Integrated Technology Planning Model towards Next Level National Research and Development in Korea

Keun-Ha Chung[1*]

Abstract
Technology planning is an essential factor in enhancing the efficiency of R&D activities. Particularly on the national level, preparatory information based on the factual researches and ex post facto information for valuation is required simultaneously. Therefore, in this study, traditional planning tools, such as technology trend analysis, science and technology foresight, the science and technology level survey and the national technology road map, are defined as informational technology planning tools; whereas the preparatory feasibility study, R&D priority, national R&D program investigation, analysis and evaluation, and R&D budget coordination related to R&D budget control and distribution are defined as executional technology planning tools. An integrated technology planning model on a national level that combines these two tools is proposed. Hence, the four hypotheses of necessity, importance, utilization of executional technology planning tools, and the importance and satisfaction difference of each tool is framed and verified. The result showed that the integrated technology planning model is an appropriate model in composing a national level technology planning system that corresponds to the recent science and technology environment changes.

Keywords: technology planning model; executional technology planning tool; informational technology planning tool; integrated technology planning

1. Introduction

Technology planning is an essential factor in improving the efficiency of research and development (R&D) activities. The preliminary preparation on what and how to develop prior to R&D activity is only fair. As the risk and size of R&D increases, the importance of technology planning also increases. This is because, in large R&D projects, the goal of each department must be distinctively distinguished and the position of each department must be located in concert with the overall planning. Recently, the interest on macroscopic technology planning tools[1)], i.e. the science and technology foresight, the technology assessment (referred as TA hereinafter) and the survey of technical levels, as well as microscopic tools[2)] such as the technical ability investigation and research on technical properties of the concerned technology has been elevated.

Besides the preparatory tools, other elements

[1]*Technology Foresight Center, Korea Institute of Science & Technology Evaluation and Planning (KISTEP), Seoul, 137-130, Korea*
*Corresponding author. E-mail: khchung@kistep.re.kr

1) Macroscopic technology planning tool: a technology planning tool for technology development strategies or goal establishment on the national level

2) Microscopic technology planning tool: it is a smaller concept that the macroscopic technology tool which is a technology planning tool for a specific technology area on the government or ministry level. Please refer to Keun-Ha Chung (2009, pp23-29) for more information

have been observed to be induced in the technology planning process. One of the examples includes the result of the R&D project assessment that was conducted according to the plans in the past. Also, the feasibility study on technology planning and the decision of priority as the result of technical planning often take place prior to the technology planning. The planning can be added or deducted according to the superordinate goals or budget situations. In this process, information other than the preparatory tools is induced additionally.

When the subject of technology planning includes the comprehensive area of science and technology, a large size of national R&D projects, or many R&D project units, it requires preparatory information in the traditional sense – information technology planning with a focus on the factual research as well as the executional technology planning tools for ex post facto valuation. On the national R&D site, it not only reviews one planning proposition in a certain technology area, but also, it forms the competition between projects in its process.

The objective of this study was to examine the technology planning tools composing the national science and technology planning appropriate for the new science and technology environment through analyzing informational technology planning tools, executional technology planning tools, and the relationship between the tools in order to reinforce the strategic functions on the national level. A new technology planning model that combines these two tools required on the national level was proposed through analyzing existing theories, and framing the hypotheses that support this model to verify the status of utilizing the planning tools.

This study is composed as following: chapter 2 explains the concept of technology planning and practice of technology planning in Korea, and introduces the preceding studies on the technology planning model; chapter 3 suggests the limitations of the existing technology planning models and proposes an integrated technology planning model on the national level; chapter 4 verifies the feasibility of the integrated technology planning model through the experts questionnaire research; chapter 5 summarizes the study results and suggests limitations and future proposals.

2. The Technology Planning Tool and the Model

2.1 Concept of technology planning

On the technology related planning sites, there often are disputes on the terminology whether the research planning or the technology planning is more accurate. In this study, the planning for both R&D and technology acquisition is considered to be an equivalent term. Although it includes activities irrelevant to R&D such as technology induction in the technology acquisition process, all the discussions required in the process of acquiring new technology are simply called technology planning. Traditionally, technology planning is a process of utilizing preparatory information such as technology trends, results of technology foresight, information on activities of relevant researchers or corporations and technology road maps. Therefore, all forms of preparatory information used in the process of technology planning are referred to as the informational technology planning tool[3].

According to Wildavsky(1974), the compilation of the budget is the final stage of planning that concretizes the planning, and the optimal strategy plan is confirmed as the budget compilation. Therefore, once the technology planning is established, the distribution of budget and technology development follows. However, in the current science and technology administration system, the allocation of the budget is conducted by the Ministry of Strategy and Finances, and the technology planning and technology development activities are conducted by science and technology related ministries such as the Ministry of Knowledge Economy and the Ministry of Education, Science and Technology. And depending

3) Informational technology planning tool: this is a comprehensive term that refers to a tool that produces the science and technology information – technology trend survey, science and technology forecast, TA, and NTRM. Please refer to Keun-Ha Chung (2009, pp29-33).

on the size of the allocated budget, the scope or size of the technology planning is determined for further R&D. Therefore, the process of the budget allocation in a broad sense can be considered as a stage of technology planning on a national level promoting competitions between the technology planning in a certain area and supporting the validity of the promotion of the selected technology planning. In this perspective, each tool including the preparatory R&D feasibility study, the framing of R&D priorities, the R&D program investigation, analysis and assessment, and R&D budget coordination is referred to as an executional technology planning tool[4].

2.2 The technology planning practice in Korea

The Fundamental Law of Science and Technology (enacted in 2001), that stipulates the comprehensive policies of science and technology in Korea, prescribes many measures supporting the technology and the use of these measures for national technology planning. This law includes the technology trend survey, science and technology foresight and national technology roadmap (referred as NTRM hereinafter) (Article 13), the technology level survey (Article 14), the TA (Article 14), framework of the R&D priority, the R&D budget coordination and distribution, the preparatory R&D feasibility study (Article 9), and the national R&D program investigation, analysis and assessment (Article 12).

1) Technology trend survey, science and technology foresight and national technology roadmap (Article 13 of the Fundamental Law of Science and Technology):

Foresight of trends of science and technology development, reflection of the result on the science and technology policies, and developing new technologies based on the result of the foresight

2) Science and technology level (Article 14 of the Fundamental Law of Science and Technology):

Evaluation of technical levels of nationally crucial technologies and establishment measures to improve related technical levels in order to promote the development of science and technology

3) Technology assessment (Article 14 of the Fundamental Law of Science and Technology):

Preparatory assessment of the impact of new science and technology development on economy, society, culture, ethics and environment and reflection of the results on the policy

4) Framework of R&D priorities, the R&D budget coordination and distribution, the preparatory R&D feasibility study (Article 9 of the Fundamental Law of Science and Technology):

Items on preparatory coordination and efficient operation of R&D priorities and their budgets administered each year by the government

5) National R&D program investigation, analysis and assessment (Article 12 of the Fundamental Law of Science and Technology:

Annual national R&D program investigation, analysis and assessment

Table 1 is a summary of various technology planning tools executed in Korea. Most of these activities are conducted by KISTEP (Korea Institute of Science and Technology Evaluation and Planning) and specialized R&D project institutions in each ministry that supports the NSTC (National Science and Technology Council). The technology planning tools largely consist of the information provision, the budget distribution for the technology planning and the assessment on the process and result of the projects.

2.3 Preceding studies

Systematic research on technology planning has been executed in advanced countries from early 1960s (Pappas & Maclaren, 1961; Baker & Pound, 1964; Rosen & Souder, 1965). Examples of technology planning includes Koerner (1989) which analyzed the process of technology planning of GM (General Motors Co.) and Boar (1993) which analyzed the technology planning model of AT&T (American

4) Executional technology planning tool: this is a comprehensive term that refers to the planning tool related to the R&D budget – preparatory feasibility study, framing priority, research, analysis, evaluation of the national R&D project, and budget coordination. Please refer to Keun-Ha Chung (2009, pp29-37). Pyeng-Mu Bark and Gi-Jong Lee (2009) also discusses 'the association of policy and budget' and explain the executional tool as coordination, distribution, assessment and management.

Table 1 Technology Planning Tools in Korea

Tool (The Fundamental Law of Science and Technology)		Operation examples / main performances
Informational Tool	Technology trend survey (Article 13)	- Macroscopic trend analysis of papers and patents - Establishment of the early warning system
	Science and technology foresight (Article 13)	- Regular foresight survey in comprehensive area of science and technology every 5 years - Conversion of forecasting to foresight*
	Science and technology level (Article 14)	- Assessment of the technology level on the nationally important core technology
	Technology assessment (Article 14)	- Evaluation of impact on future technologies
	National technology roadmap (Article 13)	- Writing of technology roadmap on 99 core technologies (‘02) and reflection on the First Science and Technology Basic Plan **
Executional Tool	Preparatory feasibility study (Article 9)	- Annual execution of economic, technical and political preparatory feasibility study on new R&D projects
	R&D priority (Article 9)	- Set up of the national strategic R&D investment priority each year - Reflection on the midterm planning
	Investigation· analysis·evaluation (Article 12)	- Annual assessment of projects of the previous year and reflection of the result on the project assessment - The importance of research performance is increasing recently.
	R&D budget coordination (Article 9)	- Execution of the next year s R&D budge coordination and distribution of each ministry and project every year (performance oriented)

Source: Fundamental Law of Science and Technology (2001.1.16), * KISTEP(2002.2), ** KISTEP(2002.7)
Although the above technology planning tools are stated on the Fundamental Law of Science and Technology, KISTEP is executing all the informational and executional technology and planning tools in the comprehensive area of science and technology on the national level and each government ministry and its affiliated organizations are mainly concerned with the informational technology planning activities.

Telephone & Telegraph Co.). After the mid 1990s, various technology planning methodologies are introduced.

First, in accordance with the active discussions in the mid 1990s on strategic planning, the methodologies of the association of technology planning and business planning (Metz, 1996), and the consolidation of technology planning, business planning and asset management (Sollee, Luquette and Maruta, 1995) appear. From the methodological aspect, there are pure technology emphasis models such as technology foresight (Bilich, 1989), technology audit (Martino, 1994) and the technology maturation model (Kimball and Sibley, 1995). Or, there are models that stressed the technology itself such as the scenario method (Waissbluth and de Gortari, 1990), the structural approach (Koc, Polat, and Yunusodlo, 2001), the integration of the scenario method, the Delphi method (Chen, Li and Tirupati, 2002), and the situational approach (Karlsson, 2004). In recent years, the NTRM that reflected the social demand (Vincent, 2004) and integrated the ability and objective of the technology planning is referred as an important means of technology planning (Phaal et. al, 2004; Lee et. al, 2007; Whalen, 2007). Particularly, there has been an effort to select important core technologies for national future developments and promote the technology development strategies (Keun-Ha Chung, 2002; Do-Young Byun and Keun-Ha Chung, 2003; Byung-Won Park, 2007). However, there is a slight gap in the element of consideration or promotion stages in technology planning on the national level. It can be classified in to a type that emphasizes the technical nature such as technology foresight (the technology-

oriented type) and a type that reflects the national demands (the goal-supporting type). This classification refers to the slight difference in the subject of technology planning and the degree of application.

There are two concepts in the science and technology predication: forecast and foresight. Forecast brings in just one future and depicts the realization time of the technology; whereas, foresight supposes that the future can be selected according to the technology. In other words, foresight includes the interactions between technology and society, and the present and future; hence, it is a more dynamic process than the forecast. According to Georghiou(2001), foresight is moving from the first generation which the science and technology experts forecasted to the second generation of science and technology and the market which the industry and university reviewed, and to the third generation of the problem solving type that includes the stakeholders in a wider sense of society and the social elements[5].

Bilich(1989) who stressed technology foresight proposed 6 elements as the basis of science and technology planning: problem diagnosis, forecast and foresight, clear goal establishment, design of multiple alternative plans, plan testing, and assessment and execution. He also emphasized the importance of socio-cultural environment, political environment, technical element and scientific element as a consideration in establishing science and technology planning on the national level as well as the importance of resource distribution of national R&D. And this is the technology-oriented technology planning model which is a methodology that is grounded on the limited technology planning tools such as the system engineering, the demand survey, the foresight survey, and scenario writing focused on the technologies to achieve the science and technology goals of the nation. This method is a circular approach subjected to the total cyclic planning process of Plan-Do-See. In reality, this cyclic approach is utilized in various fields, i.e. the research planning management of research management institutions affiliated to the government and ministries[6]. Figure 1 shows the technology planning model of Bilich.

On the other hand, Cetron (1970) remarked that the system analysis, the demand analysis, the analysis of difficulties and shortcomings must take precedence prior to setting the national goal. And it is an efficient R&D resource distribution process to conduct technology assessment (TA) and plan an R&D project after establishing the national goal and the technology goal. The process of analyzing diversity of information to set the national goal and the technology goal includes establishing a comprehensive plan for science and technology research and development. That is, the goal-supporting technology planning model frames the national goal and as a means to realize this goal, it sets up the technology goal to plan the national R&D project based on the results that conducted the technology assessment according to the established technology goals. This approach is efficient in the aspect that it selects the desirable goals and means based on the comprehensive reviews on science and technology environment and resources. Moreover, it is also efficient in the aspect that the result of planning tools available from the systematic perspective is organized by class and concentrates on the focus of policies[7]. Figure 2 shows Cetron's technology planning model.

NSTC(National Science and technology Council, 1995) of the US induced the R&D activity field in the information communication area in order to find and achieve the social goal of the US and the goals of major organizations in the federal government such as Ministry of National Defense and NASA (National Aeronautics Space Administration) in an attempt to induce the national strategy technology in the information communication area as a means to reinforce national competitiveness. This field of R&D activity is conformed to fit the social goals of the US or the goals of the major organization of the federal

5) If the first and second generation of the technology prediction refers to a forecast, the third generation refers to the foresight. Although these two concepts are mixed and have slight differences in philosophy, purposes and the process, they are still very similar in many ways. Therefore, they are used as the technology forecast in this study.

6) Please refer to Keun-Ha Chung, Sang-Yup Lee (Oct. 2007, pp81-83)

7) Please refer to Keun-Ha Chung, Sang-Yup Lee (Oct. 2007, pp81-83)

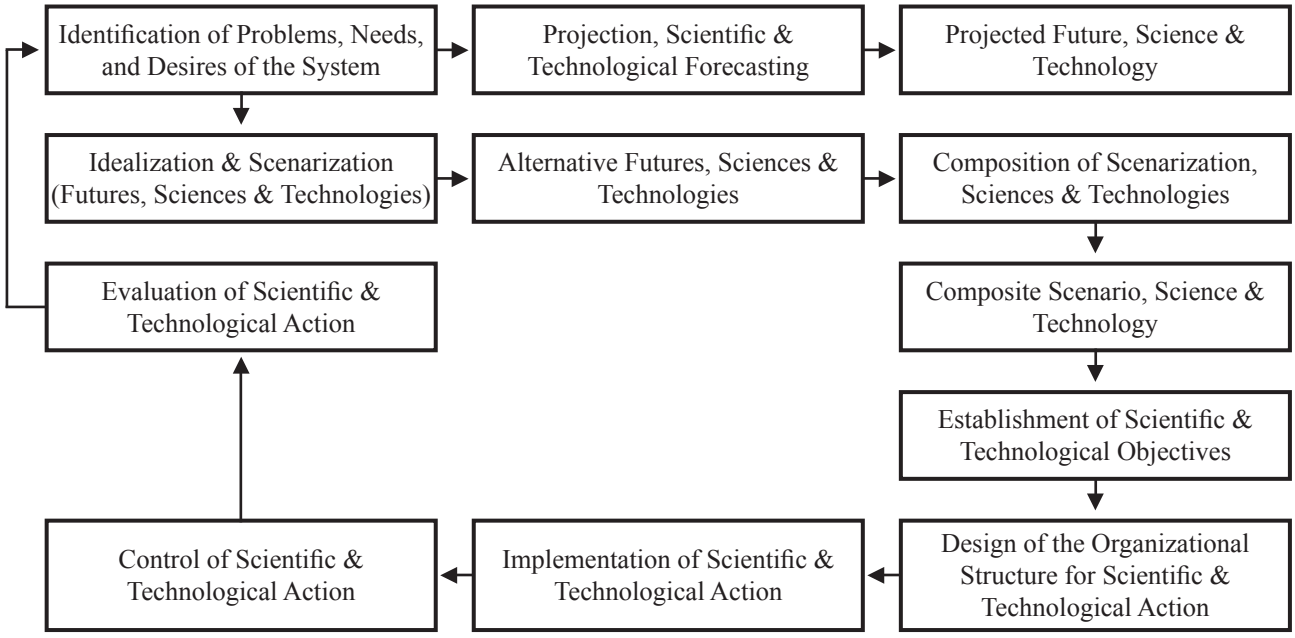

Figure 1 Bilich's technology-oriented technology planning model
Source: F. Bilich, pp.46~57, 1989

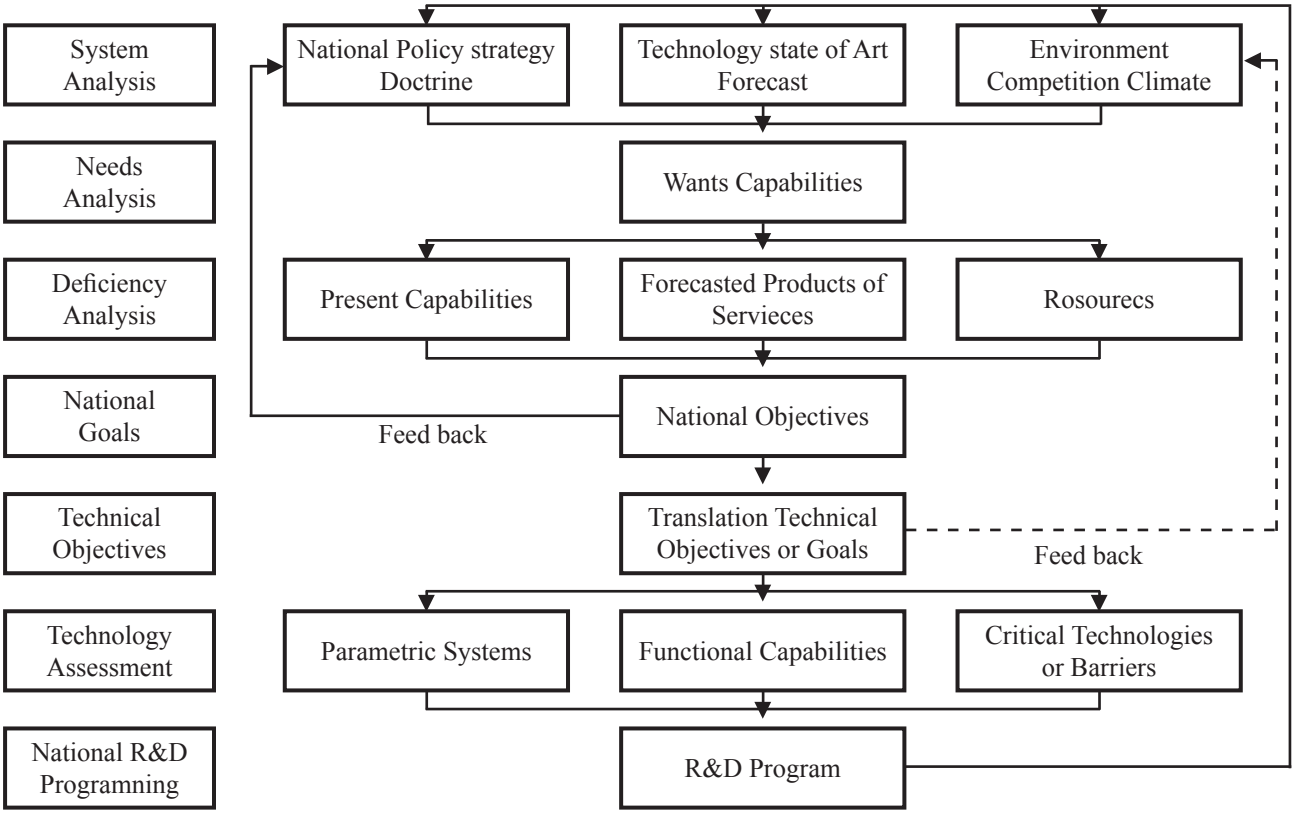

Figure 2 Cetron's goal-supporting technology planning model
Source: Cetron, p30, 1970

government through the cyclic verifications. STEPI (1995), Sung-Soo Seol (1995) and Myung-Hwan Yim (1998) that mentioned the technology planning on the national level also suggested the goal-supporting technology planning model in Korea.

3. Integrated Technology Planning Model

3.1 Limitations of the existing models

The existing technology planning model can be classified into a technology-oriented type and a goal-supporting type. The technology-oriented technology planning model emphasizes the result of science and technology foresight survey in setting up the key R&D direction. The theory of Bilich stresses the importance of the science and technology foresight and it is the key to establishing the national science and technology goal by inducing promising technologies and composing optimal scenarios. However, there is a problem of relatively meager stress on other areas than the science and technology foresight. That is, it insists on inducing forecast survey and the future science and technology after the system analysis. However, it is the recent trend to conduct the forecast simultaneously or prior to the analysis (Martin, 1989; Keun-Ha Chung, 2009). The recent trend is to forecast the future society from the political, economic, social and cultural aspect, to understand the needs of individuals, society, country and the globe, and to induce the future science technologies to satisfy these needs (NISTEP, 2004 : KISTEP, 2005). Also, considering the distinctive and rapid changes in science and technology and the extension, complexity and risk increase of the national R&D projects, the planning is overly simplified. Since this model is appropriate in mid and long term planning through the foresight survey and scenario writing, there is a limit in inducing a short-term planning result that timely reflects the rapid science and technology environment changes and aggravation of science and technology competitions. Moreover, since it assumes overly simplified technology planning means, various technology planning measures and their results influencing the comprehensive decision making can be neglected.

The goal-supporting technology planning model is a model that promotes the national R&D projects by inducing core future technologies of the related technology and understands the technology levels or development capabilities for these based on the result of the analysis of social needs and the science and technology foresight survey in order to achieve the national goal. In this process, it did not take into consideration measures other than the science and technology foresight among the informational technology planning. The next step is to induce the core technology by conducting the technology assessment as a means to achieve the technical goal. However, the process is not clarified and it depends on the simple process. Therefore, the national R&D activity requires the foresight of future science and technology development trend, the induction of promising core technology appropriate for the conditions in Korea, and the analysis of diverse scientific and technological information for the technology. Moreover, there is a possibility of a gap between the level and scope of results in each element of the system. And it creates the limitations in reinforcing the association of each class. Additionally, there is a limitation in deriving a comprehensive summary maintaining the unified view from the perspective that it requires planning subjects composed of experts in a broad variety of areas such as the science and technology policy, the foresight, the science and technology environment, the economic and social needs, the level and impact assessment, and technology and system assessment. On top of this, it is also expected to have a limitation in framing the mutual impact between each class of planning tools and relations. In case of disconnection in contextual associations in the planning measures of each class, it is impractical to maintain the unified perspectives in multi-stage processes in planning even if each planning results of the class accurately is forwarded to the right direction. And there is a limitation in classifying the planning to each stage of survey and analysis, and evaluation and decision making. This is because it is difficult to define the characteristics of planning on each stage and it is almost impossible to make clear the classification of the link between

purposes and stages of the planning, and to maintain consistent perspective on each stage of technology planning. Therefore, to present the planning result that maintains coherent perspectives in the complex science and technology environment, it is necessary to set up the mutual linkage between the technology planning activity and the result as well as the level of importance according to the objective of utilizing each planning result.

The two models are discussional technology planning models that do not take consideration into TA, NTRM and executional technology planning tools among all the informational technology planning tools. The discussional technology planning model has the advantage of giving brief introduction of the relationship between each technology planning tool and provides an efficient technology planning system to establish the strategy and plans on the national level; however, the recent expansion of economic and social conditions which the science and technology is subjected to and the explosive increase in related information could limit its utilization. That is, due to the limitations of the technology planning tools in the informatization process of massive data representing the economic and social environment surrounding the science and technology, the result of technology planning would not be able to cover the scope and content of the subject to provide the elementary information of the decision making. Furthermore, the limitation could be augmented if the major subject of technology planning changes from the existing technology planning that deals with the limited subject of the objective and needs of the nation and society, and the science and technology to a more immense and complex national level.

In fact, the close association between the executional technology planning tool and the informational technology tool is essential in order to make the planning that supports the comprehensive decision making process based on a wide range of basic information such as R&D budget coordination and distribution. Therefore, the proportion of utilization of planning results must be taken into consideration through the formation of the planning system based on the close association between the informational technology planning tool – technology foresight survey, technology level survey, TA and NTRM – and the executional technology planning tool – current status of national R&D projects, performance assessment result, and framework of priorities. In the technology-oriented and goal-supporting technology planning model, there is not enough consideration on other technology planning tools, and the utilization of the link between the technology planning tools is overly simplified which causes the limitations. Also, the limited reviews of the technology planning tools in technology-oriented and goal-supporting models can result in biased information of the results derived from these models.

3.2 Integrated technology planning model on the national level

Considering the two above models from the technology planning on the national level, it is the discussional concept that is subjected to the process of setting up the national goal, rational distribution of limited R&D resources to achieve the goal, direct selection and the promotion of national R&D projects. In a broader sense, it is important to include the plans for coordinating and distributing ultimately limited government budgets along with the trend analysis, the future prospects, science and technology demand from economic and social stance in the future and present society. This would include the economic and social impact assessment of the science and technology, the science and technology candidate area which should be supported by the country, understanding of the current status and performance of the national R&D project, framing of the strategic direction and priorities, and the science and technology level assessment.

The integrated technology planning model suggested in this study includes the R&D budget coordination planning tools individually. Also, it has important characteristics such as how the results between the national technology planning tools affect and are reflected on the rational budget coordination and distribution. Also, the national technology planning system differ in the level of importance and association of each planning tool and result in

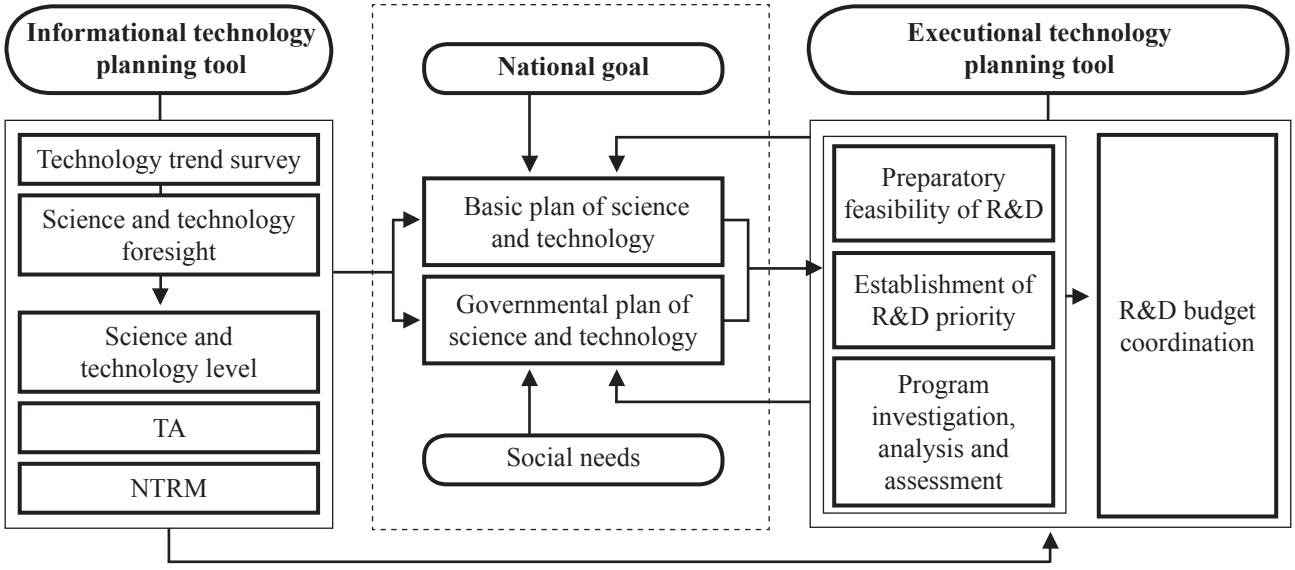

Figure 3 Integrated technology planning model on the national level

accordance with the utilization objectives. Therefore, it is significant to define a new model for establishing a planning system which can enable the selection of planning tools and results according to various types of decision making and priorities in wide areas on the national level. In other words, it is necessary to develop a new approach model that takes into consideration the feasibility study, the national R&D program investigation, and the analysis and assessment which is implemented uniquely in Korea.

As shown in Figure 3, the informational technology planning tools affect the national goal and social needs, then are reflected to the executional technology planning tools and are focused on the R&D budget coordination in the mutual relationship between the technology planning tools in the integrated technology planning model. The informational technology planning tools also have a direct impact on the executional technology planning tools. The informational technology planning tools are required to be operated in order. For instance, the research and analysis of the technology trend is conducted first, the science and technology foresight survey follows to induce the promising future technology, and the NTRM, TA and science and technology level survey is conducted. Additionally, the result of informational technology planning tools are reflected on the executional technology planning tools separately, and the result should reflect the national science and technology planning to achieve the national objective and social needs. Also, the framing of the level of importance and association of various planning tools and planning results is the ultimate precondition in maintaining the consistency in decision making among continuous complexity.

Generally, technology planning on the national level has pointed toward the informational technology planning tools of the factual survey on the science and technology itself, and it was mainly conducted to obtain basic information for promoting new national R&D projects and establishing mid and long term science and technology policies of the country. However, the concept of the integrated technology planning model takes into consideration the R&D budgets by combining informational technology planning tools and executional technology planning tools of valuation to efficiently promote the national R&D activities. This is proved by the questionnaire survey that showed 97% of consensus for the need of executional technology planning tools on the national level, as well as the level of importance of 4 executional technology planning tools shich was 81.5% on average[8].

8) Please refer to the 'Hypothesis Verification of the Model' on page 14 of this study.

Table 2 Comparison of characteristics of technology planning models

	Technology-oriented		Goal-supporting		Integrated
	Bilich	NSTC	Cetron	STEPI	
Nation/ Society					
- National objective	○	○	○	○	○
- Social needs	○	○	○	○	○
Informational technology planning tool					
- Technology trend survey	-	-	△	-	○
- Science and technology foresight	○	○	○	○	○
- Science and technology level	-	-	○	○	○
- Technology assessment	-	-	-	-	○
- National technology roadmap	-	-	-	-	○
Executional technology planning tool					
- Preparatory feasibility study	-	-	-	-	○
- Investigation, analysis, assessment	-	-	-	-	○
- Framing priority	-	-	-	-	○
- Project budget coordination	-	-	-	-	○

Source: Bilich(1989), NSTC(1995), Cetron(1970), STEPI(1995)

As shown in Table 2, the goal-supporting technology planning model is a model that promotes the national R&D projects by inducing core future technologies and understanding their technology levels or technology development ability based on the result of social needs analysis and science and technology foresight in order to achieve the national goal. Cetron and STEPI models are the examples. The technology-oriented technology planning model lays importance on the result of science and technology foresight survey and defines the direction of core R&D. These two models do not take into consideration of the TA, the NTRM and executional technology planning tools among the informational technology planning tools. Therefore, the integrated technology planning tool is a model that complemented the shortcomings of the informational technology planning tools which has not been observed in the technology-oriented type and the goal-supporting type, and combined the executional technology planning tools.

In fact, the subject and scope of planning changes with the change of economic and social trends and demand. The development of existing planning tools and new planning tools takes place simultaneously. The simple composition of the technology planning system based on the informational technology planning tool in the existing theories is the result of the simplicity of environment around the planning and the confinement in the subject of planning. The early technology planning was often conducted in microscopic dimension in the technology area, the industry, the organization and industrial areas. There is no insufficiency in providing the basic information of decision making on the level of writing the level comparison between the planning subject and related parties, and the technology roadmap in each area.

However, as the society developed, the elements of economic society became complex and magnified, and a complex situation was created with the collision of multiple beneficiaries and the changes in economic society were accelerated. Especially, in 1990, a methodology of approaching the economic society systematically based on the theoretical foundation related to the technology innovation system. Therefore, the cognition that prevailed was that many complex elements in the economic society were engaged in intimate and organic relationship and dynamically impacting each other. Furthermore, in the planning where the decision is made on the national level, the subject is expanded to the comprehensive aspects

of the national policy establishment and operation; hence, the scope of planning could not just depend on the informational technology planning tools. To provide the information for decision making on the desirable directions and concrete plans of the country by disclosing the dynamic relationship between multiple and complex elements, it is unavoidable to accept the executional technology planning with the information technology planning as a planning tool. In this study, the scope of planning tools has been expanded to technology planning that deals with close areas from the executional aspects – framing of priority, feasibility study and budget coordination – on top of the informational technology planning tools in order to enhance the level of providing information based on promoting the utilization of the technology planning results on the national level apart from the simple provision of information. It is anticipated to make innovative improvements on the utilization of technology planning results by overcoming the limitation of the planning system composed of the discussional technology planning tool.

The integrated technology planning model proposed in this study is a technology planning model in a broader sense that it takes into consideration the national goal, social needs, informational technology planning tools and executional technology planning tools. Both technology-oriented and goal-supporting types use the science and technology foresight survey as the core planning tools to uncover the association between the social needs and the national goal. Although the goal-supporting type includes the technology trend survey and the science and technology level survey, the planning system as a means of limited range is constructed and it reveals the relationship between the limited planning tools and considers the science and technology foresight survey which deals with these aspects. However, for the planning that supports comprehensive decision making on the basis of wide ranged basic information as the budget coordination and distribution, the close relationship between the executional planning tools and the informational technology planning tools is essential. Therefore, the planning system should be developed based on the close relationship between the informational technology planning tools – technology foresight survey, technology level survey, TA and NTRM – and the executional technology planning tools – national R&D project status, performance assessment result and framing of priority – in order to satisfy various economic and social demands and complex interest parties. However, in the technology-oriented and goal-supporting model, the consideration of these other technology planning tools does not vary and therefore, the limitation exists in simplification of associated utilization between the technology planning tools. The limited review of the planning tools in these models cannot avoid the connotation that the information can be biased. This means that it could be a fatal disadvantage in supporting comprehensive decision making.

That is, the size of the national R&D project is enlarging with the explosion in public R&D demands resulted from the development of the economic society. Additionally, the necessity of cooperative researches among business associations or multiple agents is increasing following the integration and combination of various technologies. The situation is changing with expansiveness, sophistication and growing risks as well as the increase in uncertainty in when to invest large funds to achieve tangible results in a desired time. The role of the national R&D project also broke out from the limitations of solving scientific and technical difficulties and expanded into solving sophisticated economic and social issues and problems.

Hence, it is necessary to establish a planning system with various planning tools from the planning to the budget coordination and distribution as a tool to achieve the national goal that reflected the economic and social needs on environmental changes and science and technology such as technology and policy trend surrounding the rapid science and technology R&D. Furthermore, changes in the environment of science and technology R&D, the advancement of various planning measures related to the national R&D project and the rational associations between each planning tools are demanded at the same time.

To make comprehensive considerations on various issues and needs in science and technology, the national R&D projects and R&D subjects, it is

essential to develop an integrated planning model as well as to establish a planning system that regards the importance, association, and utilization between each informational technology planning tool, each executional technology planning tool, and the relationship of the two according to the purpose and objectives. Particularly, the planning system supporting comprehensive decision making on the national level is established only when the planning system that deals with the integrated model is established. This is because various complex changes and demands in the national R&D projects should be comprised in the technology planning system on the national level.

4. Hypothesis Verification of the Model

4.1 Verification method

It is required to verify whether this technology planning model integrating informational and executional technology planning tools is rational, feasible or has high potential of utilization as the technology planning coping with the rapidly changing science and technology environment. Especially, it is necessary to verify the appropriateness of including the executional technology planning tools within the integrated technology planning model. Therefore, the four hypotheses are framed for questionnaire verification.

Hypothesis 1. The executional technology planning tool is required on the national level.

Hypothesis 2. The individual executional technology planning tool is an important tool to be applied on the national level.

Hypothesis 3. The level of utilization of each technology planning tool differ according to the purposes of the policy planning, the project planning and the assessment.

Hypothesis 4. The level of importance and satisfaction of each technology planning tool differs according to the professionalism of the respondent.

In this study, the hypothesis verification method through an expert questionnaire survey was chosen. For this, the specialists were divided into three groups. The first group were experts with experience of working on R&D sites. The second group were professors of technology planning fields. The third group were public officers who were in charge of budget distribution regarding technology planning and the technology development projects. The positions of the public officers who participated in this study were higher than deputy director. And other participants were the research human resources with doctorial degrees. The subject organizations were in 6 groups – R&D research; policy establishment and planning; university; professional organization; corporations and others. The questionnaire was composed of 88 questions besides the questions on basic information on the respondents such as the affiliated organizations or positions. It is shown on Table 3. Although there are 10 questions overall, they are further discussed

Table 3 Composition of Questionnaire

Composition	Questions	No. Questions
Professionalism of the respondents	Relativity	9
	Duration of experience	9
Necessity / importance	Necessity	1
	Importance	9
	Level of Korea	9
Utilization in each project	Policy planning	9
	Project planning	9
	Assessment	9
Relativity of each tool	Informational tool vs. Executional tool	20
Continuity	Level (nation / governments / organization / project)	4
Total		88

into 9 technology planning tools. Some of the questions were initially short-answer questions but they was revised after the pre-questionnaire study and the number of questions were also reduced following the 5 point Likert scales.

In order to ensure reliability, an item on the professionalism of the respondents was added. It was intended to understand the respondent's degree of understanding on the technology planning and technology planning tool. Although the respondent was defined in advance, it was attempted to screen out after the test for the reliability of the test in case there was an inexperienced respondent. It was regarded that the respondent without professionalism was not the subject of this test. The experts were classified into the pre-classified groups. I requested answers to the questionnaire from 120 subjects and received responses from 72 respondents (60%).

The relationship between the current task of the respondents and the technology planning had significant difference. When scale 5 was the highest score of relationship, the average of responses for the TA was the lowest of 3.03, and the coordination of R&D priority was the highest of 3.78. For the duration of experience in the technology planning area, 'less than three years' was 53.2%, 'more than five years' was 28.3%, and 'three to five years' was 18.5%. The lower scores in the experience of respondents on the national technology planning could be a result of the recent attempt in the national technology planning.

The method of verification may vary according to the hypotheses. But it was judged from the scale of 5 points excluding the recognition on the necessity of the executional technology planning tool. The method of verifying the response on the necessity followed a simple format of 5 point scale (much needed, needed, normal, not needed, much not needed).

4.2. Result of verification

4.2.1 Necessity of the executional technology planning tool

The questions which verify the first hypothesis, "the executional technology planning tool is required on the national level", was in 5 point scale – 1. much needed, 2. needed, 3. normal, 4. not needed, 5. much not needed. In this case, the method of verification can be considered in many forms. First, it is needed to make a judgment whether only 'much needed' and 'needed' is required or whether 'normal' must be added to make the verification. Second is how much percentage of consents is required for verification.

This study adopted a conservative view on the responses required for the verification and excluded the item 'normal' and set up the responses higher than 4 points – 'needed'. And the social standard of consents is generally more than ⅔ or 70%, hence the conservative number of 70% was used as the standard for verification. That is, this hypotheses are verified when the answer 'normal' is more than 70% of the overall response. This standard number will enable hypotheses verification without separate statistic verification.

As a result, the answer, 'very needed' was 54%, 'needed' was 43%. The result shows that the 97% of the total respondents responded that the executional technology planning tool is required for the technology planning on the national level. From this distribution, it can be judged that the hypothesis of this study which shows the executional technology planning tool is required in the technology planning on the national level is valid.

4.2.2 Importance of each technology planning tool

This is to verify the second hypothesis – the individual executional technology planning tool is an important tool to be applied on the national level. There was a problem of repetition in the level of satisfaction on the utilization of specific tools and the importance of each tool on the preparatory survey stage. Hence, the importance and satisfaction of each tool has been separated as a separate item.

Verification of the hypothesis was conducted on the basis that if the percentage of both 'high (4 points)' and 'very high (5 points)' exceeds 70% as in the Hypothesis 1, it is sufficient to be accepted. The result is shown in Table 4. All of the four executional

technology planning tools had more than 70%[9]. On the other hand, all the responses where the level of importance is low, did not reach 10% in each tool. Therefore, Hypothesis 2, the executional technology planning tool is an important tool that can be applied, is also verified.

4.2.3 Utilization of technology planning tools on each stage

The utilization of nine national technology planning tools were analyzed from the policy planning, the project planning, and the evaluation planning. Moreover, from this analysis, the third hypothesis – the level of utilization of each technology planning tool differ according to the purposes of the policy planning, the project planning and the assessment – is verified. This hypothesis verified the difference in the responses of the political planning, business planning and evaluation item through the variance analysis.

The result showed that there is no difference on the level of utilization among three tools of TA, framing of the priority and budget coordination as shown on Table 5. The reason behind this result can be anticipated as following. It is difficult to differentiate the difference between each stage since the recognition on the importance itself was low. In contrast, since the framing of priority or the budget coordination is related to the budget, it can be judged that it is associated with the political planning, the project planning or assessment.

4.2.4 Difference of importance and satisfaction according to the professionalism

The professionalism of respondents was measured with the duration of experience relevant to each area. It was divided into less than three years, three to five years and more than five years. Table 6 shows the result.

The level of importance and satisfaction in

Table 4 Importance of each technology planning tool (%)

Technology planning tool	①Very low	②Low	③Normal	④High	⑤Very high	④+⑤
R&D preparatory feasibility study	0.0	5.6	11.1	52.8	30.6	83.3
Investigation·Analysis· Evaluation[1)]	0.0	4.2	22.5	46.5	26.8	73.2
Framing of R&D priority	0.0	2.9	9.7	40.3	47.2	87.5
R&D budget coordination	0.0	2.9	15.3	50.0	31.9	81.9

1) The number of respondents was 71, which is different from other items.

Table 5 The variance analysis result of the utilization on each stage

Technology planning tool	F	p-value
Technology trend survey	13.90	0.00***
Science and technology foresight	14.1	0.00***
Science and technology level	4.08	0.02**
TA	0.05	0.99
NTRM	2.54	0.08*
R&D preparatory feasibility study	3.52	0.03**
Investigation·analysis·evaluation	6.30	0.00***
Framing of R&D priority	0.57	0.57
R&D budget coordination	0.48	0.64

Note) *** 99%, ** 95%, * 90% significance level

9) For the importance of five informational tools, only the TA was 55.6% which is lower than the hypothesis standard and other four tools were 73.6-84.7% which is higher than the standard for the hypothesis verification.

Table 6 Level of importance of each national technology planning tool in accordance with the professionalism

Technology planning tool	Level of professionalism (duration of experience)			Total	Rank
	Less than 3 years	3-5 years	More than 5 years		
Technology trend survey	3.91	4.09	4.37	4.14	2
Science and technology foresight	4.15	4.17	3.89	4.10	4
Science and technology level	3.90	3.92	4.00	3.96	6
TA	3.66	3.58	3.53	3.60	9
NTRM	3.91	4.00	3.94	3.92	8
R&D preparatory feasibility study	4.11	4.00	4.25	4.08	5
Investigation, analysis, evaluation	4.17	3.76	3.88	3.96	7
Framing of R&D priority	4.24	4.00	4.59	4.32	1
R&D budget coordination	3.98	4.36	4.23	4.11	3
Average	4.00	3.99	4.07	4.02	

Table 7 The variance analysis result of the level of importance on each professionalism

Technology planning tool	F	p-value
Technology trend survey	2.38	0.10*
Science and technology foresight	0.63	0.54
Science and technology level	0.09	0.91
TA	0.16	0.85
NTRM	0.05	0.96
R&D preparatory feasibility study	0.33	0.72
Investigation·analysis·evaluation	1.47	0.24
Framing of R&D priority	2.06	0.14
R&D budget coordination	1.35	0.27

* : Confidence on the significance level 0.1

accordance with the professionalism is a different concept. Therefore, it is necessary to divide the hypothesis on the level of importance and satisfaction. As a result of analyzing the level of importance of the technology planning tool according to the professionalism of the respondents, the difference was surveyed only in the technology trend survey and there was no difference on the recognition of the level of importance in other technology planning tools.

The statistic data for verifying the level of satisfaction of each technology planning tool in accordance with the professionalism is shown on Table 8.

As a result of analyzing the difference in the level of satisfaction in accordance with the professionalism Table 9, there were differences only in the preparatory feasibility study and the budget coordination and there were no differences in the professionalism in other technology tools.

As a result of reviewing the original data to find the difference in the level of satisfaction in the two tools, it showed that the level of satisfaction among the group with more than five years of professionalism was notably low. The level of satisfaction on the preparatory feasibility survey and the budget coordination was 2.75 and 2.69 respectively which is lower than 3 points of the normal. It can be said that the level of satisfaction on the preparatory feasibility survey and the budget coordination is very low. The level of satisfaction of the respondents with less than four years of experience were also 3.30 which shows they are not much satisfied.

Table 8 Level of satisfaction of each national technology planning tool in accordance with the professionalism

Technology planning tool	Level of professionalism (duration of experience)			Total	Rank
	Less than 3 years	3-5 years	More than 5 years		
Technology trend survey	3.13	2.73	3.33	3.11	7
Science and technology foresight	3.36	3.08	3.33	3.31	2
Science and technology level	3.07	2.92	3.15	3.08	8
TA	2.89	2.67	2.73	2.82	9
NTRM	3.21	3.30	3.41	3.29	3
R&D preparatory feasibility study	3.30	3.20	2.75	3.14	6
Investigation·analysis·evaluation	3.45	3.65	3.13	3.44	1
Framing of R&D priority	3.11	3.30	3.00	3.18	4
R&D budget coordination	3.19	3.45	2.69	3.15	5
Average	3.19	3.14	3.06	3.14	

Table 9 The variance analysis result of the level of satisfaction on each professionalism

Technology planning tool	F	p-value
Technology trend survey	2.19	0.12
Science and technology foresight	0.62	0.54
Science and technology level	0.45	0.64
TA	0.40	0.67
NTRM	0.44	0.64
R&D preparatory feasibility study	2.58	0.08*
Investigation·analysis·evaluation	1.88	0.16
Framing of R&D priority	0.47	0.63
R&D budget coordination	2.39	0.10*

(Note) Same as above

5. Conclusions

In this study, a technology planning tool that composes the national science and technology planning system appropriate for the new science and technology environment was studied through the analysis of association between the informational technology planning tool and the executional technology planning tool in order to reinforce the strategic technology planning function on the national level. Through the theoretical analysis related to existing planning theories, a new technology planning model that comprehends the informational technology planning and the executional technology planning required on the national level and the hypothesis supporting this model was set up to research the status of utilizing planning tools for verification.

This study can be summarized as following:

First, the executional technology planning tool is added to the existing informational technology planning tool based on the theoretical background and the suggestions of the experts and a new integrated technology planning model was proposed that integrates and expands on the existing tool.

Second, the necessity of this integrated technology planning model on the technology planning of the national level is verified through researches on the current status.

Third, it is confirmed that there was a close relationship between each technology planning tool.

Fourth, it is demonstrated that the integrated technology planning model is appropriate in composing the national technology planning system demanded

by the recent science and technology environment changes.

Expansion of the scope of the technology planning tool

Strategic technology planning on the national level plays a role in framing the R&D objectives and directions, and choosing and selecting the most efficient and effective method for the timely achievement of national development strategy and planning. In order to fulfill this function, there is an absolute need for understanding relations related to science and technology, R&D policies and technology trends and mid to long term economic and social prospects (informational technology planning), and providing the standard for desirable value judgment by framing the national priorities and reflecting on the budget coordination (executional technology planning) for the activation of national technology planning.

Reinforcement of relationship between technology planning tools

There was a close relationship between the informational technology planning that ensures the information on the relations surrounding R&D and the executional technology planning tool that provides the information required for the decision making related to national R&D policies and executions by analyzing widely scattered information and frequently changing the science and technology related information. Moreover, this result implies that science and technology related decision making can be conducted with more efficiency and effectiveness by associating each technology planning tool.

Systemization of national technology planning tools

The systemization of technology planning on the national level is not the simple enumeration of the technology trend analysis, science and technology foresight survey, science and technology level analysis, T, writing of NTRM, framing of priority, the national R&D program investigation, analysis and evaluation, preparatory feasibility study, and each technology planning tool for the budget coordination. But it is the organic association of preparing a system to appropriately provide high quality information on the decision making on the national level. In other words, it is to set up a system to provide high quality information to the decision makers through haste information analysis and processing with comprehensive consideration of the purpose of technology planning, associated planning, mutual utilization and feedback of the planned results, efficient utilization of technology planning resources such as related data and expertize, the level of planning results, and timely.

Moreover, in national technology planning, the possibility prevails that the association between the subjects of technology planning also is a very important factor in composing a system since it requires the analysis and processing of wide ranged data. The result of each technology planning through these processes is refluxed again to the next stage of technology planning activity to have a system to utilize the basic information of the planning. This will be the essential element in the professionalism and enhancement of the technology planning results.

A study on the application of the mutual relationship between integrated technology planning tools

It is necessary to reveal the relationship between the informational technology planning tools and the executional technology planning tools by specifying the relationship in the future. Especially, in order to establish the national technology planning system that efficiently deals with more sophisticated and diverse subjects of planning, it is necessary to analyze the relationship between each tool. Also, it is required to review the association system between the planning activities based on the relationship. This is an essentially study to establish a concrete national technology planning system that corresponds to the rapidly changing science and technology environment based on this relationship. Therefore, the study should continue to optimize and improve on the national technology planning system appropriate to the status in Korea.

Study on the segmentation and enhancement of technology planning by a dynamic feedback system

It is necessary to study the specifications of the dynamic feedback system reflecting the complementary plans through both informational and the executional technology planning in addition to influencing the policy turnouts. This is not just a step of inducing significant implications or judgment standards but the utilization should be expanded to work as a cause to enable the specified plans through active feedback on the next stage of technology planning activities. Moreover, utilization constantly triggers the development of methodologies that promotes the level of information achieved as an information technology planning tool and maintains consistency among a large quantity of information and as a result, naturally engages the heightening of the technology planning tools.

The desirable future national technology planning system would be based on the compositional element from the existing informational technology planning tool and the executional technology planning tool. Also, by providing the planning result in association with each technology planning tool, it will provide the standard and direction of decision making related to the execution of policies according to the current status, priority and investment directions of the national R&D project. Also, it reflects the economic and social demands, sets up the national goal and establishes a national science and technology basic plan to achieve it. This is reflected back to the comprehensive national plans which segment the development goal of the nation to achieve specified goals in each ministry. The specific executional plans must be established for the national development based on the science and technology by coordinating from the general ministry level with the consideration of the rational distribution of limited R&D resources. Lastly, the executional plans and results from these processes should be systematically refluxed to each technology planning activity which can be utilized as basic information for the next planning.

6. References

Baker, N. R. and W. H. Pound (1964), R&D Project : Where We Stand, IEEE Transactions on Engineering Management, EM-11, pp. 124~134

Bark, Pyeng-Mu and Lee, Gi-Jong (2009), A Study on the Improvement of National R&D Evaluation System under the Science and Technology Innovation System: Focused on the R&D Budget Evaluation System, Technology Innovation Journal, 12:4.

Bilich, F. (1989), Science and Technology Planning and Policy, Elsevier Science Publishers, pp. 47~57.

Boar, B. H (1993), The Art of Strategic Planning for Information Technology, AT&T, John Wiley & Sons

Byun, Do-Young and Chung, Keun-Ha (2003), National Technology Roadmap, KISTEP, Ministry of Science and Technology.

Carter, K. (1996), After the Plan's Approved: Keeping the Technology Planning Process Alive and Moving, Technology & learning, 16:28-37.

Cetron, M. J. (1970), A Method for Integrating Goals and Technological Forecasts into Planning, Technology Forecasting and Social Change, 2:30.

Chen, Z.-L., Li, S., Tirupati, D. (2002), A Scenario-based Stochastic Programming Approach for Technology and Capacity Planning, Computers & operations research 29(7):781-806.

Chung, Keun-Ha (2002), A Study on the National Technology Roadmap (I), Ministry of Science and Technology.

Chung, Keun-Ha (2007), A Study on the Technology Planning Tool on the National Level, Hannam University.

Chung, Keun-Ha (2009), A Study on the Science and technology Planning for Efficient Accomplishment of the National Science and technology Goals, KISTEP.

Chung, Keun-Ha and Ko, Dae-Seung (2002), The Third Study on the Technology Induction for Science and technology Foresight, KISTEP.

Georghiou, L. (2001), Third Generation Foresight - Integrating the Socio-economic Dimension, The Proceeding of International Conference on Technology Foresight, NISTEP.

Grupp, H., Linston A. Harold (1999), National Technology Foresight Activities Around the Globe, Technical Forecasting & Social Change, Elsevier, New York.

Haselkorn, A. ; Rosenstein, A. H. ; Rao, A. K. ; Van Zuiden, M. ; Coye, M. J. (2007), New Technology Planning and

Approval: Critical Factors for Success, American journal of medical quality : The Official Journal of the American College of Medical Quality.

Karlsson, M. (2004), Organizing Technology Planning - A Contingent Approach, Doktorsavhandlingar vid Chalmers tekniska hogskola.

Kimball, C., Sibley, P. A (1995), New Paradigm for Technology Planning: The Technology Maturity Model, Emerging technologies, ISTE, pp.140.

Koc, T.V., Polat, S., Yunusodlo, V., (2001), A Structural Approach to Corporate Technology Planning, Portland International Conference on Management of Engineering and Technology.

Koerner, E., (1989), Technology Planning at General Motors, Long Range Planning, 22(2):9~19.

Korea Institute of Science and Technology Policy (KISTEP) (2005), The Third Science and technology Foresight Survey: Prospects on the Future Society and the Science and technology of Korea.

Lee, Sang-Yup and Chung, Keun-Ha, (2007), A Study on the Induction of Issues and Analysis for Efficient Evaluation of the National R&D Project, KISTEP.

Lee, Sungjoo, Sungryong Kang, YeSeuk Park and Yongtae Park, (2007), Technology Roadmapping for R&D planning: The Case of the Korean Parts and Materials Industry, Technovation, 27(8):433-445.

Lim, Ki-Chul (2000), A Study of Domestic and International Technology Planning Methodology, KEIT.

Martin, B., (1989), Research Foresight : Priority Setting in Science, London & Newyork.

Martino, J.P., (1994), A Technology Audit: Key to Technology Planning, Aerospace and Electronics Conference, Proceedings of the IEEE, pp.1241-1247.

Metz, P.D., (1996), Integrating Technology Planning with Business Planning, Research, Technology Management, 39(3):19-22.

National Institute of Science and Technology Policy (NISTEP) (2004), The Eighth Science and technology Foresight Survey Report.

National Science and Technology Council(NSTC), (1995), Strategic Planning Document - Information and Communication.

Pappas, G. F. & D.D. Maclaren, (1995), An Approach to Research Planning, NSTC/CIC.

Park, Byung-Won (2009), A Study on the Methodology and Framework of Science and technology Foresight Survey, KISTEP, Ministry of Science and Technology.

Park, Byung-Won (2009), The Total of the National R&D Project, KISTEP, Ministry of Science and Technology.

Phaal, Robert, Clare J. P. Farrukh and David R. Probert, (2004), Technology Roadmapping - A Planning Framework for Evolution and Revolution, Technological Forecasting and Social Change, 71(1-2):5-26.

Rosen, E. M. & W.E. Souder, (1965), A Method for Allocation R&D Expenditures, IEEE Transaction on Engineering Management, EM-12. pp. 87~93.

Seol, Sung-Soo et al (1995), A Study of Overseas Information Communication R&D / Technology Planning - Promotion of a Korean Technology Planning System, Board of Information Communication Research Management, Electronics and Telecommunications Research Institute.

Sollee, S. S., Luquette, G. P. (1995), ; Maruta, H., A Business Planning Approach that Integrates Asset Management, Strategic Planning and Technology Planning, The petroleum industry's contribution to Indonesia's development: past, present and future, The petroleum industry's Association, pp. 495-508.

STEPI, (1995), A Long-Range Plan for Science and Technology Toward the Year 2010, Science and Technology Policy Institute, Seoul.

Vincent, J., (2004), Incorporating Social Shaping into Technology Planning for 3G/UMTS, 3G Mobile Communication Technologies, 2004, Fifth IEE International Conference.

Waissbluth, M. ; de Gortari, A., (1990), A Methodology for Science and Technology Planning based upon Economic Scenarios and Delphi Techniques - The case of Mexican agroindustry, Technological Forecasting and Social Change, 37(4):383-397.

Whalen, P. J., (2007), Strategic and Technology Planning on a Roadmapping Foundation, Research Technology Management, 50(3):40-51.

Wildavsky, Aaron, (1974), The Politics of the Budgetary Process, 2nd Ed., Boston: Little Brown.

Yim, Myung-Hwan, A Technology Planning Model for the Induction of Key R&D Projects - Focused on the Information Technology Development Plans in the Public Area", Study on the Technology Innovation.

Yoon, Sung-Sik (2003), A Theory on Budgets, Nanam Publishing.