Master Class

Foresight for Science and Technology Priority Setting in Korea

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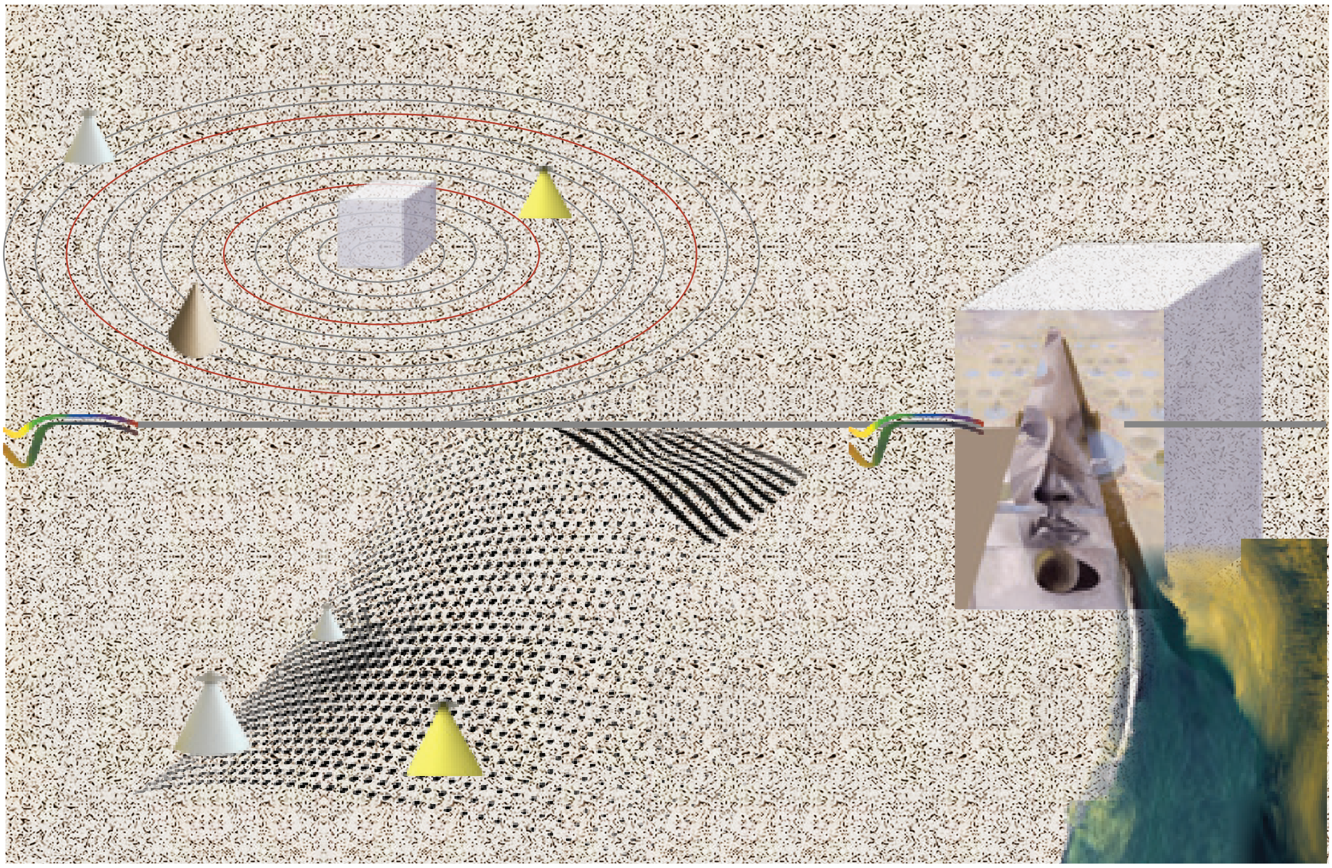

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Abstract

The main purpose of Technology Foresight (TF) in Korea is to predict the development of S&T and use the results in developing S&T policies. However, informing the public about what the future holds based on the development of S&T is an equally important role of TF.

Since the introduction of the first TF in 1994, Korea has conducted four such studies. TF in Korea has become a key process in setting S&T policy, such as the Science and Technology Basic Plan (S&T Basic Plan). The S&T Basic Plan determines the national strategic technologies by reflecting on future technology. The S&T Basic Plan is a mandatory legal planning process established every five years by the Korean government. It is the top-level policy document affecting S&T-related policy making in Korea.

TF in Korea primarily utilizes the Delphi method. The third and fourth TFs have strengthened the links between S&T and society by determining future technologies capable of solving future needs. The fourth TF presented scenarios and special illustrations to show members of the public the future technologies and their implications for society. Additionally, the fourth round of TF analyzed the potential negative impacts of future technologies.

Keywords: technology Foresight; science and technology (S&T) policy; Delphi method; technology assessment; S&T strategies

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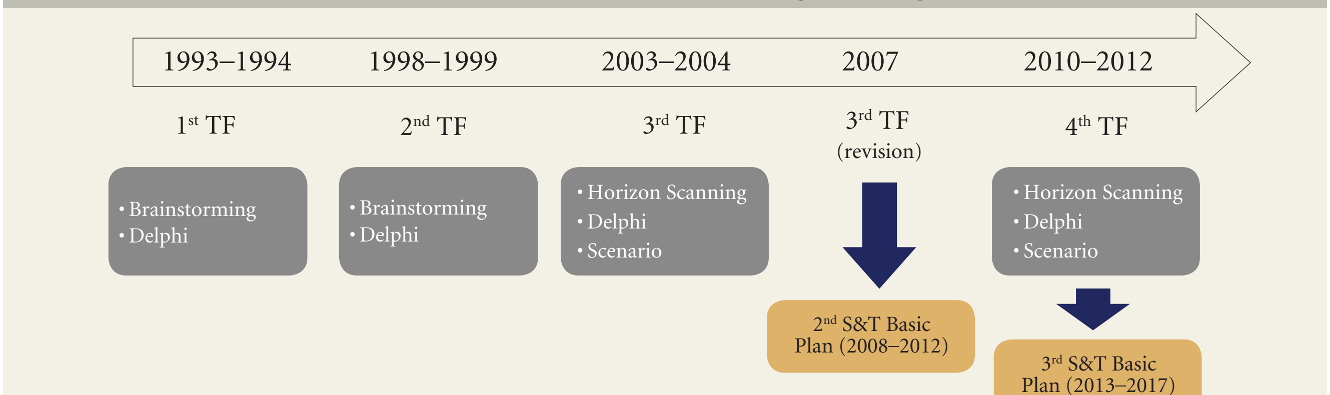
Since the implementation of the first TF in 1993–1994, TF in Korea has continuously advanced in response to society's increasing demands. Since the Framework Act on Science and Technology in 2001, which specified regularly carrying out TFs, national TFs have been conducted every five years. Thus, from the third TF onwards, Korea carries out TFs every five years. In 2007, the third TF was revised to increase complementarities with the S&T Basic Plan, the nation's top-level plan in the field of S&T. The results of the revised TF were directly reflected in the second S&T Basic Plan. Furthermore, the results of the fourth TF (conducted during 2010–2011) found expression in the third S&T Basic Plan. All four TFs performed to date have primarily used the Delphi method. Since the third TF, future social trends were first identified and then future technologies predicted based on these trends; moreover, scenarios were developed founded on the results of the TF (Figure 1). Currently, the Ministry of Science, ICT and Future Planning (MSIP) is responsible for TFs while the Korea Institute of S&T Evaluation and Planning (KISTEP) conducts the TFs.

Outline of Korean Technology Foresight

The first TF aimed to identify a long-term development strategy for S&T. At the same time, Korea launched a large-scale, inter-ministerial R&D project (1992) which aimed at "raising the level of Korean S&T in the 2000s to the level of the G7 countries". In 1993, Korea's national R&D budget exceeded one trillion won for the first time. In the first TF, S&T professionals determined 1,174 future technologies over the next 20 years (1995–2015). Using the Delphi method, this TF surveyed the importance of future technologies, as well as their implementation time and technological level. In addition, the TF identified the factors hindering the creation of future technologies and the main actors in the development of future technology [*Shin*, 1998].

The year 1999 saw the release of the results of the second TF. A Ministry for S&T had been created in 1998, and the National S&T Council was set up in 1999. The purpose of the second TF was to study the future developments of S&T and to compare Korea's level of technology with that of more developed countries. This would enable policy makers to set goals for S&T policies and acquire the data needed for preparing a S&T strategy. In other words, the goal of the TF was to present a portfolio for the distribution of S&T resources nationally and to establish strategies for R&D projects based on the results of the TF. The second TF categorized the overall field of S&T into 15 areas, set the forecast period at 25 years from 2000 to 2025, and identified 1,155 future technologies. As in the first round of TF, the 1999 round employed the Delphi method to examine the importance, implementation time, and technological levels of future technologies. The 1999 TF also identified the main actors and the necessary policy measures for implementing future technologies [*Lim*, 2001].

Fig. 1. **Outline of Korean technology foresight**



Source: compiled by the authors.

Table 1. **An example of future needs and issues in the third TF (individual level)**

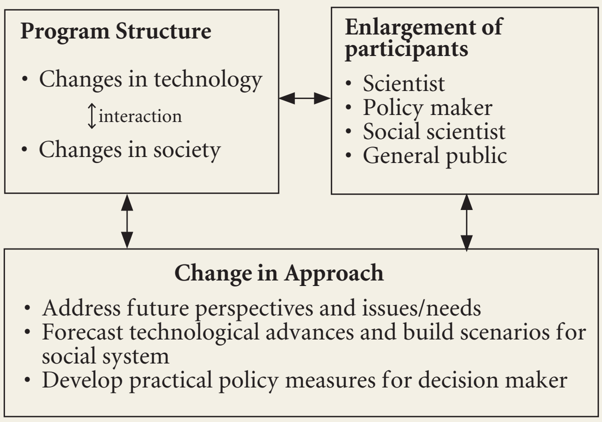
Actor	Need		Need or issue
	Main theme	Detailed theme	
Individual	Healthy life	Dealing with diseases	• Prevention, diagnosis and treatment of diseases that are hard to cure • Geriatric diseases • Chronic diseases • Contagious diseases • Artificial organs • Application of biotechnology
		Quality health service	• High quality healthcare system (ICT) • Alternative medicines • Secondary infection in hospitals
		Healthy normal life	• Comfortable daily life • Health-maintaining system
		Safe foods and consumer products	• Safer foods • Safer consumer products • Environmentally-friendly foods and consumer products

Source: [*Park, Son*, 2010].

Figure 2 below indicates the conceptual diagram of the third TF, conducted from 2003 to 2004. Unlike the previous two TFs, the third TF considered the relationship between technology and society. In addition, the scope of participation expanded from S&T experts to include policy makers and social scientists. The third TF had three stages. The first stage identified the future issues and needs of society and the future technologies to address these needs. To organize future society's needs systematically, the TF separated them into individual, social, national, and global needs. Table 1 shows examples of future needs associated with individuals. Eight specialized divisions in the field of S&T were configured to determine future technologies; the forecast covered the period from 2005 to 2030, and identified 761 future technologies. The second stage evaluated the impact of various factors such as the implementation time of future technologies via the Delphi method. Finally, the third stage created scenarios about likely future challenges in education, health, labor resources, and security [*Park, Son*, 2010].

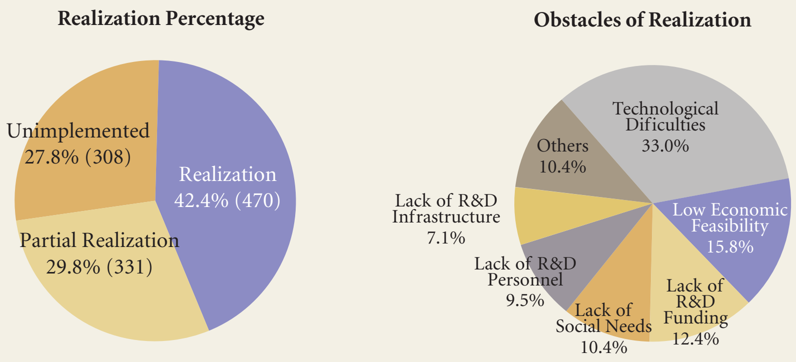
How reliable have the previous TFs been in their predictions about future technologies? An evaluation of the 1,109 future technologies predicted to exist by 2010 according to the first TF of 1994 found that 470 of these technologies were

Fig. 2. **Conceptual diagram of Korea's third TF (2003–2004)**



Source: [*Park, Son*, 2010].

Fig. 3. **Implementation percentages and obstacles to implementing the future technologies as identified by the first TF**



Source: calculated by the authors.

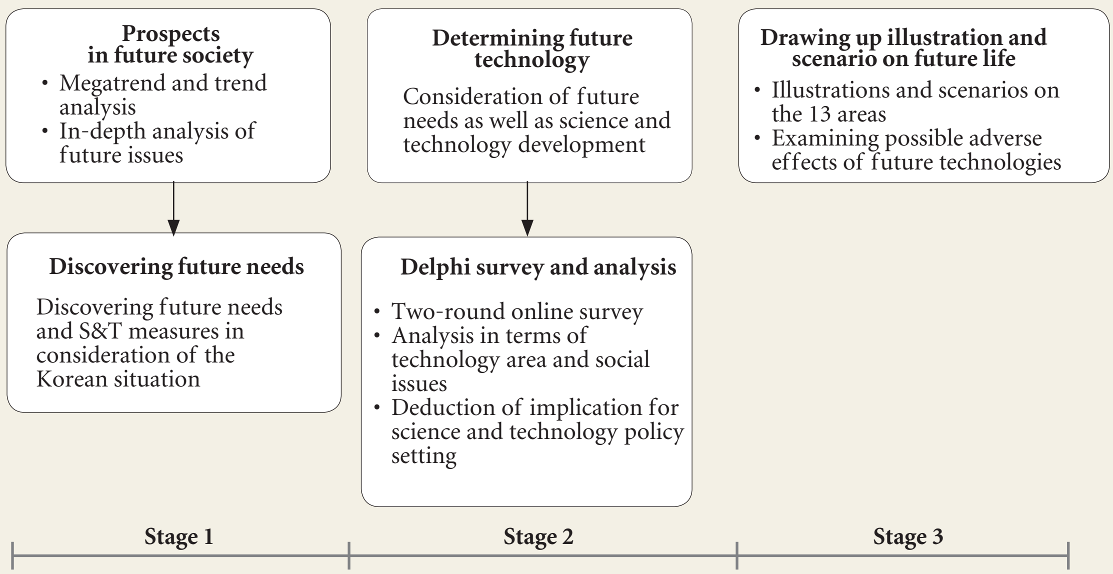
fully implemented and 331 partially implemented. This means the first TF's accuracy rate is 72.2%, when we include the partially implemented technologies.

The partially implemented technologies include cases where the assessment of implementation depended on the viewpoint of the evaluation because any one future technology is determined by multiple technical factors or the concept of the future technology is ambiguous. Using the Delphi method, the major obstacles for implementing future technologies were found to be, in descending order: 'Technological Difficulties' (33.0%), 'Low Economic Feasibility' (15.8%), 'Lack of R&D Funding' (12.4%), followed by 'Lack of Social Needs' (10.4%) (Figure 3).

The Fourth Korean Technology Foresight

The fourth TF forecasts the future up to 2035 and had three stages (Figure 4). The first stage forecast the future of Korean society and examined future needs. The second stage identified future technologies and conducted the Delphi survey to examine factors such as the technological implementation time and the time for socially distributing future technologies, Korea's level of technology,

Fig. 4. **Procedure of the fourth TF**



Source: [*Choi et al.*, 2014].

the main actors for technological development, and governmental policies required for implementing technologies. The third and final stage created scenarios and illustrations depicting the shape of the future world that would be changed by implementing and distributing future technologies divided into 13 different areas, such as home and school. In addition, the fourth TF presented the possibility of various social changes caused by the development of future technologies by drawing up scenarios on the negative impacts of technological development.

Forecast for the Future Society and Discovering Future Needs

The fourth TF identified the most significant global trends that will affect societies up to 2035, or 'megatrends'. These megatrends are: i) further globalization; ii) increasing conflicts; iii) demographic changes; iv) greater cultural diversity; v) depletion of energy and resources; vi) greater climate changes and associated environmental problems; and vii) development and convergence of S&T. Furthermore, the continuing rise of China can also be considered a megatrend in its own right, which further accelerates the seven other megatrends. Table 2 below shows these eight megatrends, along with the 25 trends comprising the eight megatrends. For each trend, the TF examined the risks and opportunities for Korean society. Based on this analysis, the TF drew up the future society's needs.

Determining Future Technologies

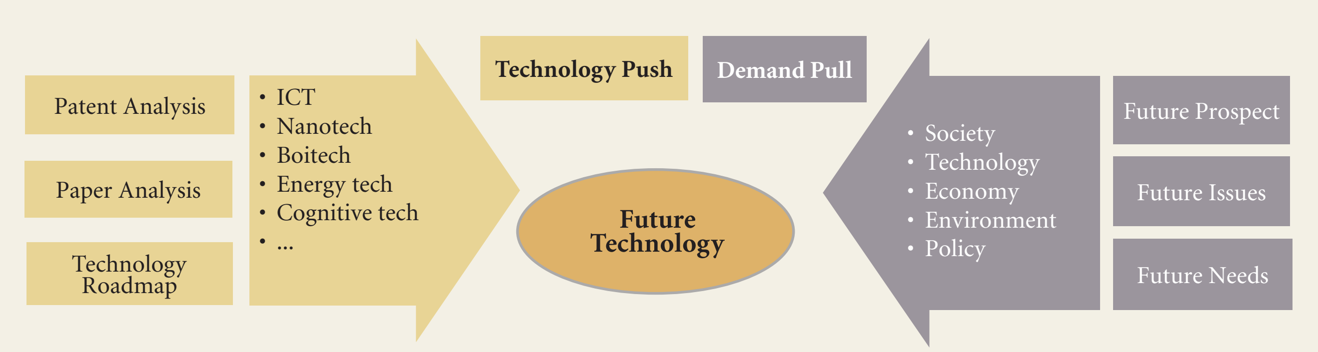
The fourth TF defined future technologies as the 'technology that can be implemented technologically or distributed socially by 2035 and has the potential for significant impacts on S&T, society, or economy.' [NSTC, KISTEP, 2012b]. S&T experts determined future technologies in two ways, as shown in Figure 5. One way is the Demand Pull type future technology, where future technologies capable of addressing the needs of future society are determined through predicting the characteristics of future society. Another method is the Technology Push

Table 2. **Megatrends and trends of the fourth TF**

Megatrend	Trend
Further globalization	• Integration of the global market • Multi-polar world order • Globalization of workforce • Extension and diversification of the governance concept • Rapid spread of epidemics
Increasing conflicts	• Deepening of conflicts between peoples, religions, and nations • Increase in cyber terrorism • Increase in risks of terrorism • Greater polarization
Demographic changes	• Continuously low birth rates and ageing populations • Increase in urban population globally • Changes in the concept of family
Greater cultural diversity	• More cultural exchanges and multicultural socialization • Improvements in women's status
Depletion of energy and resources	• Increased demand for energy and resources • More shortages of food and water • Greater use of energy and natural resources as weapons
Greater climate changes and environmental problems	• Greater global warming and increases in abnormal weather phenomena • More environmental pollution • Changes in ecosystems
Continuing rise of China	• Increase in China's economic influence • Increase in China's diplomatic and cultural influences
Development and convergence of science and technology	• Development of information technology • Development of life science technology • Development of nanotechnology

Source: [*Choi et al.*, 2014].

Fig. 5. **Methods to identify future technologies used in Korea's fourth TF**



Source: [*Choi et al.*, 2014].

type future technology, where future technologies are expected to emerge from the development of S&T regardless of social needs. Technology Push type future technologies include technologies expected to emerge due to the accumulation of S&T knowledge, as well as technologies that currently only exist in conceptual form yet will become visible in the future. The fourth TF used methods such as patent trends, analyses of scientific papers, and technology roadmaps to determine Technology Push type future technologies.

This method enabled a list to be compiled of the 652 future technologies expected to emerge by 2035. As shown in Table 3 below, 601 (92.2%) of the 652 future technologies are expected to emerge to address the needs of society in the future, while only 51 technologies (7.8%) are expected to appear because of developments in S&T. In addition, 394 technologies are related to more than two future trends, which means that more than 60% of future technologies will address future needs related to plural trends. Examining the distribution of future technologies by sector reveals that there are over 90 technologies related to each of the following sectors: machinery, manufacturing, aerospace and astronomy, agriculture, forestry and fishery, and materials and chemical engineering. This is a relatively high indicator. In contrast, the fields of information, electronics, and communication had the lowest number of technologies at 55 each (Figure 6). The reason for the low number of technologies in the latter fields is that technologies utilizing information and communication technologies (ICT), such as biosensor technology, are included in their field of application rather than in the ICT field. Table 4 below gives examples of detailed fields included within their respective fields.

Delphi Survey and Analysis

The fourth TF included a two-round online Delphi survey, which twice collected the opinions of experts. Responses were received from 6,248 people in the first round and from 5,450 in the second round. The number of respondents who participated in the first and second rounds increased significantly compared to the first three TFs (Table 5). Table 6 summarizes the Delphi survey questions used in the fourth TF.

Table 3. **Future technologies identified by Korea's fourth TF and the distribution correlation between future trends**

	Number of future trends related to each technology						Total
	Technology Push	Demand Pull					
Number of technologies	51	207	262	99	29	4	652
Proportion (%)	7.8	31.7	40.2	15.2	4.4	0.6	100.0

Source: calculated by the authors.

Table 4. **Examples of the detailed fields within each field of the fourth TF**

Field	Detailed Field
Machinery, Manufacturing, Aerospace and Astronomy	manufacturing and process, robot, space and exploration, satellite, aircraft, unmanned aerial vehicle, automobile, shipbuilding, defense, counterterrorism, etc.
Agriculture, Forestry and Fishery	crop production, animal science, animal disease, zoonoses, fish farming, tree breeding, forest environment, customized food, etc.
Construction and Transportation	construction material and equipment, building control management system, railroad, aviation, distribution, safety management, etc.
Life and Healthcare	brain science, pathogen measurement, medical engineering, cancer diagnosis and treatment, medicine, artificial organ, oriental medicine, etc.
Materials and Chemical Engineering	functional alloy material, nano-sensor, semiconductor material, medical material, battery, carbon nanotube, chemical process, etc.
Energy, Resources and Extreme Technology	smart grid, electric power, nuclear energy, resource and exploration, solar energy, extreme technology, etc.
Information, Electronics and Communication	virtual reality and augmented reality, display, sensor, telecommunication, information protection, information theory, etc.
Environment and Earth	weather and climate, air quality management, ecosystem restoration, carbon capture and storage, eco-friendly material and process, earthquake, marine environment, etc.

Source: compiled by the authors.

Table 5. **Number of Delphi survey respondents in four TFs**

		1st TF	2nd TF	3rd TF	4th TF
Number of future technology		1174	1155	761	652
Response	1st round	1590	1833	5414	6248
	2nd round	1198	1444	3322	5450

Source: calculated by the authors.

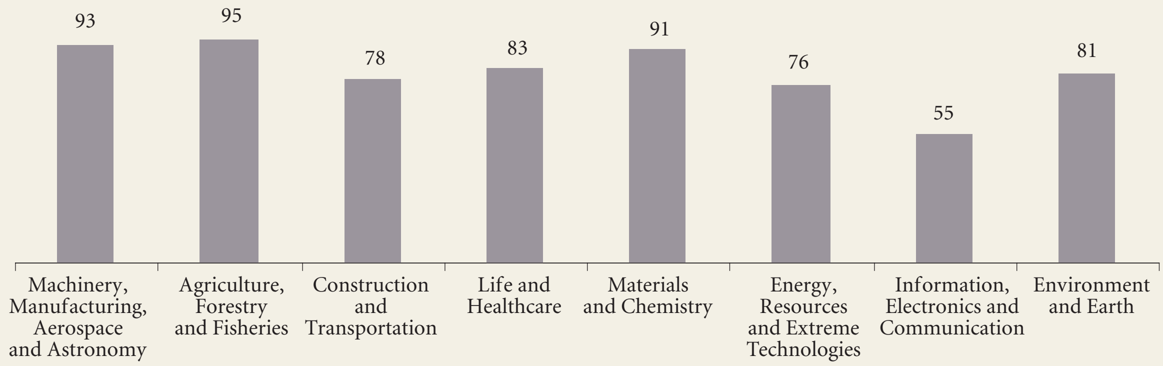
Table 6. **Delphi survey items of the fourth TF**

Survey item	Survey content
Technology level	Nation at the forefront of the technology level
	Korea’s technology level
Technological implementation time and social distribution time	Implementation time, and general public use time in Korea
	Realization time and general public use time in most-advanced technology nations
Technological implementation measures	Main actors in R&D
	The need for collaborative research
Role of government	The need for government investment
	Government priority measures to be implemented
Importance in future society	• Contribution with respect to technology aspects • Contribution with respect to public benefits • Contribution with respect to economy and industry
Possibility of negative effect	Possibility of negative effect caused by general public use
Institutions involved in research	Local and international research institutions
Interrelationship with future trends	Relationship to 22 future trends*

* Three technology-related trends were excluded from the 25 future trends.

Source: compiled by the authors.

Fig. 6. **Future technology distribution according to Korea's fourth TF**



Source: calculated by the authors.

The average time for technological implementation of future technologies as determined by the fourth TF was by 2021. The TF predicted their widespread distribution across society to occur in 2023.

When comparing each field's results with the average technological implementation time estimates, the field of information, electronics and communication was the fastest (2019), while the field of life and healthcare was the slowest (2022). Experts surveyed agreed that 519 future technologies (79.6% of the total identified) will be technologically implemented in Korea within the next 10 years (by 2022). Furthermore, they predicted that 294 technologies would be distributed across society within the same period of time. The predicted average time for future technologies to be widely implemented across society is 2.7 years.

When examining the current state of countries with the highest level of technology in relation to the 652 future technologies, the fourth TF found that the United States possesses the highest level of technology in 495 technologies. Japan was second with 141 technologies, and the EU was a distant third with 32 technologies. The research revealed that Korea's average technology levels were 63.4% of the leading countries regarding the 652 future technologies. The level of technology for 18 future technologies was above 80%, which indicates that Korea leads the field in these technological areas, with nine included in the field of information, electronics and communication, which is more than that in any other field. At the same time, the study found that the levels of 22 technologies were below 40% and thus were part of the 'lagging' group, among which nine were in the field of machinery, manufacturing, aerospace and astronomy. Of the 652 future technologies, Korea's highest technology level was in 'terabit level next-generation memory device technologies' (90%).

When examining the priority policy measures that the government should enact to help implement future technologies, the survey results showed that most respondents felt increased R&D funding was highest priority (31.6%). The next most important policies stated were greater collaboration, training for staff, and infrastructure construction. The need for system improvement ranked the lowest; however, it was higher in the construction and transport field (13.8%) and environment and earth sciences (10.4%) than other fields. Future technologies with faster implementation times placed more value on infrastructure construction and system improvements, while future technologies with longer implementation times placed relatively more value on staff training and greater collaboration (Table 7).

Table 7. **Priority policies to support the development of future technologies by time needed for technological implementation based on the results of Korea's fourth TF**
(share of respondents who chose each option, %)

Technological implementation time	Increased R&D funding	Greater collaboration	Staff training	Infrastructure construction	System improvements
Short(-2017)	28.5	20.0	16.9	22.1	12.5
Medium (2018-2022)	31.7	22.9	18.9	18.9	7.6
Long (2023-)	31.9	23.7	22.3	18.3	3.8
Total	31.6	22.8	19.5	19.0	7.1

Source: calculated by the authors.

Unlike the previous TFs, Korea's fourth TF asked about any unintentional negative impacts on society, culture, or the environment of the widespread social distribution of future technologies. Some examples of future technologies with relatively high likelihoods of negative impacts are:

- Technology for building underground waste storage
- Personal life log technology which can create a database by saving one's personal life with sound and image data (Write scenario)
- Gene therapy technology for fetus
- Electro Magnetic Pulse (EMP) bomb disturbing electronic parts in the enemy's weapon system by detonating it in the air of the enemy
- Technology of developing functional transgenic fish species that can produce useful substance (nutritional contents, medicine and medical supplies)
- Conversion technology from uranium-238 to plutonium-239 using the liquid metal reactor.

Six of these technologies were included in a future scenario, accompanied by an analysis of both the positive and negative effects.

The World of the Future Changing through S&T

The main purpose of TF in Korea is to predict the development of S&T and use the results in developing S&T policies. However, informing the public about what the future holds based on the development of S&T is an equally important role of TF. For this purpose, the future world is divided into 13 different areas (home, school, hospital, office, factory and plant, transportation, fishing village, farming village, city, disaster, space, war and terror, and underground) and each area is connected with the future technologies. The scenarios and accompanying illustrations are composed by classifying the future into ten years later (year 2022) and the year 2025 to compare the future world over time (Figure 7). The periods of time when the future technologies are likely to be widely distributed — as determined through the Delphi survey — were used as the reference points for selecting the future technologies specific to each point in time.

Policy Implications

By analysing the Delphi survey results about future technologies as part of Korea's fourth TF, we identified the following policy implications.

First, the share of Korea's technologies belonging to the leading group (level of over 80%) or the next group (level of 61–80%) is 72% of the 478 technologies that experts expect to be implemented within the next five to ten years. Korea has the possibility of joining the world-leading group if it pursues R&D more actively. However, Korean technologies are not yet at the highest level. Therefore, policy support for developing unique technologies is necessary. Creating future

Box 1. **Scenario of a future society (a family in 2035)**

The phone rings while Jung-Hoon and his wife are watching TV. Their daughter appears, smiling brightly, on the TV screen. For a second, Jung-Hoon and his wife think that the drug which their daughter has been taking for three months for depression caused by her inability to become pregnant is effective. The drug their daughter takes is a **non-addictive** chemical that she can take any time **to enhance positive emotions, such as happiness, without causing harm to her body**. The drug regulates crime-related emotions in a calculated manner and improves brain capacities, such as reasoning skills, creativity, and memory storage abilities; therefore, it is used in rehabilitating criminal offenders and rehabilitation education as well as a supplement food for students preparing for a test.

The daughter's news that they hear as soon as they answer the phone brings joy greater than her bright face. 'Dad, Mom, I'm pregnant!' The daughter says that the device she received a while back from her friend greatly helped, and she begins to explain the process one by one, from the strange feelings she was getting these days to visiting the hospital and hearing the news of her pregnancy. The friend's present is **a portable device that tells the user her biological cycle, and it diagnoses the bio-molecular changes related to pregnancy and predicts the possibility of pregnancy to inform her when she is at her optimal fertile period.**

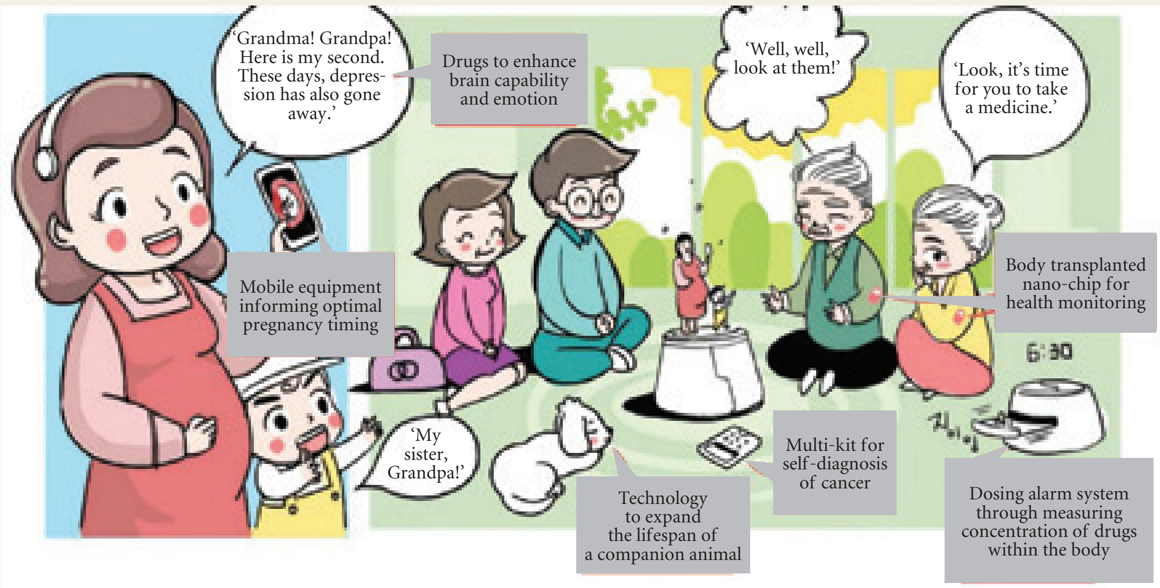
After the phone call with her daughter, Mi-Young runs into the room. "What are you up to?" asks Jung-Hoon as Mi-Young opens the drawer looking for something. 'We must stay healthy if we want to see our grandchild… Found it!' Mi-Young heads to the bathroom holding a cancer diagnostic kit. **The cancer diagnostic kit is a self-diagnostic kit that is able to identify the five major cancers from urine and even helps the user discover cancers with very few early symptoms, such as liver cancer.** 'What are you doing? You should also get tested.' As Jung-Hoon holds the diagnostic kit waiting for the results, a smile spreads across his face as he thinks about the new family member they will soon meet.

Source: [NSTC, KISTEP, 2012b].

technologies requires a diversity of 'technology sprouts' as successful development and the ripple effects of success remain largely uncertain.

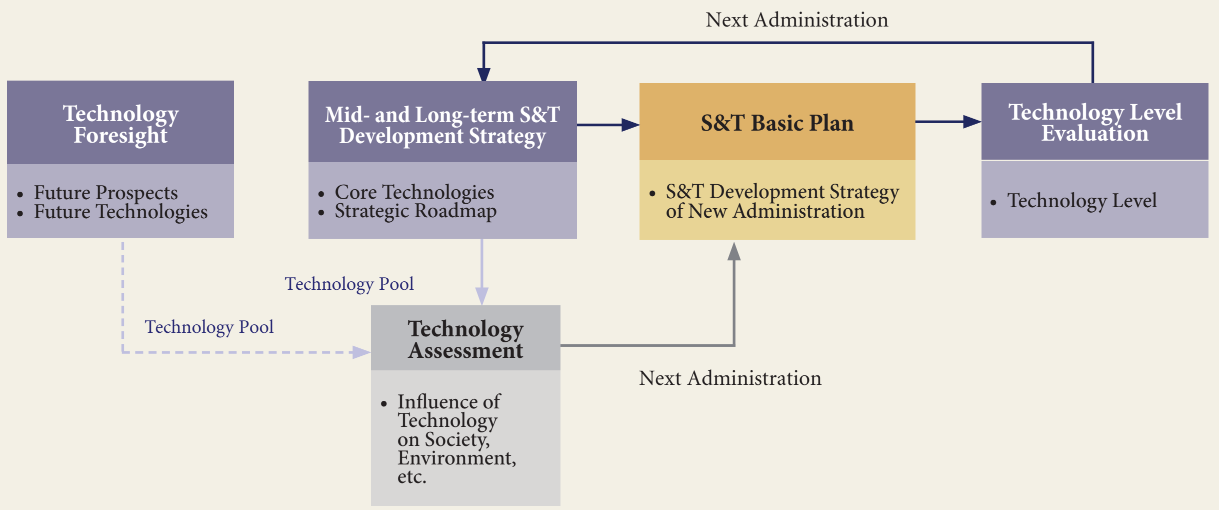
Second, achieving advanced technologies effectively is possible through joint research between industry, universities, and research institutes as well as through international collaborative research. Furthermore, the high demand for staff training and infrastructure construction, as identified by our analyses, indicate that future technologies require systemic support in the medium and long-term. At the same time, it is important to implement policies to minimize the adverse effects of certain future technologies through Technology Assessment mechanisms.

Fig. 7. **Illustration of the scenario (a family in 2035)**



Source: [NSTC, KISTEP, 2012b].

Fig. 8. **S&T planning activities in Korea**



Source: compiled by the authors.

Third, it is important to pay sufficient attention to the social aspects of S&T, given the importance and possible consequences (the ripple effect) of social problems in the future. By carrying out national R&D projects that address these kinds of issues, the effectiveness of S&T in responding to future issues will be strengthened (together with other solutions). To achieve this goal, it is necessary to analyse future issues and existing factors, including the implementation time of future technologies, the level of technology, and the R&D Plan. Furthermore, an optimal technological development strategy is required that would set out the priorities taking into account the roles of each technology in solving specific issues, and clarify the roles and accountability mechanisms of various government departments and research institutes.

Technology Foresight and S&T Planning

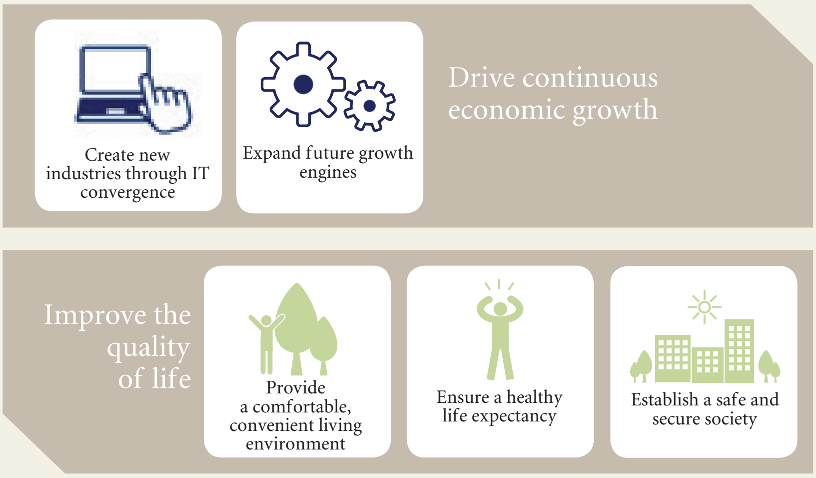
Korea develops a new S&T Basic Plan every five years alongside the launch of a new administration. All S&T planning activities at the national level are connected with the S&T Basic Plan (Figure 8). The National Mid- & Long Term S&T Development Strategy selects the national core technologies based on the future technologies determined by the TF and establishes a strategic roadmap for these technologies. These results are reflected in the focused initiatives related to the technological development of the S&T Basic Plan. The 652 future technologies identified by the fourth TF went through a reviewing process by committees responsible for the national R&D budget as well as by R&D-related ministries. As a result, a list of 120 national strategic technologies was compiled; these technologies were also identified by the third S&T Basic Plan (Figure 9).

The importance attributed to Korea's technology foresight (TFs) has grown with every round of TF. Accordingly, the third TF — in contrast to the two preceding TFs in which only scientists and engineers participated — examined future social development and factors of demand to identify future technologies that could address society's demands. Moreover, the third TF was modified to ensure closer integration with the 5-year S&T Basic Plan and help provide a systemic basis for national level S&T planning. In this process, TFs have consistently provided background information that feeds into policies and medium and long-term S&T strategies.

In addition to the TF, Korea regularly conducts Technology Level Evaluation and the Technology Assessment exercises (Figure 8). The Technology Level Evaluation targets the national strategic technologies as indicated in the S&T

Fig. 9. **The third S&T Basic Plan: Developing national strategic technologies**

Cultivate 120 national strategic technologies in five key areas



Source: [MSIP, KISTEP, 2013c].

Basic Plan, and takes place every two years. The Technology Level Evaluation exercise compares the technological levels of Korea, the United States, China, Japan, and the EU using Delphi survey methods, patent analyses, and research paper analyses [MSIP, KISTEP, 2013b]. Those who devise strategic roadmaps for national core technologies use the results of this evaluation as inputs.

The Technology Assessment evaluates the positive and negative impacts caused by new S&Ts on areas such as the economy, society, culture, ethics, and the environment. It also suggests ways to enhance the positive impacts and avoid the adverse effects. Korea conducts a Technology Assessment annually, and as part of this assessment surveys not only experts from the humanities, social sciences, and S&T, but also members of the public. Recently, the country undertook a Technology Assessment on big data [NSTC, KISTEP, 2012a] and 3D printing [MSIP, KISTEP, 2013a]. The process of selecting a target technology for Technology Assessments draws on the list of future technologies identified by TFs. The results of the Technology Assessment are reflected in the research plans regarding R&D projects in the corresponding fields. Furthermore, the results of the Technology Assessments are not only taken into account when formulating the S&T Basic Plan but also when devising policies to minimize the negative impacts of new technologies. F

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