The overall analysis method is described in section six. Section seven focuses on the results of the PFS conducted so far and issues on the PFS. The final section explains the importance of the ex-ante evaluation of R&D programs in the budgetary process.

2. Main Criteria of the PFS of R&D Program

The PFS of each R&D program is conducted by a multi-disciplinary research team organized by KISTEP. As project manager (PM) of PFS, the research staff of KISTEP is in charge of the research team for the R&D program. The PM composes his or her research team with external experts that have expertise in technology, policy, and economics. The mix of specialists from different backgrounds and organizations helps provide diverse ideas for the evaluation and improves the transparency and objectivity of the decision-making process. Experts in technology, policy, and economics analyze the program proposal at each point of view. Then the research team discusses together several times about their opinions and develops a comprehensive evaluation report of the program proposal.

Figure 1 shows the basic analysis structure of the PFS of R&D programs. This analysis structure has three levels and every R&D program proposal should be analyzed according to this structure. The AHP method is performed for all criteria in the analysis structure.

Figure 1. Basic analysis structure for the ex-ante evaluation of R&D programs



3. Technological Feasibility Analysis

In the technological feasibility analysis, the completeness and appropriateness of an R&D program proposal are analyzed. The technological feasibility analysis consists of three sub-criteria: R&D logic analysis, technological viability, and overlap possibility.

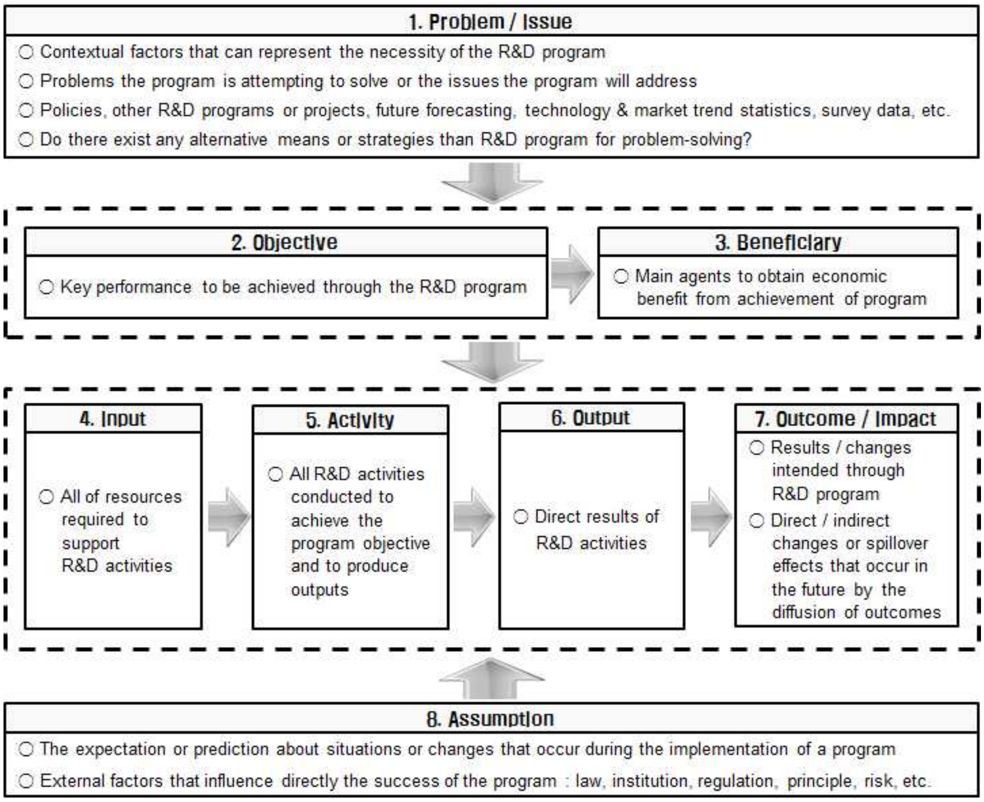
3.1. R&D Logic Analysis

The R&D logic analysis includes the whole framework for analyzing logical linkages and rationales of an R&D program proposal. The R&D logic analysis can explain what the proposed program is, why the proposed program is valid, how the investment results in desired outcomes, and who the private or public beneficiaries are. This 2nd level criterion is most important in the PFS of R&D programs.

We developed the logic analysis model as an important tool in identifying problems and issues for the ex-ante evaluation of R&D programs as shown in Figure 2 (Kang, 2013). The program logic model creates a picture of how organizations do their work and how outputs/outcomes link to relevant issues/problems, program objectives, and activities/processes. A logic model is a systematic and visual way to present and share the understanding of the relationships among the resources, activities, and changes or results to be achieved. Many papers have demonstrated that the logic model can provide a basis for good evaluation and performance monitoring as well as being utilized for program design and building a shared understanding of what a program plans to achieve and how the program will achieve (McLaughlin et al., 1999; Millar et al., 2001; W.K. Kellogg Foundation, 2004; Renger and Hurley, 2006; McLaughlin, 2010; Samsuri, 2011).

The logic model is a core tool for the R&D logic analysis. The meaning of each element of the logic model is shown in Figure 2. Arrows in the logic model illustrate the direction of the relationship between elements. We simplified the logic model to make it easier to apply. However, the logic model presented in Figure 2 is a general model and can be modified to match the characteristics of each R&D program.

Figure 2. Logic model for the ex-ante evaluation of R&D programs



The logic model analysis plays an important role in helping the PFS evaluators define key issues for designing an evaluation plan at the beginning of the PFS prior to the in-depth analysis according to each evaluation criterion. The logic model disassembles the program into problem/issue, objective, input, activity, output, and outcome/impact to understand the concept of the program. Using this logic model, we can generally identify important factors of an R&D program proposal such as why this program is needed, what the objectives are, who the beneficiaries will be, what and how many resources will be necessary, what activities will be conducted, what kind of output will be produced and when, and what outcomes and impacts will occur. We also can analyze the logic flow of an R&D program proposal and find any disconnects or gaps in the logic flow among elements.

The R&D logic analysis consists of three sub-criteria (level 3): proper planning process, proper objectives, and proper composition and contents. We established evaluation questionnaires to maintain the consistency of analysis in each sub-criterion as shown in Table 1. To develop the standard questionnaire, we reviewed past cases of PFS and evaluation systems of other countries such as the Program Assessment Rating Tool (PART) by the Office of Management and Budget (OMB) and the Evaluation Methods by the Department of Energy (DOE) in the United States, and the Green Book in the United Kingdom.

The questionnaire consists of essential and optional questions. Whereas essential questions should be applied to all R&D programs, optional questions may be applied depending on the characteristics of each R&D program. For each question, evaluators can apply one or more suitable methods from several evaluation methods for R&D programs (Ruegg and Jordan, 2007).

Table 1. Questionnaire of R&D Logic Analysis

Level 3 Criteria	Evaluation questions
Proper planning process	1. Was the expert group that participated in the planning suitably organized?
	2. Was the demand for R&D of the related field suitably understood?
	3. Was the priority setting process rationally carried out?
Proper objectives	1. Is the problem or issue to be solved suitably deduced?
	※ Is there any other efficient alternative plan aside from R&D?
	2. Does the program objective specifically present the effect that is intended to be accomplished?
	3. Is there a correlation between the objective and the problem to be solved?
	(System development program) Is the mission and concept design suitably organized?
	4. Is the targeting of the beneficiaries for the program outcome suitably carried out?
	※ Is the promotion strategy to accomplish the objective suitable?
	※ Is the role of government support considering the attributes of technology suitable?
Proper composition and contents	
	1. Are detailed activities deduced and presented at a suitable level?
	2. Are detailed activities logically related to the objective?
	(R&D Infra establishment) Are facilities/equipment established in consonance with R&D activities?
	(System development program) Is a suitable work breakdown structure (WBS) organized around the core component technology?
	3. Are the outcome indicators of detailed activities suitably presented?
	4. Are the period estimates of detailed activities and temporal order logical?

'※' mark means that the question is optional.

3.2. Technological Viability

Technological viability is intended to analyze in terms of the attributes of the technology to be developed in an R&D program. This criterion is not meant to analyze the success or failure of technology development. Because It is not desirable to pursue large-scale investments with only vague expectations about the effect of R&D, technological viability aims to analyze whether the present time is the appropriate time for a large-scale investment in the proposed technology field and whether there may be schedule delays or cost overruns not identified in the R&D program proposal. This criterion consists of two analysis elements: technological trend analysis and technological competitiveness analysis.

Technological trend analysis determines whether this is a suitable time for large-scale investment considering the objectives of an R&D program and the advancement trend of a proposed technology. Methods such as data mining, expert judgement, and technology readiness level (TRL) may be used for technological trend analysis. Generally, patent analysis is utilized most frequently as a proxy for data mining. If it is hard to expect the rise of a proposed technology in the near future because the technology is at very early stage, or if the proposed technology is worn-out, it is not an appropriate time for a new large investment in the technology. If the timing of the investment is not appropriate, there is a high probability of schedule delays or cost overruns not identified in the R&D program proposal.

Technological competitiveness analysis assesses the competitive position and technology gap among key research subjects. Technology level evaluation reports published biannually by KISTEP, scientometrics, expert judgement may be used for this purpose. If domestic technology level is high and R&D is considered as the only source of growth, technological competitiveness analysis will yield a relatively favorable opinion. On the other hand, if the domestic technology level is low and there are alternative methods of growth besides R&D, the analysis will yield a relatively negative finding.

3.3. Overlap Possibility

National fiscal management aims to establish a foundation for efficient, performance-oriented, transparent fiscal management and soundness (MoSF, 2006). Therefore an investment in an R&D project that overlaps an existing R&D project is likely to be regarded as inefficient and useless. The Korean government is actively pushing the readjustment of similar and overlapped R&D projects to solve the problem of redundant investments. Overlap possibility analysis also is important in minimizing the causes of waste in fiscal management. In this criterion, the overlap possibility of the R&D program, R&D activity, large research facility, and equipment are analyzed. If the overlap possibility is high, a negative evaluation opinion is given.

4. Feasibility Analysis on Policy

To conduct the government R&D program, a significant amount of tax revenues may be expended. As a result, government R&D programs should be based on the national science and technology (S&T) strategies and the level of program expenses should reflect a consensus of national policy and society. We recognize the importance of analyzing policy issues in the PFS of R&D programs and have devised approaches to analyze the feasibility on policy.

The feasibility analysis on policy deals with policy issues and other issues that could not be analyzed in technological and economic feasibility analyses. This evaluation criterion has two second level sub-criteria: the policy consistency and program implementation system and the potential risk.

4.1. Policy Consistency and Program Implementation System

4.1.1. Consistency with National Plans

Because government R&D programs are a method for implementing national S&T strategies, programs should be planned in accordance with national strategies. The extent to which an R&D program is consistent with national S&T strategies is one criterion to evaluate whether an R&D program will be promoted. To evaluate this criterion, objectives and contents of the R&D program should be compared to and analyzed with contents of national S&T plans. In Korea, national S&T strategy has been hierarchically organized in the Science and Technology Basic Plan - a top-level plan that includes many sub S&T plans from various technological and policy areas.

To promote the efficient use of a limited governmental R&D budget, the Korean government specifies important technologies in medium- and long-term S&T plans (i.e. 120 strategic technologies in the 3rd Science and Technology Basic Plan). For any R&D program to develop specific technology or to construct specific R&D infrastructure, we can determine that the program has a consistency with national S&T strategies, if the technology or R&D infrastructure is described obviously in some national S&T plans. The Science and Technology Basic Plan, the supreme master plan, is analyzed for all R&D programs and other S&T plans are analyzed selectively. The consistency level between an R&D program and S&T plans is evaluated as high, medium, or low.

4.1.2. Implementation System and Stakeholders' Initiatives

Implementation system proper to characteristics of individual R&D program is likely to enhance the probability of program success. To ensure the successful enforcement of an R&D program, the role-sharing and cooperation among the principal ministry, related ministries, and research institutes should be reviewed. The efficient program operation scheme and the strong will of participating agents also are important to consider.

The propriety of comprehensive program management system that involves the vertical funds transfer structure and horizontal cooperation system must be analyzed in terms of R&D program governance. In other words, the evaluation of the implementation system is intended to analyze the appropriateness of program management system and procedure to achieve policy goals from a legal and institutional point of view.

To evaluate the stakeholders' initiative, the will of agents to conduct an R&D program and the preferences of the stakeholders (beneficiaries or expense persons) should be analyzed. The will to conduct a program can be evaluated by the extent of preparation in the detailed contents and strategy of an R&D program proposed by any government ministry. The preferences of the stakeholders can be evaluated by identifying the number of agents, such as research institutes, companies, and universities trying to participate in the R&D program, and the extent of their will to participate as well as the size of matching funds from private companies.

4.2. Potential Risk

The risk factor analysis is performed to identify the stakeholders' responsibilities by raising the transparency of risk information inherent in the R&D program. The potential risk analysis for the feasibility analysis on policy deals with the external risk factors that are not directly relevant to the technology development activities, such as fund procurement risk and legal and institutional risks.

4.2.1. Financial Capability

Financial capability is determined by analyzing the possibility of problems in the time and scale of R&D program expenses. This analysis exposes risk factors that could delay the implementation of the R&D program due to problems with financial procurements. R&D program expenses are classified as central government expenditure, local government expenditure, and matching funds from private sectors. The certainty of the procurement plan by these financial resources and other risk factors is analyzed to evaluate the financial risk.

4.2.2. Legal and Institutional Risk

The legal and institutional risk factors are classified as domestic laws and institutions, and international treaties and conventions. Because a government R&D program is conducted mainly with public investments, it should be analyzed to determine if the program will be carried out in accordance with the relevant laws, institutions, and treaty provisions. It’s also possible to identify conflicts with laws in R&D activities and the use and spread of outcomes from R&D programs.

There is a point that should be considered when the products developed through any R&D program will be international trade goods. As international trade has increased, incidents related to government R&D programs that evoke a conflict with foreign nations also have increased. Because R&D activities spread in an industry in conjunction with technological innovation, the possibility that R&D activities may cause regulatory issues in trade with other nations is higher than in the past. To minimize these trade issues, R&D programs that develop industrial technologies should consider the Agreement on Subsidies and Countervailing Measures established by World Trade Organization (WTO).

Information on these risk factors can be utilized as important basic data for the risk response plan in the implementation process of the R&D program, so there is a need for the careful consideration about risk factors at the planning phase of a program.

5. Economic Feasibility Analysis

The economic feasibility analysis is done to estimate the total cost for conducting an R&D program and to identify outcomes and spillover effects caused by an R&D program based on the efficiency of the fiscal management.

First, the appropriateness of the budget of an R&D program proposal is reviewed and analyzed for hidden costs. To estimate the appropriate cost of a proposed R&D program, we use the cost classification scheme shown in Table 2. This cost classification scheme for R&D programs is the standard format in Korea. Every ministry that proposes a new R&D program should submit a detailed proposal showing all costs for R&D, research facilities and large equipment, and program management. To estimate reasonable costs in a proposed program, several methods such as analogy estimating, statistical analysis, detailed calibration, and expert opinion may be used.

Economic analysis is used to evaluate the domestic economic effects produced by outcomes of an R&D program. For this purpose, cost-benefit analysis, which is an incremental approach, is used widely. The cost-benefit analysis compares a scenario with-the-program with a counterfactual baseline scenario without-the-program (EC, 2014). The difference in social welfare should be determined by comparing benefits "with or without" implementing the program, not by comparing benefits "before and after" the implementation of the program. In the PFS, only direct benefits of an R&D program are examined. Direct benefit means a benefit directly related to the objective of the R&D program. We classify benefits of R&D programs in Table 3.

Looking at past PFS cases, the most frequently applied benefit is the producer-based, value-creating benefit because the proportion of R&D programs aimed at creating an industrial spillover effect is high. For this case, we developed the market demand approach to estimate the benefit. This benefit can be estimated from the probabilistic value added or created in the future target market due to the contribution of the R&D program.

Table 2. Classification of costs of R&D programs

Categories	Contents
Cost for research & development	Labor cost of researchers, research fund, etc.
Cost for research facilities and equipment	Cost for purchase and maintenance of research facilities and large equipment
Cost for R&D management	Cost for planning & assessment, management of the R&D program, etc.

Table 3. Classification of benefits of R&D programs

Categories	Subcategories
Value-creating benefit	Consumer-based benefit Producer-based benefit
Cost-reducing benefit	Production cost-reducing benefit Damage cost-reducing benefit

Cost-benefit analysis is used as the basic method to analyze the effects of an R&D program on the national economy. If the expected outcome or spillover effect of an R&D program can be quantified as a monetary value, the cost-benefit analysis may be used for economic feasibility analysis. However, if the outcome or spillover effect of an R&D program cannot be quantified as a monetary value, the cost-effectiveness analysis should be used.

6. Overall Feasibility Analysis

A final decision on whether to invest in the R&D program is made by synthesizing evaluation results from technology, policy, and economics analyses. Technological, policy, and economic analyses are performed independently and the results are combined in the final analysis. Analytic Hierarchy Process (AHP) (Saaty and Vargas, 2006) method, a multi-criteria analysis method, is utilized as a means for collecting the decision-making information for each R&D program proposal. AHP decomposes a problem into a hierarchy with several levels where each decision element should be independent (Lee et al., 2009). The evaluation is conducted based on pairwise comparisons at each level of the hierarchy (Saaty, 1987).

AHP has been employed in many different areas, such as selection, evaluation, benefit-cost analysis, allocation, planning and development, and priority and ranking (Vaidya and Kumar, 2006). It also has been used widely as an R&D evaluation method that can handle multiple objectives for R&D projects and can decompose the problem into a multilevel structure or hierarchy. AHP has merit in that both qualitative and quantitative data can be considered simultaneously (Pho et al., 2001). Because results of technological analysis and policy analysis are qualitative and result of economic analysis is quantitative, AHP is useful to the PFS.

Generally, the overall AHP score of more than 0.5 means that an R&D program is feasible. Based on the final AHP result, MoSF can make the decision of whether to invest in the R&D program.

7. Results and Issues

7.1. Results of PFS on R&D Programs

KISTEP finished a PFS for 130 R&D programs from 2008 to September 2017. Because 86 R&D program proposals had positive results, the pass rate for all proposals was about 66.2%. The budgets for passed programs have been adjusted to enhance the efficiency of the investment and, as a result, budgets of most programs have been reduced. Therefore, the pass rate of program budgets was about 37.4% for all examined programs and about 51.7% for passed programs.

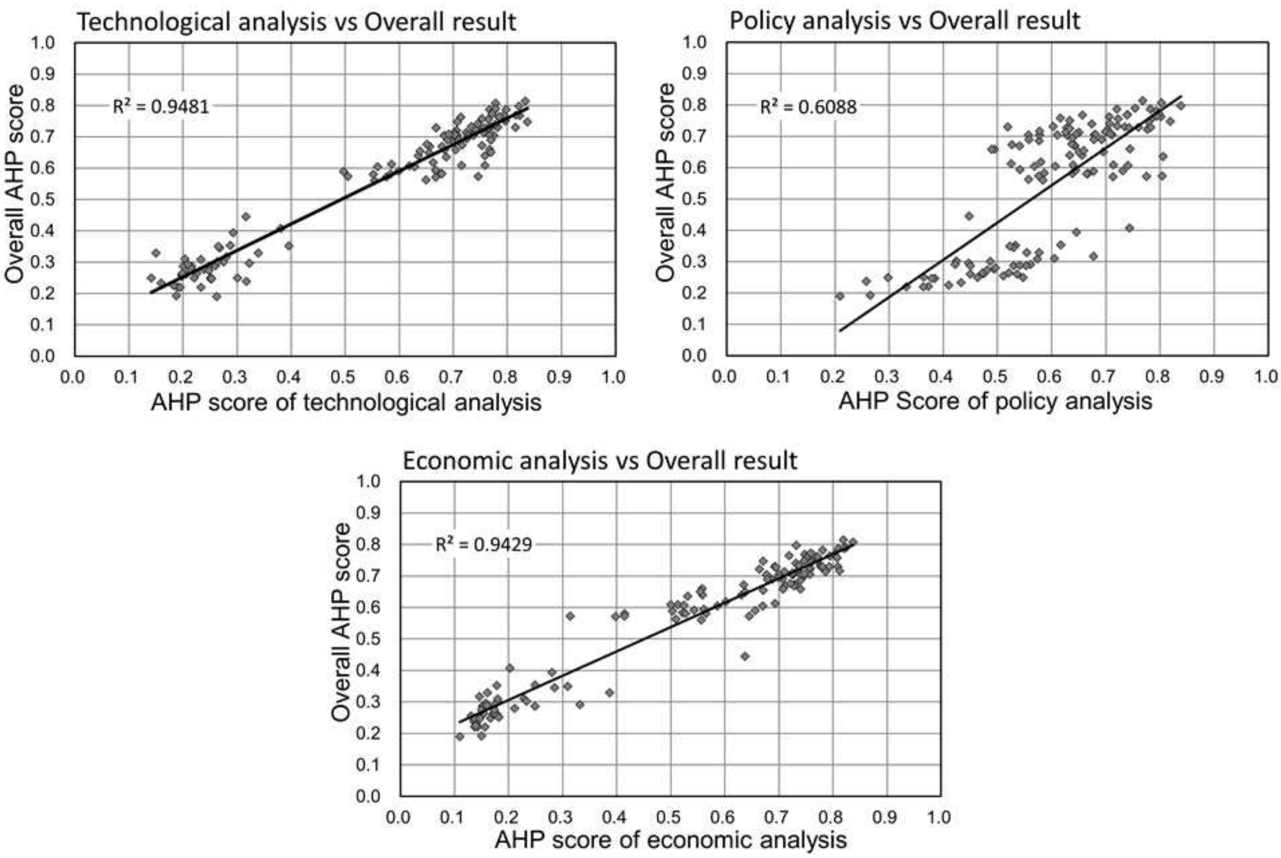
Because PFS pass rates were the same for programs with or without matching funds from the private sector, the participation of private companies does not seem to affect the pass rate for R&D programs.

The correlations between overall AHP score and each AHP score from the technological, policy, and economic analyses, were analyzed to identify which criterion was most relevant to the overall feasibility result. As shown in Table 4 and Figure 3, the technological feasibility analysis had the highest correlation with overall AHP score. Therefore, we can understand that in the PFS of R&D programs the most important criterion is the technology analysis. The correlation between the overall AHP score and the policy analysis score was relatively low because most R&D programs had been based on national S&T strategies and contained few risk factors.

Table 4. Correlation coefficients between overall AHP score and each AHP score of major criteria

	Technological analysis - Overall	Policy analysis - Overall	Economic analysis - Overall
Correlation coefficient	0.974	0.780	0.971

Figure 3. Correlation analysis between overall feasibility and each major criterion



7.2. Current issues on the PFS

There is the controversy about pre-evaluating the economic effect of an R&D program to be occurred in the future. Because the amount of future benefit due to the R&D program is the important information for the R&D funding allocation, the fiscal authority wants to predict it. However the period of R&D programs is generally 5~10 years, and the benefit analysis in the distant future after the end of programs involves high uncertainty. Therefore the careful reconsideration about applying the benefit analysis in the ex-ante evaluation on all R&D programs is needed. On the other hand, the strict cost analysis should be conducted beforehand for the efficient fiscal management.

There is an issue that the evaluation period is prolonged because the modification of program proposals of ministries is permitted during the PFS period currently. Ministries tend to poorly establish program proposals to apply for budgets early. If the program proposal gets negative result from the intermediate evaluation, most ministries will modify their program proposals for several months and this will lead to a longer PFS period. Because the PFS is one of the budgetary processes conducted by government, it is desirable not to allow the modification of program proposals during evaluation period to prevent the waste of administrative power and the prolongation of PFS period.

Each PFS of an R&D program is conducted for at least six months. Through this in-depth analysis of the R&D program proposal, reasonable directions and policy suggestions may be derived for the implementation of the program. To ensure the coherence of policy, it is necessary to link ex-ante and ex-post evaluations (Mergaert and Minto, 2015). Therefore, it is important to the improvement of the national R&D system to link the results of PFS of an R&D program to the implementation and ex-post evaluation of program.

8. Conclusions

Because there is no country that conducts the ex-ante evaluation of all large-scale R&D programs under the leadership of government except Korea, this paper is meaningful in that it describes the regional and practical case of the unique government fiscal and R&D system. The purpose of the PFS is to promote the use of sound, evidence-based decision making in the budgetary process. Most of the PFS results have been reflected directly in the formulation of program budgets in Korea, making the PFS an important step in budgetary decisions. The PFS also has contributed to enhance of fiscal efficiency of public investment by preventing non-feasible programs from being launched (Kim, 2012; MoSF, 2014).

The improvement of an ex-ante evaluation system on government programs at the ex-ante phase is very important for ensuring sound public expenditure. To establish the rational ex-ante evaluation system of government R&D programs, we have developed and improved the evaluation system and methodologies, such as logic model and questionnaire for R&D logic analysis and the market demand approach for estimating benefits. This paper has explained the framework and methodologies for the ex-ante evaluation of R&D programs being conducted in Korea. The standard guidelines for PFS of R&D programs (KISTEP, 2016) were established to ensure the consistency, objectivity, and transparency in analysis processes and methods. The PFS of R&D programs consists of three major evaluation criteria based on technology, policy, and economics. Technological feasibility analysis is the most important criterion in the decision of 'whether to invest in the R&D program proposal'.

To make the PFS a more credible system, continuous efforts should be made to improve the ex-ante evaluation methodology. Based on the PFS results and issues for the last 10 years, discussions are underway to improve the PFS system. We expect improvements in the PFS system because of these in-depth discussions on evaluation procedures, criteria, and methodologies.

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