

2017/18 Knowledge Sharing Program with Mexico (I):

Strategic Technology Planning for the National Polytechnic Institute of Mexico



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the National Polytechnic Institute of Mexico



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Preface

Knowledge is a vital ingredient that determines a nation's economic growth and social development. Its true value was brought to light by the advent of the knowledge economy and a key question policymakers now face, especially in developing countries, is how an environment can be established that encourages and facilitates the creation and dissemination of knowledge across the nation. This need has led many countries to engage themselves in active policy dialogue to share their development experiences and benefit from mutual learning.

Korea's development has also depended heavily on knowledge. Its remarkable transition from a predominantly agrarian economy to an industrialized economy was made possible by its well-rounded and extensive understanding of technology, management, public policy, and other diverse issues acquired from domestic and foreign sources and through trial and error. Building on these rich experiences, the Korean Ministry of Economy and Finance (MOEF) launched the Knowledge Sharing Program (KSP) in 2004 to assist partner countries to improve their policymaking. KSP, as implemented by Korea Development Institute (KDI), focuses on providing solutions customized to each country's economic, social and administrative settings, building capacity for effective policymaking and strengthening global networks for development cooperation. In 2017/18, KSP policy consultations were organized with 31 partner countries, with Mekong River Commission joining the partnership for the first time.

The 2017/18 KSP with Mexico (I) was undertaken by MOEF and Mexican Agency for International Development Cooperation (AMEXCID) of the United Mexican States to support the "Strategic Technology Planning for the National Polytechnic Institute (IPN) of Mexico." To that end, KSP and Mexican counterparts made a range of collaborative efforts by exchanging development experiences, conducting joint studies and designing a policy action plan in line with the country's development targets.

With that, it is with great optimism for the future of Mexico that the results of the 2017/18 KSP are presented. I firmly believe that KSP will serve as a stepping stone to further elevate the mutual learning and economic cooperation between the two countries and hope it will contribute to Mexico's sustainable development in the future.

I wish to convey my sincere gratitude to Senior Advisor Mr. Young Ju Kim, Principal Investigator Dr. Dong Hoon Oh as well as project consultants Dr. Sun Hark Bong and Dr. Dong Nam Kim for their extensive contributions. I am also grateful to Executive Director Dr. Youngsun Koh, Project Manager Dr. Changjae Lee, Project Officer Ms. Geummulgyul Hwang and all members of the Center for International Development (CID) for their hard work and dedication. Lastly, I extend my warmest thanks to the AMEXCID, IPN and related agencies in Mexico for their active cooperation and great support.

Jeong Pyo Choi
President
Korea Development Institute (KDI)



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2017/18 KSP with Mexico (I)

Geummulgyul Hwang (Project Officer, Korea Development Institute)

Since 2004, the Ministry of Economy and Finance (MOEF) of the Republic of Korea (hereafter “Korea”) and Korea Development Institute (KDI) have implemented the Knowledge Sharing Program (KSP) to share Korea’s development experience with partner countries. This knowledge-intensive economic cooperation program has drawn attention from the high-level talks between Korea and Mexico in 2010 and 2012, respectively, and was launched in 2012 based on strategic bilateral relationship. As of the first half of 2017, KSP with Mexico has covered over 18 projects with a wide range of topics from labor and education policy to industrial policy for 6 consecutive years.

For the seventh year of long-standing cooperation, the 2017/18 KSP with Mexico was implemented under the main theme of “Strategic Technology Planning for the National Polytechnic Institute of Mexico” with the aim of achieving sustainable development. Indeed, Mexico has been of great importance in the global value chain as a manufacturing base. However, the mid- and long-term economic prospects of the country are uncertain due to lack of in-country S&T capacity in meeting the needs of the market. In turn, this constraint makes Mexico’s economy more vulnerable to external shocks, such as volatile global economic environment and changed political landscape.

In this context, the National Polytechnic Institute (hereafter “IPN” by its Spanish acronym), a well-known higher education institution in Mexico, submitted a demand survey for the 2017/18 KSP with Mexico (I). The project and the following Korean

researchers specializing in strategic technology planning were selected through careful reviews process by the selection committee composed of MOEF and Korean experts. Also, Mexican researchers joined as local consultants to develop a clear picture of the current status of Mexico. Through joint research, capacity-building workshops, and high-level talks, the researchers came up with detailed practical recommendations.

〈Table 1〉 2017/18 KSP with Mexico (I): Topics and Participants

Project Title: Strategic Technology Planning for the National Polytechnic Institute of Mexico Senior Advisor: Mr. Young Ju Kim, Former Minister, Ministry of Commerce, Industry and Energy, Republic of Korea Project Manager: Dr. Changjae Lee, Visiting Senior Fellow, CID, KDI Principal Investigator: Dr. Dong Hoon Oh, CEO, Innovation Engineering Laboratory		
No.	Sub-topics	Korean Researcher
		Local Consultant
1	Development of Technology Foresight System	Dr. Sun Hark Bong (CEO, TBNA)
		Mr. Víctor Ahui Malvaez Campos (Consultant, IPN)
2	R&D Priority Setting for Strategic Technology Planning	Dr. Dong Hoon Oh (CEO, Innovation Engineering Laboratory)
		Ms. Alexandra Ortiz Guzman (Senior Patent Agent Analyst, Fuentes Carrasco y Asociados)
3	A Study on Implementation of TRM-based R&D Planning Methodology Customized for Mexico & IPN	Dr. Dong Nam Kim (CEO, Veritanos)
		Mr. Irving Munoz Lopez (Researcher and Technology Management Consultant, Breakthrough IP Intelligence)

For the first stage of the 2017/18 KSP with Mexico (I), the Korean delegation visited Mexico City from September 11th to 15th, 2017 for the Launching Seminar and the High Level Meeting. The Korean delegation discussed with IPN both at working level and high level to gain a comprehensive understanding of the demand. More importantly, the Korean delegation met Dr. Elias Micha Zaga, Coordinator of Science, Technology and Innovation (STI) of the President's Office to convince him of the role of strategic technology planning in economic development. By doing so, both parties, the Korean delegation and IPN, were able to narrow down the research coverage and confirm the sub-topics. With reference to data collection, the Korean delegation visited relevant institutions to examine data availability and knowledge

levels of stakeholders regarding strategic technology planning.

Afterwards, the Korean delegation visited Mexico City from December 11th to 15th, 2017 for the KSP Policy Seminar and In-Depth Study. By spending time with a number of experts from the government (CONACYT, the Ministry of Economy, Mexican Petroleum Institute), academia (UNAM, CamBioTech A.C., CIATEJ and PROTEAA), and private sector (Grupo Neolpharma S.A. de C.V., FUMEC and Polimeros de Uretano S.A. de C.V.), the second visit provided an insight and opportunity to bridge a gap between the research and the current status on the ground in Mexico.

For the next stage, the Mexican delegation visited Korea from February 4th to 10th, 2018 to participate in the Interim Reporting and Policy Practitioners' Workshop. In the Interim Reporting Workshop, the Korean researchers and the local consultants shared the interim results of their research and received feedbacks on the tentative recommendations. During the Policy Practitioners' Workshop, the Mexican delegation learned a great deal of first-hand knowledge in the fields of 1) Technology Foresight, 2) Priority Setting for R&D, and 3) Technology Road mapping. The workshop featured prominent experts from the Korea Institute of & Technology Evaluation and Planning (KISTEP), Science and Technology Policy Institute (STEPI), Electronics and Telecommunications Research Institute (ETRI), Korea Agency for Infrastructure Technology Advancement (KAIA), Korea Institute of Planning and Evaluation for Technology in Food, Agriculture and Forestry (IPET), and Korea Atomic Energy Research Institute (KAERI).

For the final stage, the Korean Delegation visited Mexico City from April 23rd to 26th to attend the Final Reporting Workshop and Senior Policy Dialogue. The Korean delegation delivered the core KSP research findings and recommendations to senior and working-level stakeholders from relevant institutions (IPN, CONACYT, OECD, PEMEX, Samsung Engineering Mexico and FUMEC). In addition to the workshop, the Korean delegation had a dialogue with the decision makers of IPN to discuss future cooperation for implementing recommendations.

Throughout the project cycle, KSP raised the issue of strategic technology planning with a broad array of stakeholders and facilitated continuous engagement by building networks in Mexico. Previously, there was little dialogue among policy makers and practitioners. But, following discussion with various actors and institutions, the consensus was made that it is important to take part in strategic technology planning, which is beyond the reach of IPN's action alone. In addition to this, the recommendations will be put into practice during the 2018/19 KSP with Mexico. Accordingly, KSP will help IPN and Mexico to pave the way for strengthening in-country innovation capacity, while also opening up opportunities for economic cooperation between Korea and Mexico in the realm of science and technology.

Executive Summary

Dong Hoon Oh (Innovation Engineering Laboratory)

Growing attention has been devoted to the issue of technology planning to enhance accountability, effectiveness, and efficiency of R&D investment of public resources. Mexico is also trying to establish an effective technology planning system that is suitable to the situation in Mexico. The Mexican government hopes to learn lessons from Korea's experiences in technology planning. The National Polytechnic Institute (IPN), as a higher education and research organization, is interested in contributing to the achievement of national S&T goals. IPN wants to make an effective technology planning system including technology foresight, priority setting for R&D and technology roadmap (TRM).

The aim of technology planning is to decide the goal, subject, cost, and timing of the technology to be developed by reviewing the socioeconomic needs and policy considerations based on technology information. Prioritization of R&D, therefore, is a critical step in the process of strategic technology planning for efficient use of limited resources. Strategic technology planning could be divided into several stages: technology intelligence, technology foresight, priority setting, and technology roadmap. Technology intelligence includes S&T level analysis, R&D capacity analysis, STEEP (Social, Technological, Economic, Environmental and Political) analysis, and market analysis. Technological planning includes S&T foresight, TRM, and R&D priority setting that are covered in this project. In order to achieve good results of priority setting, preliminary analyses of social, technological, national strategy, and economic aspects should be done as well.

The purpose of technology intelligence (TI) is to collect and analyze technology-related information needed for technology and business decision-making in companies and organizations. TI aims to capture and disseminate the technological information needed for strategic planning and decision making. Because of the speed of technology change and the changing global business environment, TI has been becoming increasingly important. At the national level, TI includes S&T level and capacity analysis, mega-trend analysis, market analysis, and R&D investment analysis.

Technology foresight is a process of comprehensively examining the future of science and technology and the socio-economic change in the future from a long-term standpoint in order to select research areas that are expected to produce the greatest socio-economic benefits (OECD, 1996). Also it is a means for presenting the mid- to long-term vision of technology. Furthermore, it derives the problem to solve from technological point of view, which is based on the needs of the future society.

The purpose of R&D priority setting is to compile the R&D promotion ranking or resource allocation plan by comprehensively considering the competence of the technology development entity, given the circumstances, technological importance, and socio-economic ripple effects of technology. In the case of government research, public concern or benefit of the technology is one of the most important factors in setting priorities.

The technology roadmap (TRM) is a kind of guide map for developing and securing core technologies. It is a tool to effectively integrate and express various viewpoints of strategy, technology, and products and to effectively eliminate functional barriers that are placed between different technologies. TRM is often classified as either a market-driven model or a technology-push model. The market-driven model expresses the path of the market, product, and technology as a roadmap. Market needs are very important in this case. In the case of the technology-push model, the new technology creates a new market by taking the path of technology → product → market.

Among these steps, the procedure of technology road mapping and prioritization may be reversed. In the first case, we can make TRM first and then set priorities. We can make a TRM that is based on the future goals that we hope to accomplish. We then set the R&D priorities according to our capabilities and resources. On the contrary, there could be another case where prioritization is done first and then the TRM could be made. In other words, technology foresight determines the technology to be developed in the future. After that, core technologies should be strategically selected in terms of the strategic goals of technology, urgency of development, technology level, and technology development capacity. Then, TRM could be drawn

according to those priorities, including technology acquisition means, performers, time, product, and resources.

- **Technology Foresight**

This study introduces the effective implementation plan for building up the technology foresight (hereafter “TF”) system of TechnoPoli in IPN based on evidence of Mexico and implications from the Korean experience.

TF emphasizes action-orientation for priority setting activities to achieve future goals, but technology forecasting has more emphasis on accuracy of results of prediction and quality of information for decision making. In fact, TF is the third generation of technology forecasting (Georghiou, 2003; UNIDO a, 2005). TF is an attempt to draw the future of technology development that has a key role for the development of society in the direction that we desire, with the interaction between technology and society in mind.

A wide range of methods is applicable to TF from qualitative methods such as literature review, expert panel, and brainstorming, to quantitative methods such as simulation modeling and bibliometrics. However, popular methods for TF to be used widely are trend extrapolation, simulation modeling, Delphi technique, expert panel, future wheel, cross impact analysis, and the scenario planning method.

In fact, Mexico had a tradition of foresight and future research and led the foresight study as a pioneer in the region of Latin America. Mexico had been introducing some of the first books and exercises in the 1970s and leading the first Latin initiative to promote the integration of foresight effort. But Mexico lost this leadership during the 1990s and now has an endeavor to recover it (Georghiou *et al.*, 2008). Mexico still has not organized foresight efforts into a fully-fledged national foresight program, so usage of TF studies is not common to Mexican organizations such as private companies, research institutes, and the federal and state governments.

14 studies related to the foresight made in Mexico and foresight studies especially focused on the technology perspectives such as technology prospect, technology forecasting, and technology foresight were found. These research projects were relatively small in comparison with the GDP scale and industrial competitiveness of Mexico. Furthermore, major foresight studies focused on the technology perspectives appeared in the 2010s in Mexico.

IPN has some strength in TF-related capability from its long history of business and technology intelligence service of UPDCE, TechnoPoli, and CIEBT. IPN also has a strong DB (database) of science and technology personnel and information system

for this business and technology service. The DB of science and technology personnel belonging to IPN is actively used and is updated live for various IPN services. IPN also has a substantial external network for the extension of its science and technology personnel and information system.

Korea has various organizations that conduct TF studies, such as the central government, regional governments, government-funded research institutes, public research institutes, and private companies. The central government establishes laws, and the regional governments establish municipal ordinances and rules to accomplish the legal basis to safely conduct the TF study. The government-funded research institutes and the public research institutes have no duty to conduct the TF study based on the articles of association like the regional governments. However, they conduct the TF study of the related fields of technologies as one of their activities to establish a medium-and long-term development strategy every 3 to 5 years. In particular, the government-funded research institutes propose medium-and long-term development strategies during the process of approval of management performance plans by the government during a 3 to 5-year term of the chief of the institutes. Also, each government-funded research institute conducts the TF study to explain its roles and functions to the public during the change of the government administration or every 10 years. Like the government-funded research institutes and the public research institutes, the private companies also conduct the TF study of related fields of technologies as one of their activities to establish a medium-and long-term development strategy or to find a new business or a new field for investment.

For the implementation of effective TF study from TechnoPoli in IPN, this report suggests several directions from the analysis of the current situation of TF in Mexico, as previously discussed. First of all, this report recommends that 5 years is a suitable time span for TF in Mexico. Also, this report recommends that the intersection of the competitive area of IPN and national strategic industry for Mexico is suitable as the target technology area to be studied in the foresight study. This report also suggests that the study on the future technology should focus on the key technologies for problem solving for the industry and society in IPN and Mexico within 10 years. Finally, it is suggested that sophisticated S&T trend analyses, such as big data analysis and advanced bibliometric analysis, should also be replaced by literature review.

This report suggests a stage model that consists of stages for development of a necessary technology and identification of a promising technology. Also, this report suggests the institutional structure of the TF study for TechnoPoli in IPN.

It consists of a headquarter of IPN, extension and social impact secretary, TechnoPoli, and 3 committees: an advisory committee, executive committee, and technology committee. The advisory committee should be set up to establish legitimacy for the TF study, to support the execution of the TF study, and to implement the results of the TF study. The executive committee will have the role of important decision making at each stage of the TF study and confirming the results of the study. Technology committees will be set up along with target technology areas.

For effective implementation of the TF study, more than \$150,000 is recommended as a budget for each target technology area. This includes all of the costs needed, such as operation costs of the 3 committees, operations costs of activities of TechnoPoli by the dedicated human resources, and operation costs of web-based survey system. Finally, there is no further need for any information system acquisition because TechnoPoli has enough internal information service systems for business and technology intelligence and also has an external network for information service.

- **R&D Priority Setting**

The purpose of this study is to strengthen IPN's capabilities of technology planning. It is expected that efficiency and effectiveness of R&D investment will be enhanced if IPN's strategic technology planning capability is increased. This project, therefore, aims to help Mexico's socio-economic development by enhancing the quality of R&D results. In order to reach these goals, the study has 2 following objectives: firstly, to understand the aim, structure, practice, and application of Korean R&D priority setting and draw policy implications and lessons; secondly, to provide suggestions to Mexico for a more advanced practice of R&D priority setting in order to enhance the efficiency and effectiveness of research and technology development activities in IPN by providing detailed information and knowledge that are based on the Korean experience.

To accomplish the above-mentioned objectives, the study consists of 4 modules. The aim of the first module is to provide a theoretical review of R&D priorities. The second is to summarize the policy implications and lessons from Korea's experience. The third is to understand Mexico's S&T system and R&D priorities. It is essential to understand Mexico's S&T system and R&D activities in order to propose policy suggestions for Mexico. Finally, the fourth module aims to provide some suggestions for setting up the R&D prioritization system for IPN in the Mexican environment of S&T. The study therefore covers 4 tasks as follows: Theory of R&D Priority Setting; Experience and Lessons of R&D Priority Setting in Korea; Review of the S&T System and Capacity of Mexico for R&D Priority Setting; and Suggestions and Solutions for Mexico.

The Analytical framework used in this study is an overarching meta-evaluation framework. Each PS system can be regarded as being composed of 5 main areas: i) paradigm, ii) resources, iii) implementation, iv) utilization, and v) environment. This report proposes principles and suggestions for a more advanced PS according to this framework. The report also provides an advanced PS model for IPN according to this framework.

In Korea's case, there are a few lessons to be learned in order to effectively set R & D priorities. First of all, there need to be an effective system and efficient procedures to set priorities for a clear purpose. Second, strategic technology planning is a matter of resource allocation, which means resources are concentrated on promising areas rather than on equal research support. Therefore, continuous interest and support from top decision makers is very important. If not, it will stay in the plan and will be difficult to actually execute. Third, it is necessary to build an independent organization to take charge of strategic technology planning. Researchers involved in individual research and development are likely to represent their own interests. It is therefore desirable to have an independent and professional organization free from conflict of interest issues. Fourth, there are many considerations for prioritization. Theoretically, these cannot reflect all of the many influencing factors. Therefore, it is very important to use various methods integrally; in other words, "one does not fit all." Fifth, priority should be set based on scientific method and data as much as possible, but it is also the product of political negotiations among the people involved. Therefore, the result is not an absolute standard. In the end, it is very important to have process of reaching consensus, so that stakeholders can fully accept and actively cooperate with the plan after R&D priority, has been set.

IPN needs to reach a consensus on key research fields with a top-down approach, considering its missions. At the national level, it is necessary to establish an adjustment system of R&D investment for technology foresight, TRM, and setting priorities. R&D management and resource allocation policies based on performance-based management (PBM) should be established at the IPN level, and this work should be steadily promoted for at least 5 years.

In order to increase the acceptability of IPN people for differentiated resource support, there is a need for mutual agreement among the members to ensure that sufficient compensation will be provided for IPN research units and researchers with excellent performance.

It is necessary to establish a department to analyze, coordinate, and evaluate IPN's research activities as a whole so that the planning, execution, and evaluation activities of R&D can be carried out in a comprehensive and systematic manner. If it is hard to start right away, a temporary organization (task force team) should

be organized. It is also necessary to establish a coordinating body (committee/council) within the IPN to deliberate and make decisions on budget adjustment and prioritization. In this case, the IPN president needs to lead the committee.

A data collecting and sharing system is needed to objectively analyze R&D investment, evaluation information, investment priorities, activities, outputs, and benefits for beneficiaries. If a research fund costs more than a certain amount, it is obligatory to submit a “technology development plan report.” The relevant laws and regulations must contain provisions that define specific actions for strategic technology planning and evaluation.

It is necessary to invest about 5% of IPN's total research expenses in activities related to technology planning, such as technology foresight, roadmap, and priority setting. In 2018, approximately 4 to 5 dedicated personnel members will need to be deployed to implement the actual strategic technological plan.

The results of the proceedings should be reported directly to the Director General of IPN. It takes about 1 year to conduct a pilot project, but it may take 6 months to accelerate the accumulation of experience by working more intensively. It could be necessary to set detailed priorities for the 6 sectors for the current Mexican economic development.

Therefore, it needs to present a concrete and detailed implementation plan for how we can achieve the desired goals. The figure could be a frame of IPN for setting priorities. Results should never suggest just directions, but should be specific enough to allocate resources accurately. Strategic implementation of budget execution for years should follow the priority setting. It is required to monitor, assess, and receive feedback on the effect of the strategic investment allocation.

- **TRM**

Throughout the years, Mexico has been growing as a production base for global companies in North America. However, due to the strengthened re-shoring and protective trade policies in major trading partners such as the United States, Mexico has come to face a situation in which it needs to reinforce its future industry competitiveness. Therefore, in order to prepare for the fourth industrial revolution, Mexico needs to advance its science and technology innovation system to foster new growth engines and strengthen industrial competitiveness by introducing a sophisticated technology planning and R&D management systems.

Although IPN is making efforts to provide technical and market information through TechnoPoli, it still lacks the maturity in practical skill and experience for technical planning as a whole.

Therefore, this study shares the knowledge and experiences of R&D projects and methodologies that were based on the Technology Roadmap of Korea. Moreover, it proposes a TRM methodology that can be practically used.

The purpose of this study is to introduce methodologies of technology roadmapping reflecting Mexico's technology planning capability and conditions, so that the major R&D organizations in Mexico, such as IPN, can utilize it. It is intended to share TRM-based technology planning cases in the public and private sectors of Korea and pass on methodologies and processes that can be used from a practical perspective.

This study is mainly composed of a theoretical review of technology road mapping, case study of TRM applications in public and private sector in Korea and major industrialized countries, analysis of the technology planning capacity and situation in Mexico, and TRM-based technology methodology and suggestions.

According to a report by the local consultant, Mexico's science and technology innovation system operates in relation to LCyT (the Science and Technology Law) and PECITI (The Special Program for Science Technology and Innovation). The CONACYT, a committee under the Ministry of Education, serves as a control tower of science and technology innovation policy. On the other hand, there are very few examples of establishing science and technology policies and running technology roadmap-based technology planning systems in major organizations. Some institutions are trying to develop roadmaps, but the general judgement is that they lack systemicity, usability, and specificity.

The theoretical review section of the technology roadmap presents the concept and definition of technology road mapping, the importance of TRM for improving the systematic and efficiency of R&D investment, and the underlying process. This study proposes various types of and differences in technology road mapping used in the public and private sectors by presenting many application cases of technology road mapping in Korea and developed countries. Some examples from developed countries include the U.S. National Aeronautics and Space Administration (NASA)'s Technology Roadmap and the EU's Energy Technology Roadmap. In the case of Korea, the National NBIC's Convergence Technology Map (2008) and the SMEs Technology Roadmap (2016) were introduced as examples in the public sector, and L's TRM case was introduced for the private sector.

Based on these cases, considering the reality and capability of IPN, TRM methodology and process are presented in Chapter 5 with examples and templates. The study concludes with policy recommendations to improve Mexico's technology

plans.

Taking into consideration the increasing complexity in technology trends and state-of-the-art technology in the age of the Fourth Industrial Revolution, a national science and technology system should be strategically planned and create economic and social added value through convergence. Therefore, it is very important to implement R&D mechanism that can closely link science and technology policy, planning, R&D investment, and R&D performance utilization.

Systematic technical planning, such as TRM, improves the productivity of R&D investment and creates many jobs and competitive enterprises as guidelines for enhancing national R&D accountability.

In order to proliferate the technology planning method, it is critical to make a policy effort, such as providing law and institutional strategy, training professionals, and continuously implementing and encouraging learning. In particular, strategic investment is needed to enable the leading R&D institutions of Mexico, such as IPN, to rapidly increase their technology planning capabilities and to share them with more diverse public and private R&D actors.

2017/18 Knowledge Sharing Program with Mexico (I):
Strategic Technology Planning for
the National Polytechnic Institute of Mexico

Chapter 1

Development of Technology Foresight System

1. Introduction
2. Definition and Concept
3. Current Situation of Technology Foresight in Mexico
4. Korean Experience of Technology Foresight
5. Suggestion of Implementation Plan of the Delphi Based Technology Foresight System

Development of Technology Foresight System

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Summary

This study aims to conduct the investigation on the current situation of the environment for technology foresight (hereafter TF) study in Mexico and suggest an effective TF system for TechnoPoli of National Polytechnic Institute (IPN by its Spanish acronym). This report introduces an effective implementation plan for establishing the TF system of TechnoPoli of IPN based on evidence from Mexico and implications from the Korean experience.

TF places emphasis on the action-orientation for the priority setting activities to achieve a future goal, but technology forecasting places emphasis on the accuracy of the prediction outcomes and quality of information used for decision making. In fact, TF is a third-generation version of technology forecasting (Georghiou *et al.*, 2008; UNIDO, 2005a). TF is an attempt to draw out the future of technology development that plays a key role for the development of society in the direction that we desire, with consideration to the interaction between technology and society.

A wide range of methods are applicable to TF from qualitative methods such as literature reviews, expert panels and brainstorming, to quantitative methods such as simulation modeling and bibliometrics. However, popular methods for TF, to be used widely, consist of trend extrapolation, simulation modeling, Delphi technique, expert panel, future wheel, cross impact analysis and scenario planning methods.

Keywords: Technology Foresight, Implementation System Development, Delphi Technique, IPN

In fact, Mexico has had a history of foresight and future research and pioneered foresight studies in the Latin American region. Mexico introduced some of the first books and exercises in the 1970s and led the first Latin initiative to promote the integration of foresight efforts. However, Mexico lost its leadership during the 1990s and now seeks to recover the leadership it once possessed (Georghiou *et al.*, 2008). Mexico has been unable to organize foresight efforts into a fully-fledged national foresight program (Georghiou *et al.*, 2008). Therefore, utilization of TF studies is not common to Mexican organizations such as private companies, research institutes as well as the federal and state governments.

14 studies related to foresight conducted in Mexico and foresight studies particularly focused on technology perspectives such as technology prospects, technology forecasting and technology foresight. These studies were relatively small in comparison to the GDP scale and industrial competitiveness of Mexico. Furthermore, major foresight studies focused on the technology perspectives emerged in Mexico in the 2010s.

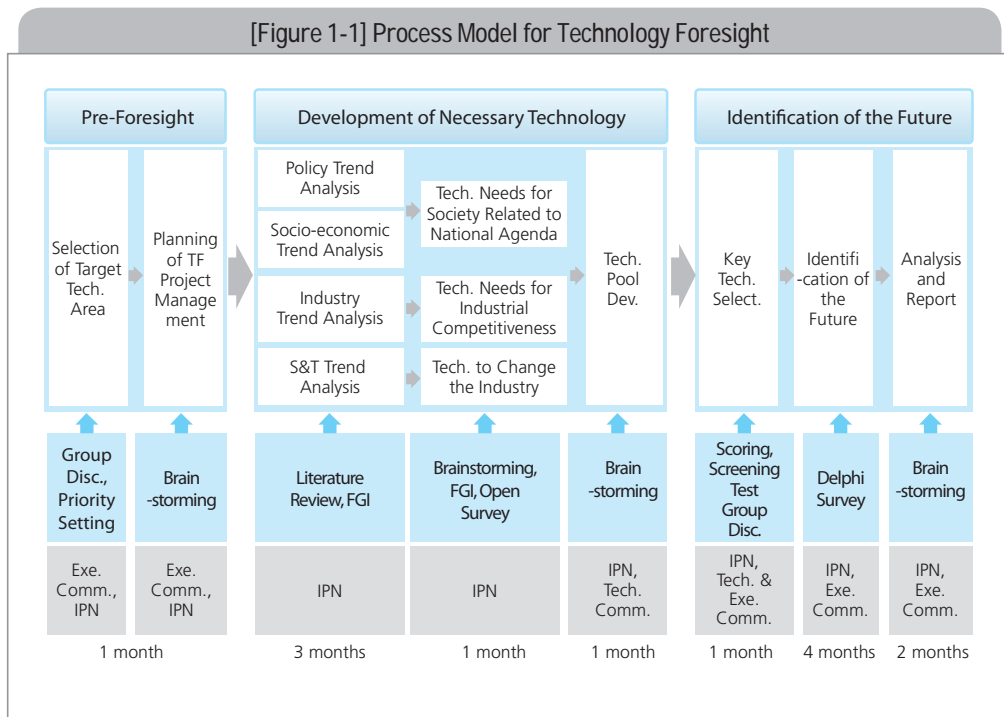
IPN possesses a fairly strong TF related capabilities based on its long history of business and technology intelligence services of UPDCE, TechnoPoli, and CIEBT. IPN also has a strong database (DB) of science and technology personnel and information systems for this business and technology service. The science and technology personnel DB belonging to IPN is updated real-time and actively used for various services of IPN. IPN also has a sufficient external network for the extension of science and technology personnel and information systems.

Korea has various organizations that conduct TF studies such as the central government, regional governments, government-funded research institutes, public research institutes and private companies. The central government established laws and the regional governments established municipal ordinances and rules to build up the legal foundation to safely conduct TF studies. Government-funded research institutes and public research institutes have no obligation to conduct the studies based on the articles of association like the regional governments. However, they conduct TF studies on the related fields of technologies as one of their activities to establish a mid- to long-term development strategy every 3 to 5 years. In particular, government-funded research institutes propose a mid- to long-term development strategy during the approval process of management performance plans by the government during the 3 to 5 year term of the chiefs of the institutes. Also, each government-funded research institute conducts TF studies to explain their roles and functions to the public during the change in government or every 10 years. Like the government-funded research institutes and the public research institutes, private companies also conduct TF studies of related fields of technologies as one of their activities to establish a mid- to long-term development strategy or to find a new

business or a new field for investment.

For the implementation of effective TF studies by TechnoPoli of IPN, this report suggests several directions from the analysis of the current situation of TF in Mexico as previously discussed. First of all, this report recommends that 5 years is a suitable time span for TF in Mexico. Also, this report recommends that the intersection of the competitive area of IPN and national strategic industry for Mexico is suitable as the target technology area to be covered in foresight studies. This report also suggests that studies on future technology could be excluded and more focus can be placed on the key technologies for problem solving for the industry and society within IPN and Mexico for 10 years. Finally, it is suggested that sophisticated S&T trend analysis such as Big Data analysis and advanced bibliometric analysis could be also replaced by literature review.

This study suggests a stage model consisting of stage for development of the necessary technology and stage for identification of the promising technology. Also, this report suggests the institutional structure for TF studies to be conducted by TechnoPoli of IPN.



Source: Compiled by author.

It consists of the IPN headquarters, the extension and social impact secretary, TechnoPoli and 3 committees, comprised of the advisory committee, executive committee, and technology committee. The advisory committee should be set up to obtain legitimacy for TF studies and support for execution and extrapolation of the outcomes of TF studies. The executive committee will hold the role for making important decisions in each stage of the TF studies and confirming outcomes of TF studies. Technology committees will be set up along with target technology areas.

For effective implementation of TF studies, more than \$150,000 is recommended as the budget for TF studies in each target technology area. It includes all of costs to be incurred during TF studies such as the operation cost of 3 committees, operations cost of activities of TechnoPoli by the dedicated human resources and the operation cost of the web-based survey system, etc. Finally, there is no further need of any information system acquisition since TechnoPoli has a sufficient internal information service system for business and technology intelligence as well as an external network for information services.

1. Introduction

IPN was created by the Mexican government in 1936. IPN was established as an engine for Mexico's development and a space for equality, by supporting the industrialization process and providing educational alternatives to society. IPN is formed in high schools, undergraduate and graduate schools, research institutes, and R&D service organizations to utilize its technological capabilities for society, particularly the industrial sector.

The Secretary of Social Extension and Integration is a bureau in the IPN responsible for contributing to the technological capability of IPN to be transformed into a product of industry by R&D service function such as technology transfer and commercialization. Specifically, TechnoPoli, which is a department of the Secretary of Social Extension and Integration, was established in 2001. TechnoPoli plays the role of linking R&D investment with the demands of the private sector and building up the technological ecosystem. Main services of TechnoPoli include: hosting companies for joint projects development and management; technical assistance for public funding opportunities; soft landing for market opening; networking opportunities and business boosting services; consulting services in technology transfer and commercialization; and specialized services in competitive intelligence and technological innovation.

Although TechnoPoli plays the role of linking R&D investment with the demands of the private sector and building up the technological ecosystem, it has no

experience of technology foresight (TF), dissemination and use of outcomes for R&D decision making at the IPN level. Also, Mexico does not have enough experience in TF, dissemination and use of outcomes for R&D decision making actively at the national level.

TechnoPoli has little technical knowledge on TF, scenario creation and future planning. Also, TechnoPoli lacks knowledge in tools which allow management and interpretation of strategic information to guide and facilitate appropriate decision making for innovation and technological development.

For this reason, TechnoPoli of IPN suggested a sub-project of creating an implementation plan of TF by IPN in the context of Mexico to design and operate a Center for Scientific, Technological and Industrial Intelligence and Foresight, as an institutional tool for strategic future planning.

The goal of this report is to conduct an investigation on the current environment for TF studies in Mexico and suggest an effective TF system for TechnoPoli of IPN. This report will contribute to introducing an effective implementation plan for establishing a TF system at TechnoPoli of IPN based on evidence from analysis of Mexico situation and implications from the Korean experience.

The scope of the study is as follows. First, this study will understand the needs and situation of TechnoPoli of IPN, such as identification of the goal and expected outcome of TF at IPN, the expected duration of each survey, the number of survey scope, application field of foresight and capability of TechnoPoli to conduct TF.

Secondly, this study will investigate TF projects of other organizations in Mexico, such as academies, research institutions, and private sector in terms of the history of TF in Mexico, goal, scope, process, methodology, duration, responsible institutions, organization in charge, contents of application and dissemination in each study.

Thirdly, this study will draw out the pros and cons of each of the TF projects and have a SWOT analysis for TF studies of TechnoPoli of IPN. Fourthly, this study will benchmark the TF cases of the government and research institutes in Korea.

Finally, this study will suggest an implementation plan for TF studies by TechnoPoli of IPN such as a foresight framework based on the stage model, activities and methodologies in each stage, institutional structure and role of each unit in charge, and resources and infrastructure for foresight.

2. Definition and Concept

2.1. Definition of Technology Foresight

Technology foresight is an attempt to draw out the future of technology development that plays a key role for the development of society in the direction that we desire, with consideration to the interaction between technology and society. Many countries, state governments, public research institutes, private companies and many other organizations around the world have been continuing their efforts to detect and develop promising technologies for economic prosperity and sustainable growth of enterprises.

There are 2 terminologies, which can easily confuse, related to taking a picture of the future of technology development or the future of society by the technology development. One is technology forecasting and the other is technology foresight.

Technology forecasting senses the trends, pressures and emerging capabilities; then interprets them in terms of needs and indicates the likely level of support; and finally predicts the form of possible innovations and the respective time scales. Usually technology forecasting places emphasis on the production of accurate outcomes of predicting future technology. Also, technology forecasting has linear and deterministic characteristics for prediction of the possible future. As a result, technological forecasting is concerned with the investigation of new trends, radically new technologies and new forces which could arise from the interplay of factors such as new public concerns, national policies and scientific discoveries. Many of these forces are beyond the control, influence and knowledge of individual companies.

However, technology foresight involves setting a goal for the future as well as drawing out and executing activities to achieve them. Technology foresight is a combination of creative thinking, expert views and alternative scenarios to make contribution to strategic planning. Because of this exploratory and non-linear characteristic of technology foresight, technology foresight places more emphasis on the future-oriented thinking, process of information gathering, and the inter-learning effect during the process of technology foresight rather than the outcomes of prediction (Keenan, 2003).

Usually, technology forecasting makes fixed assumptions on how the future will unfold and attempts to be precise in predicting how the world looks like at a certain point in time in the future. By contrast, technology foresight does not seek to predict but to create consensus building of the future that stakeholders are willing to expect by the actions they choose to take today. In this way, technology foresight is not focused on exact prediction of the future, but it is focused on creating it.

Technology foresight usually places emphasis on action-orientation for priority setting activities to achieve a future goal, but technology forecasting places more emphasis on the accuracy of prediction outcomes and quality of information for decision making. Also, technology foresight puts importance on consensus building between participants including government officers related to resource allocation and experts related to the economy and industry. But the major participants of technology forecasting studies are scientists and engineers related to respective area of technology. Also, recent technology foresight has highlighted execution, consensus building, and economic and social needs over the accuracy of prediction outcomes. "The process is highly interactive, open and has a bottom-up to identify breakthroughs and explore hypothesis that support strategy-formulation" (Tübke, 2001).

Today, technology and society are more closely influenced by one another and developed by this interaction. With this phenomenon of interplay between technology and society, a decision maker can predict to make requirements for the action plan to be executed for the future society by the stakeholders, rather than merely predicting the outcomes of future technology. Also, it is widely accepted that technology foresight is more important to a country, government and research institution rather than technology forecasting. As a result, technology foresight in its current form was adopted by many countries as a first step for technology development strategy planning and has become the norm since 1990 (UNIDO, 2005b).

The use of technology foresight is promoted by UNIDO. But UNIDO places importance on that technology foresight does not replace technology forecasting and says that each activity has its role and can offer mutual support (UNIDO, 2005a).

Usually, technology foresight is a process for bringing together scientists, industrialists, government officials and others to identify areas of strategic research and emerging technologies likely to yield the greatest economic and social benefits (Martin, 1996). This report uses the following definition of technology foresight: "foresight is a systematic, participatory, future-intelligence-gathering and mid-to-long-term vision-building process aimed at present-day decisions and mobilizing joint actions" (EC, 2001).

According to Martin (1996), the broad aim of technology foresight is used to identify emerging technologies likely to have the great impact on the economy and society. More specifically, the goals of technology foresight is as follows: explores the future technology opportunities and analyzes the trends in various angles in order to provide useful information to decision makers; develops characteristics of future product and services based on the future needs of society and technology in order

to provide basic information for new product development; establishes an effective resource allocation plan and efficient R&D strategy from a point of view of profit maximization (ETRI, 2009).

Technology foresight is regarded as the most upstream element of technology development process (UNIDO, 2005a). UNIDO (2005a) argues that it provides inputs for formulation of technology policies and strategies that guide development of the technological infrastructure. In addition, also according to UNIDO (2005b), technology foresight provides support to innovation with incentives and assistance to enterprises in a domain of technology management and technology transfer, leading to enhanced competitiveness and growth.

Technology foresight is an important input to strategy process or policy formulation and planning. Technology foresight has been used to identify threats and opportunities likely to be faced by policy outcomes, products and markets and, consequently, of the nature of the magnitude of changes needed. Also, it helps a country, research institute, or company to reorient its policy and strategy to avoid a threat or to seek new opportunities by redefining the industry or the company's business areas from the viewpoint or framework of new technological competition; modification of the corporate or business strategy; and redirection of R&D or technology strategies. Finally, it helps a country, research institute, or company to improve operational decision making of R&D portfolio management, R&D project selection and resource allocation between technologies. Also, it could be used for investment in plants and equipment including laboratory equipment, recruitment policy of human resources as well as product and marketing strategies.

2.2. Methodology for Technology Foresight

In fact, technology foresight is a third-generation version of technology forecasting (Georghiou *et al.*, 2008; UNIDO, 2005a). The first-generation version is technology forecasting by participation of science and technology experts only, second-generation of technology forecasting entails industry and market experts as participants, while as a third-generation, technology foresight adds social and user-oriented perspectives.

Due to the evolution of TF characteristics, technology forecasting used to be more prominent in the late 1950s as it began in the defense sector in the United States. Also, many of tools for technology foresight has been developed as principal tools of technology forecasting by consultants such as the RAND Corporation for technology forecasting activity in the defense sector of the United States. Since then, the public sectors and many private companies implemented technology forecasting in the United States.

But, at the end of the 1960s, Japan decided to use technology forecasting as a policy development tool so they adopted a method of technology forecasting first and adapted to technology foresight. During technology forecasting studies started in the 1960s, Japan identified that the change of technology would be more influenced by the change of society in the 1980s. This is the reason why Japan introduced methodologies of technology foresight such as bibliometrics and scenario planning to TF studies. Accordingly many of methodologies for technology foresight were used for technology forecasting interchangeably.

As a result, historically, Japan is the first country that had been engaging in extensive technology foresight activities since 1970 (Martin, 2001). Since then the United States, Australia and Germany launched national technology foresight programs in the 1980s, and the 1990s was the decade in which the national foresight programs were conducted by many other countries (UNIDO, 2005b). In the 1990s, the Netherlands, Australia, Britain, France and various countries launched national foresight exercise programs (Martin, 2001).

A wide range of methods are applicable to technology foresight from qualitative methods such as literature reviews, expert panels, and brainstorming, to quantitative methods such as simulation modeling and bibliometrics. Some are specifically designed for technology foresight while others are borrowed from management and planning research fields (UNIDO, 2005a). For example, the Delphi technique and scenario planning have been borrowed from other fields and were developed by futurists.

Widely used methodologies are trend extrapolation, simulation modeling, Delphi technique, cross impact analysis, scenario planning methods, expert panels and future wheels. <Table 1-1> shows the key characteristics of each TF methodology.

Trend extrapolation assumes that everything will continue to change steadily in the future with a certain pattern in which they have been changing in the past. Simply speaking, trend extrapolation is a straight-forward projection based on past observations like time series data to the future estimation using a statistical analysis method such as linear regression. Past observations could be historical data such as population growth, economic development and social attitudes (UNIDO, 2005a). Extrapolation essentially consists of collecting relevant historical data, fitting a curve to the data using statistical analysis methodologies, and finally, extending the curve into the future.

Simulation modeling is usual prediction method mainly using computer simulation techniques by support of computer system, which can be used to predict how the system will operate over time or outcomes of specific interventions. In this TF methodology, the future to be predicted is perceived as a system or a model consisting of components (node) and relationships (link). The quality of the system or the model is only as good as that of the assumptions it is based on and the data with which it has been calibrated (UNIDO, 2005a).

Delphi technique is the most widely used methodology for TF. It was originally developed in the United States in 1950 by the RAND Corporation. It is composed with a series of surveys created based on opinions of experts. The survey is designed to give feedbacks to its respondents who are the experts as well. The survey is circulated to the same set of respondents at least twice (UNIDO, 2005a).

<Table 1-1> Summary of Key Characteristics of Some TF Methodologies

Methodology	Definition	Key Feature	Time Required
Trend Extrapolation	Projection of the past observations to the future estimation using the statistical analysis method	<ul style="list-style-type: none"> • Straight-forward projection is done based on the past observations like time series data to the future estimation. • Identification of forces to drive the trend is important. 	Several Weeks
Simulation Modeling	Simulation techniques by the support of computer system to predict how the system will operate	<ul style="list-style-type: none"> • Future to be predicted is perceived as a system or model consisting of components and relationships. 	Several Weeks
Delphi Technique	Consultation process used to gather opinion from a wide group of subject experts about the future and to prioritize the issues of strategic importance	<ul style="list-style-type: none"> • Opinion gathered from a group of experts refine thinking on the future. • It highlights the potential trade off and choices that policy design will need to address. • It highlights conflicting views of the future and expectations of the policy. 	Several Weeks
Cross Impact Analysis	A family of techniques often thought of as an extension of the Delphi technique for identifying and evaluating the impact of trends or events upon each other using a matrix format	<ul style="list-style-type: none"> • It explores a hypothesis and finding points of agreement and divergence. • It targets audiences comprising experts from industry, academia, research and government. 	Several Weeks

⟨Table 1-1⟩ Continued

Methodology	Definition	Key Feature	Time Required
Scenario Planning Method	Stories that describe alternative ways that the external environment might develop in the future. Each scenario explores how different conditions might support or constrain the delivery of policy and strategy objectives.	<ul style="list-style-type: none"> • It explores different ways that the policy area might develop in the future. • It consider how key actors - government, businesses, citizens, competitors - might behave under different conditions. • It identifies the key requirements of policy under different external conditions. 	2 to 3 Hours or More (depending on size of group and objectives)
Expert Panel	Consensus building of the future of specific issues by pre-determined group of experts and renowned people	It includes: <ul style="list-style-type: none"> • Qualitative input and feedback on issues. • Quantitative feedback on issues. • Manifold applications wherever expert opinion is required. 	Several Weeks
Future Wheel	Graphical visualization of direct and indirect future consequences of a change or development	<ul style="list-style-type: none"> • It organizes thoughts about a future development or issue. • A series of wheels can be constructed to consider different aspects of issues. 	2 to 3 Hours or More (depending on size of group and objectives)

Source: GO-Science (2017), UNDP (2014), JRC website and compiled by the author.

In order to promote exchange of opinions and information among respondents and to see how far away their forecast and expectation from each other the Delphi technique provides feedback and a chance for the respondents to modify their judgments. The respondents in the each later round of the Delphi survey receive the outcomes of the previous round of the Delphi with the same set of questionnaires.

Cross impact analysis is an expert-based methodology producing quantitative result like Delphi technique (UNIDO, 2005a). In fact, the cross impact analysis is more advanced from Delphi technique and it is useful to prepare scenarios. The approach is to ask the experts to rate the likelihood of various events occurring and then to rate the likelihood of each event occurring if each of the others does or does not occur (UNIDO, 2005a). Because of this characteristic of the cross impact analysis, it is possible to analyze the interaction effect of each other technology to be predicted.

Scenario planning is introduced in the U.S. by RAND Corporation originally at the time of World War II to anticipate and respond to the enemy's attack strategy and nowadays it is widely used in public and private organizations such

as private companies. A scenario method is a technique to predict or expect the future that is likely to happen in the future and has a high impact on people and society, especially the economy. Scenarios consist of future statement and courses of development, organized in a systematic way with texts, charts, etc. (UNIDO, 2005a). Scenarios include images, stories, and maps that describe the path from the present to the future. It assumes that the future is influenced by the past and the present and therefore scenario development in the scenario method is based on trend extrapolation of the past and the present. Usually, alternative scenarios are developed to allow experts to participate in predicting alternative futures likely to happen and to identify clearly possible consequences of present technology developments and decision making.

Expert panel is widely used for deducing the knowledge of experts. TF, by definition, should consider interaction of science and technology with society. This characteristics makes use of knowledge of experts frequently based on the best available evidence and judgment of experts than statistical or historical evidence to predict or deduct the future of society and deliverables of science and technology these days. The panels typically consist of 10-20 individuals who have the expertise in science and technology, product family, or industry (GO-Science, 2017). Usually, 3 to 18 months were given to deliberate upon the future of science and technology, product family, or industry. Steps of usage are as follows. First, issues of the study, the role of experts, and the method of engagement are determined. Widely used methods of engagement are telephone interviews, face-to-face meetings and electronic meetings. The input of experts, judgement or opinion, is received for the issues of the study and the input of each expert is reviewed. If there is some disagreement, a further process is iterated for resolving the disagreement. Then a draft of final report is produced and reviewed by the experts panels and a final report is produced as a result (Jackson, 2013).

Future wheel is useful to visualize the future of consequence of some event, development or issues (UNDP, 2014). The future wheel is a tool for identifying the impact of important event or trend and mapping the causality of each event and its consequence. In this method, important events or issues should be centered at the future wheel. Participating experts draw a "spoke" of the wheel by identifying the consequence of an event which is placed on the center of future wheel. Like this, 3 or 4 layers of a "spoke" could be built from the center of the future wheel (GO-Science, 2017).

3. Current Situation of Technology Foresight in Mexico

3.1. History of Technology Foresight in Mexico

As mentioned in the previous section, TF has been increasingly recognized as a powerful instrument for establishing technology policy making in not only advanced countries but also developing countries such as Central and Eastern European (CEE) countries and the Newly Independent States (NIS) for narrowing their competitiveness gap in the global economy (UNIDO, 2005b).

The importance of right technology policy making to narrow the competitiveness gap in the global economy is also applicable to Mexico. Therefore, TF could be strong instrument for right technology policy making and effective development of technology infrastructure to Mexico.

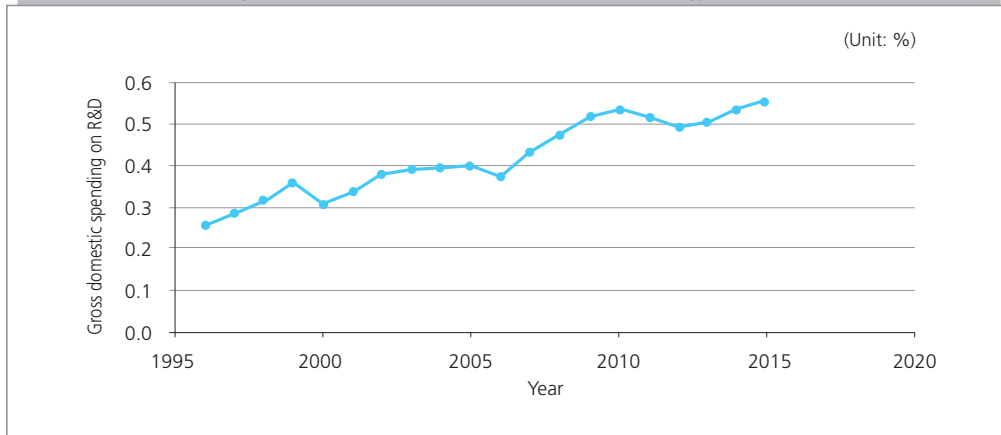
Regardless of the importance of utilizing TF outcomes in technology policy making and implementation for Mexico, utilization of TF studies is not common to Mexican organizations such as private companies, research institutes, and federal and state governments.

Mexico has a history of foresight and future research and pioneered the foresight studies in Latin America and the Caribbean region by introducing some of the first books and exercises in the 1970s. Also, Mexico led the first Latin initiative to promote integration of foresight efforts. But, Mexico has lost its leadership during the 1990s and now has an endeavor to recover it. However, Mexico still has not integrated foresight efforts into a fully-fledged national foresight program (Georghiou *et al.*, 2008).

One of the main reason why Mexican organizations do not have enough TF studies could be shortage of sufficient R&D budget for the TF studies and utilizing outcomes of TF studies as an input to technology policy making. Another reason could be absence of enough success experience in R&D program developed from TF studies.

According to World Bank statistical information, investment in science and technology by Mexican government began in 1996 and the amount of investment in science and technology was not enough as shown in [Figure 1-2].

[Figure 1-2] Investment in Science and Technology in Mexico



Source: World Bank Group (2017).

UNIDO (2005b) shows that the national TF program in Mexico was started in 2000. Also, this report found the technology prospect study began in 2001 by the Ministry of Communication and Transportation in the Mexican federal government. The data shows that attempt to introduce TF studies to policy making in Mexico was very late relative to other developing countries such as Philippines, India, Indonesia, Thailand, Hungary and Nigeria. These developing countries are introducing TF studies at least in the middle of the 1990s.

There were 14 studies related to foresight made in Mexico and foresight study especially focused on technology perspectives such as technology prospect, but technology forecasting and TF was not enough. Furthermore, major foresight studies focused on technological perspectives emerged in Mexico in the 2010s. Various organizations were the responsible entities for conducting foresight studies especially focused on the technological perspectives. Major entities responsible for TF studies are the ministries in federal and state governments, government-affiliated agencies, universities and private companies.

3.2. Analysis of Technology Foresight Studies in Mexico¹⁾

This section introduces 14 foresight studies related to TF such as technology prospects, technology forecasting and technology foresight in Mexico with a brief description for each of them. Also this makes a classification of each case with a responsible entity and provides a summary of the specifications including the aims and methodology with explanation. Various responsible entities are classified into

1) This chapter is mainly prepared by the local consultant, Mr. Victor Ahui Malvaez Campos.

the public sector, private sector, and research organization. A ministry of the federal and state governments and government affiliated agency or organization belong to the public sector, and private company, association or society of private companies belong to the private sector. A research institute affiliated to the public sector and universities belongs to a research organization.

Foresight studies conducted by the public sector are described in <Table 1-2>. Firstly, “Prospect Projects in Communications and Transports Industry” was created by the Ministry of Communications and Transportation in Mexico in 2001. This study only showed a list of possible changes in transportation and communications in Mexico.

Secondly, “Technological Foresight Study in the Mexican Auto Industry” was conducted for automotive manufacturing sector in Mexico made by AT Kearney, a global consulting company, and the Ministry of Economy in 2011. The automotive industry is considered by the Mexican government as a strategic sector and therefore this study was based on the outcomes of trend analysis, route map of the future and SWOT analysis.

Thirdly, “Roadmaps Created for Internet of Things (IoT)” was created in 2014 in communications and Transportation, according to trends analysis and environment scanning of the internet service industry.

<Table 1-2> TF Studies Made by the Public Sector in Mexico

No	Title	Responsible Entity	Year	Economic Sector	Methodology
1	Prospect in Communications and Transportation Industry	The Ministry of Communications and Transportation (SCT)	2001	Communication & Transportation	Suggestion on Short- and Mid-term Plans
2	Technological Foresight Study in the Mexican Auto Industry	The Ministry of Economy (with A.T. Kearney)	2011	Manufacturing -Automotive	SWOT, Trends, Roadmap
3	Roadmaps for Created for Internet of Things (IoT)	ProMexico & The Ministry of Economy	2014	Communication & Transportation, Satellite Services	Roadmap, Big data
4	Roadmap for Medical Devices	ProMexico & The Ministry of Economy	2011	Manufacturing -Medical, Electronic Equipment	SWOT, Trend Analysis
5	Roadmap for Manufacturing Advance	ProMexico & The Ministry of Economy	2011	Manufacture - Advanced Manufacturing	SWOT, Trend Analysis

〈Table 1-2〉 Continued

No	Title	Responsible Entity	Year	Economic Sector	Methodology
6	Roadmap for Aerospace Sector	ProMexico & The Ministry of Economy	2012	Manufacturing -Aerospace Equipment	SWOT, Roadmap, Scenarios Planning, MICMAC
7	Roadmap for Optics and Photonics	ProMexico & The Ministry of Economy	2016	Manufacturing - Computation Equipment, Communication, Measurement and Other Equipments, Components and Electronic Accessories	Roadmap, Trend Analysis
8	Technological Foresight and Strategic Innovation for Cattle Industry in Tabasco Mexico	INIFAP	2015	Agriculture, Cattle Industry, Forestry & Fishing	Delphi

Source: Compiled by author.

Fourthly, “Roadmap Medical Devices” was made as a part of an institutional strategic plan of ProMexico, in an economic sector of medical electronic devices in 2011. This study made a diagnosis of the environment and suggests tools how to improve technologies in this area.

Fifthly, “Roadmap Manufacturing Advance” was a plan in manufacturing economic sector identifying technologies, resources and capacities for the Delphi MTC center in Chihuahua made by ProMexico and the Ministry of Economy in Mexican federal government in 2011. This study was based on the trend analysis of technology and SWOT analysis.

Sixthly, “Roadmap for Optics and Photonics” was an analysis of resources and capacities of the industry related with enterprise infrastructure made in 2012, as a part of the strategies analysis of ProMexico. This study was based on SWOT analysis, roadmap, scenarios planning and MICMAC matrix.

Seventhly, “Roadmap Optics and Photonics” was a study made by ProMexico and the Ministry of Economy in 2016. The objective is to create a link among government, industries and universities in technological fields related to the photonic and optical industries. This study identified opportunity areas to increase quality in electronic devices manufacture and derive strategies using methodologies such as roadmap and trends analysis.

Finally, “Technological Foresight and Strategic Innovation for Cattle Industry in Tabasco Mexico” was made by different panel experts in Mexico such as INIFAP, National Center for Disciplinary Research in Animal Physiology and Improvement; INIFAP-CIRGOC, Experimental field in Huimanguillo; INIFAP, National Center for Disciplinary Research in Conservation and Improvement of Forest Ecosystems; UJAT, Academic Division of Agricultural Sciences. This study used Delphi methodology with different questionnaires in agriculture, cattle industry, forestry and fishing sectors.

<Table 1-3> TF Studies Made by the Private Sector in Mexico

No	Title	Responsible Entity	Year	Economic Sector	Methodology
1	Technological Foresight and Patents Analysis to Identify Specific Requirements in Air Systems Does Not Crewed	Quetzal Aeroespacial Enterprise	2015	Communications & Transportation, Airlifts	Patents Analysis
2	Mexico 2030, Foresight Vision	Mexican Institute of Finance Executives (IMEF) Created by PricewaterhouseCoopers (PwC)	2012	Communications & Transportation, Linkage between Energy and Electricity, Water, Oil, Construction of Public Infrastructure	Suggestion on Short- and Mid-term Plans
3	Automotive Roadmap	FUMEC	2011	Manufacturing -Automotive	SWOT, Trend Analysis
4	Foresight Analysis of Tilapia Supply Chains in 4 States in Mexico: Stages and Strategies for 2018	Mirolava Vivanco, Francisco José Mojica, Franciso Javier Martínez	2010	Agriculture, Cattle Industry, Forestry & Fishing	MICMAC. Discriminant Analysis

Source: Compiled by author.

Foresight studies conducted by the private sector are described in <Table 1-3>. Firstly, “Technological Foresight and Patents Analysis to Identify Specific Requirements in Air Systems does not Crewed” was an analysis of air system that does not crewed made in 2015 by Quetzal Aeroespacial enterprise in Mexico. This study identifies opportunities for implementing, benefits to society, requirements to improve tourism and transportation through patent analysis.

Secondly, “Mexico 2030, Foresight Vision” was made by Mexican Institute of

Finance Executives (IMEF) and PwC (PricewaterhouseCoopers) in 2012. This study was only a descriptive study of infrastructure and its relations with technology and financial statement in Mexico and suggested recommendations to improve infrastructure in Mexico in a short- and mid-term.

Thirdly, “Automotive Roadmap” was made by FUMEC (US-Mexico Foundation for Science). Automotive program has been implemented since 2011 and it was started from an agreement between FUMEC and automotive industry in order to link foresight actors. This study used SWOT analysis and trend analysis as a methodology for prospective aims, but without a foresight scope.

Fourthly, study on “Foresight Analysis of Tilapia Supply Chains in 4 States in Mexico: Stages and Strategies for 2018” was done in 2010. This study analyzed agriculture, cattle industry, forestry & fishing using MICMAC and discriminant analysis to explain technics and factors to produce Tilapia (fishing activity) in some key geographic areas in Mexico.

<Table 1-4> TF Related Studies Made by Research Organizations in Mexico

No	Title	Responsible Entity	Year	Economic Sector	Methodology
1	Foresight Risk Management in Drone Industry	Institute Technology Orizaba & Autonomous University Popular of State Puebla	2016	Communications & Transportation - Satellite Services	SWOT, PEST, Scenarios Planning
2	Technological Foresight Model for the Identification of Business Opportunities (TEFMIBO)	ITESM David Güemes, Geovanny Romero & Amado Villareal	2014	Other Private Services Non-financial Management Strategies	Scenario Planning

Source: Compiled by author.

Foresight studies done by research organizations are described in <Table 1-4>. Unfortunately, there were no foresight studies from the public research institutes or the government-funded research institutes in Mexico. Firstly, A research paper title “Foresight Risk Management in Drone Industry” was published in 2016. This research paper analyzes different scenarios in communications and transportation sector by planning different scenarios, which come from SWOT, PEST and scenarios analysis.

Secondly, A research paper “Technological Foresight Model for the Identification of Business Opportunities (TEFMIBO)” was made by Monterrey Institute of

Technology and Higher Education (ITESM) in 2014. This research paper explains different kind of tools to create a technology foresight foresight strategy through scenarios generation method by managers who are related with innovation and technology.

<Table 1-5> shows more details of these TF studies in Mexico and reviews some important features with a view of methodology. Most of TF studies are placed at the technology forecasting rather than technology foresight. Also, these outcomes of TF studies were not related to decision making of government or organization. This study could not find any evidence that the outcomes of TF studies is used directly or indirectly as an important information to decision making of R&D policy such as new R&D program launching and resource allocation or as a draft material for science and technology strategy.

<Table 1-5> Review of TF Studies Made in Mexico

Type of Study	Name of Study	Prospect	Forecasting	Comments
Analysis of Trends	Prospect in Communications and Transportation industry	Study describes trends and behaviors in communications and transportation industry until 2025.		This study does not include a method to develop technological foresight.
Forecasting Analysis	Technological Foresight and Patents Analysis to Identify Specific Requirements in Air Systems that Does Not Crewed	Patents Analysis	Patents Analysis	This study only includes market description and air model systems marketing in countries of Latin America and the Caribbean.
Forecasting Analysis	Technological Foresight Study in Mexican Auto Industry	Create Future Trend	Opportunities Matrix	This study shows opportunities and rising trends in automotive market through matrix.
Forecasting Analysis	Mexico 2030, Foresight Vision	Future forecasting with Government Information Data	Analyzing and Collecting Government Information Data	This study was made from different aspect of economic, political and financial sector (development bank).
Forecasting Analysis	Roadmaps Created for Internet of Things (IoT)	Technology Roadmap		This study specifies trends, strategic landmarks, their definitions and scale of importance.
Forecasting Analysis	Roadmap for Medical Devices	Technology Roadmap		This study specifies trends, strategic landmarks, their definitions and scale of importance.

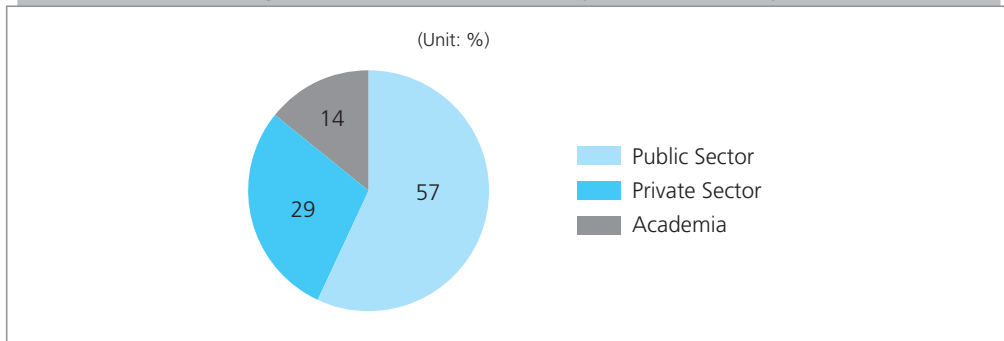
〈Table 1-5〉 Continued

Type of Study	Name of Study	Prospect	Forecasting	Comments
Forecasting Analysis	Roadmap for Manufacturing Advance	Technology Roadmap		This study specifies trends, strategic landmarks, their definitions and scale of importance.
Forecasting Analysis	Roadmap for Aerospace Sector	Technology Roadmap		This study specifies trends, strategic landmarks, their definitions and scale of importance.
Forecasting Analysis	Roadmap for Optics and Photonics	Technology Roadmap		This study specifies trends, strategic landmarks, their definitions and scale of importance.
Forecasting Analysis	Automotive Roadmap	Technology Roadmap		This study specifies trends, strategic landmarks, their definitions and importance scale.
Forecasting Analysis	Technological Foresight and Strategic Innovation for Cattle Industry in Tabasco Mexico		Expert Panel	In this study, 21 experts participated as researchers for developing strategies for research and education institutions. As a result, the technology strategies and policies in cattle industry of Tabasco were made.
Forecasting Analysis	Foresight Risk Management in Drone Industry			This study shows stage planning and elaborates scenarios related with risk management in security drone industry.
Process of Technology Foresight	Technological Foresight Model for Identification of Business Opportunities (TEFMIBO)	Trend Analysis & Dynamic Diagnostic Methods	Change Drivers Identifications	This study shows tools for technology forecast and business model.
Forecasting Analysis	Foresight Analysis of Tilapia Supply Chains in 4 States in Mexico: Stages and Strategies for 2018		Structural Analysis	Structural Analysis

Source: Compiled by author.

57% of the TF studies were conducted by the public sector, 29% by the private sector and only 14% of studies were made by research organization, especially universities as shown in [Figure 1-3]. More detailed information related to foresight of these studies is shown in <Table 1-4>.

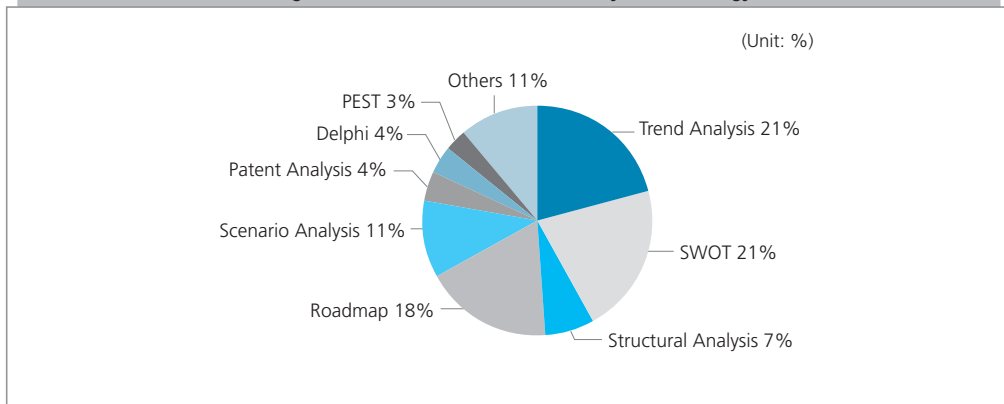
[Figure 1-3] TF Studies Classified by Responsible Entity



Source: Compiled by author.

Methodologies used for foresight study is analyzed in [Figure 1-4]. Trend analysis and SWOT analysis are major methodologies for foresight study, accounting for 21% respectively of the total share of methodologies used in TF studies. Other methodologies account for remaining portion as follows; scenario analysis 11%, structural analysis 7%, patents analysis 4%, Delphi 4%, PEST analysis 3%. But the amount of foresight studies in Mexico is relatively small and this limitation pay attention to its interpretation for the suggestion to effective TF studies implementation strategy for IPN.

[Figure 1-4] TF Studies Classified by Methodology



Source: Compiled by author.

Although it was difficult to analyze due to limitation of data collection (e.g. final report), other studies related to technology foresights were identified in a field survey. PEMEX (Mexican Petroleum, Mexican state-owned petroleum company created in 1928) and PROTEAA (Laboratory of Technological Prospecting for the Innovative Development of Foods in the Center for Research and Assistance in

Technology and Design of the State of Jalisco) also had an experience of technology forecasting. Also, CONACYT (National Council of Science and Technology in Mexico) conducts future foresight studies for anticipation of the future of Mexico.

This section shows that the most of TF studies in Mexico were executed not as an independent TF report but as a part of planning report such as technology roadmap for development of specific industry, while enough independent TF studies for R&D policy has not been done yet. Furthermore, exploratory method such as SWOT analysis, Delphi method, trend analysis have been widely used for TF rather than normative method. Usually, exploratory method is extrapolating or predicting the future of some events or issues based on the past trend or causal dynamics. But, normative method is backcasting the relevant prerequisite from the desirable or possible future of interest. Finally, IPN did not conduct TF studies regardless of its role in R&D for socio-economic development in Mexico.

The analysis result shows that IPN could strengthen TF capability quickly by outsourcing to qualified external institutions or hiring talented personnel with TF experience. Also, it is more preferred to conduct technology foresight with exploratory method such as Delphi technique or trend analysis rather than normative method. Furthermore, IPN could have a leadership in Mexico TF studies by actively executing TF studies, using the outcomes in decision making process for R&D policy planning and implementation of IPN, and ultimately influencing the national R&D policy making process and disseminating the outcomes across the country.

3.3. Capabilities and System Readiness for Technology Foresight of IPN

This section analyzes human resources of the innovation system related departments in IPN such as Polytechnic Unit for Development and Business Competitiveness (UPDCE), Technology Development Unit (TechnoPoli) and Incubation Center for Technology-Based Companies (CIEBT). Also, this section examines the pool of R&D experts registered and managed by IPN or CONACYT. Finally, this section lists and explains information service and information system owned by the aforementioned departments.

UPDCE services are focused on enterprises consultancy to improve capacities, processes, infrastructure, business models, marketing, finance, etc. Trainings given by UPDCE are related with enterprise competitiveness in TF field, which supports the enterprise for technological strategies with continuous monitoring and control in the short- and mid-term.

<Table 1-6> External Networks of UPDCE in the Science and Technology Field

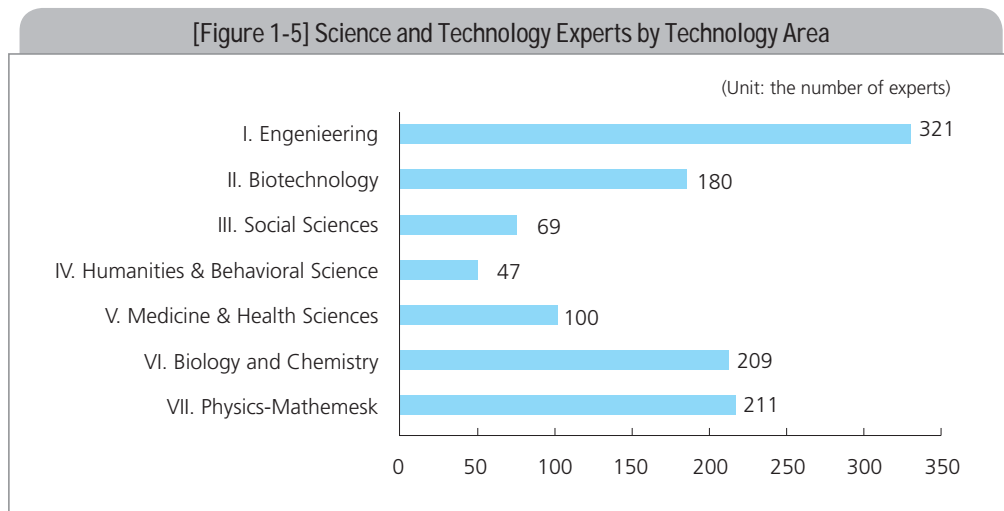
Unit	Name	Research Area
CIIDIR Durango	Ph.D Juan Manuel Vigueras Cortés	Biotechnology
	Ph.D Marco A. Garzón Zúñiga	Biotechnology
CICATA Altamira	Ph.D Luis Ponce Vidal	Laser technology and Ceramics
	Ph.D Teresa Flores Reyes	Laser technology and Ceramics
CICATA Legaria		Silver Nanoparticle
ENCB Santo Tomás	Ph.D Sonia Mayra Pérez	Blood Products
CIC	Ph.D Adrian Martinez Rivas	Microtechnology and Embedded System
	Ph.D Génesis	
CEPROBI	Ph.D Silvia Bautista Baños	Biotic and Antimicrobial Developments
ESIME Zacatenco	Ph.D Javier Tejada López	Antenas and Devices for Reconstructing Signals
	Ph.D Vladimir Kazakov	
	Ph.D Daniel Rodriguez Saldaña	
	Ph.D Yahir Felix Olvera Mejía	
ESIME Zacatenco	Ph.D José Martínez Trinidad	Materials and Hardening Iron
	Ph.D Iván Enrique Campos Silva	
	Ph.D Noé López Perrusquia	
	Ph.D Milton Carlos Elias Espinosa	
	Ph.D Oscar Armando Gómez Vargas	
	Ph.D Martín Ortiz Domínguez	
ESIME Culhuacán	Ph.D Volodymyr Ponomariov	Solar Panels and Photovoltaic Optimization
	Ph.D Jaime Vega Perez	
UPIIG-IPN	Ph.D Alfredo De Santiago Parra	Devices for Hearing Improvement

Source: Compiled by author.

UPDCE has 85 staffs in total including contract-based workers. Majority of the staffs in UPDCE have a career in business and social science and contract-based workers also have careers in business intelligence. And UPDCE has strong science and technology network by providing technology services to private companies. For example, <Table 1-6> shows researchers linked with UPDCE project in 2017. According to the information shown in <Table 1-6>, it is possible to identify that research areas in which researcher work are telecommunications, electronic, mechanic, materials, biotechnology, etc. This information strongly supports that IPN has systematic infrastructure and networks for effective TF studies.

TechnoPoli supports applied research, technological development and innovation of productive sector to respond society demands for achieving crucial economic and sustainable development. TechnoPoli manages technology and innovation flow among institutions, technology-based companies and markets and provides open spaces and facilities to host knowledge-intensive enterprises. Especially, TechnoPoli provides business and technology intelligence and has “Surveillance and Technology Foresight Department” dedicated to TF studies.

CIEBT has a role of contributing to economic and social development in Mexico. Therefore, it introduces creative strategy to motivate and develop entrepreneur culture and supports incubation of enterprises by training entrepreneurs and encouraging development, innovation and technology projects with aim to invigorate the polytechnic community and society.



Source: Compiled by author.

[Figure 1-5] shows science and technology experts who have experience(s) in working for innovation services of UPDCE, TechnoPoli, CIEBT in innovation service of UPDCE, TechnoPoli, CIEBT in IPN. These science and technology experts also can participate in IPN’s TF studies.

Although it is unable to analyze thoroughly because of limitation of collecting detailed result report or data, CONACYT also has DB of science and technology experts in Mexico. CONACYT uses this DB for various purposes such as future foresight, questionnaire survey and R&D evaluation. IPN can use this DB as CONACYT gave permission for use upon request from IPN.

TechnoPoli has an observatory OTTP-PNI to allow and operate an easy access for science and technology and marketing information. Observatory Information is useful for technological management among agents involved in technological innovation development. The information is also crucial for government, industry and society in Mexico. OTTP-PNI analyzes, searches, consults, publishes and evaluates strategic and priority information. The information is about development trends at the regional, national and international level which is of great interest in Mexico.

Main services offered by OTTP-PNI are as follows; surveillance of the state of the art technology, academic strategy papers, technological research, intellectual property papers, technological strategy information, exclusive information source, exclusive informatics tools, market research, benchmarking, business training, business planning, cost-benefit analysis, technological and economic feasibility and participation schemes.

For the information services providing special, strategic, valuable information for technological innovation for users, OTTP-PNI has several information systems. IHJ Goldfire is based on an innovative system in patents. SciVerse Spotlight and SciVerse SCOPUS are used for operating surveillance of the current status of technological landscape, competitive technological intelligence, and intellectual property documents collected by the observatory.

Another strength of IPN is strategic relationships among the IPN Observatory and other institutions, for example, there is a good practice with Alicante Observatory because some information was useful to take an advantage from technology transfer and innovation. In addition, there are other supportive relationships like Mexican Scientific and Technological Parks and Network of University-Company in Latin America and the Caribbean and the European Union (REDUE-ALCUE).

3.4. Obstacles and Challenges in Technology Foresight of IPN

This section reviews the current status of TF studies in Mexico and then analyzes strengths, weakness, opportunities and threats of TechnoPoli for TF studies. Finally, this section shows the result of SWOT analysis for strategy of TF studies by TechnoPoli, IPN.

First of all, Mexico does not have enough experience in TF studies as an input of technology policy making and R&D program planning. Several foresight studies are made by the federal or state governments, private companies, associations of private companies, and universities. However, many of studies are technology prospect, future foresight or market foresight.

This is due to low gross R&D spending in Mexico and lack of R&D budget for systematic TF studies which can be expensive. On the other hand, this is partly due to little demand for TF studies in Mexico. Generally speaking, technological capability of Mexican industry is not competitive compared to other advanced countries such as the United States, Germany, Japan, Korean and China. Therefore, Mexican private companies are more interested in predominant technologies rather than emerging technologies in the future. It is most likely that this tendency is the main reason for absence of systematic TF studies in Mexico.

As shown in <Table 1-7>, IPN has strengths based on its long history of business and technology intelligence service of UPDCE, TechnoPoli and CIEBT. IPN also has ample experts DB in science and technology and information system for its services. IPN also has sufficient external network for extending pool of experts in science and technology system. The DB is lively updated and actively used for various service of IPN.

<Table 1-7> SWOT Analysis for TF Studies in IPN

		Strength	Weakness
		<ul style="list-style-type: none"> • Accumulation of TF related capability in IPN • Experienced human resource and third party organization in Mexico • Establishment of S&T expert DB in IPN and other organization 	<ul style="list-style-type: none"> • Lack of talented human resource in IPN • Lack of experienced human resource with normative methodology in Mexico
Opportunity	<ul style="list-style-type: none"> • Strong willingness of Mexican government to R&D-driven economic development 	SO Strategy	WO Strategy
		<ul style="list-style-type: none"> • Quick establishment of TF capability • Active extrapolation of result of TF studies 	<ul style="list-style-type: none"> • Hire talented human resource for full-time work • Use of exploratory methodology for TF in early stage
Threat	<ul style="list-style-type: none"> • Leadership of other organization 	ST Strategy	WT Strategy
		<ul style="list-style-type: none"> • Co-working with other organization for internalizing their capabilities 	

Source: Compiled by author.

IPN has some weaknesses for TF studies such as absence of any talented or skilled experts. Furthermore, there are no enough experts who have an experience in TF studies using normative methodology in Mexico. Therefore, if IPN decides to implement TF studies by using the normative method, IPN should hire talented or skilled experts from abroad or should provide education and On-the-Job Training for

the experts. But if IPN wants to use the exploratory method, IPN could directly hire experienced experts or outsource TF studies to external organization in the Mexico.

By implementing TF studies, IPN can provide great opportunity for development of science and technology and contribute to create innovation-friendly environment in Mexico. Mexico has been lagging behind in developing science, technology and innovation, which are the key to improvement of productivity and competitiveness of the industry and society in Mexico. In 2012, the Mexican government set the National Development Plan (PND by its Spanish acronym) and launched an ambitious 25-year Special Program for Science, Technology and Innovation (PECITI by its Spanish acronym) to achieve sustainable socio-economic growth of the country (Rosanis and Casanova, 2015). The federal government committed increasing R&D budget by 25.6% during 2014-2018 and 1% of GDP by 2018 from 0.4% in 2015. Although commitment of the federal government for the increase of R&D budget is not realized, it is obvious that the only way of boosting the economy is to create the right conditions for start-ups and innovators and to keep emphasizing on fostering science, technology and innovation.

Major threats of IPN for implementing TF study are not clear at this point. But opportunities to introduce national foresight program to CONACYT or other government-affiliated organizations such as ProMexico or non-governmental organizations such as FUMEC could be one of the threats to IPN's efforts towards TF study. As discussed in the opportunity, it is clear that Mexico will include science and technology in the national agenda and focus more on the science, technology and innovation in a new government. Therefore, it is likely that the federal government or state governments will put efforts to identify the key or emerging technologies for development, and TF can be an alternative to use. Also, there are many institutions with experiences in capacity building and teaching programs such as Javier Barros Sierra Foundation, the College of Mexico, the Autonomous University of Mexico, and Technological Institute of Monterray (Georghiou *et al.*, 2008). The institutions could have started TF studies at the national level.

It could be another threat to IPN that IPN has no legitimacy of TF at the institutional or the national level. IPN can conduct TF studies by single event with close relationship between the government and IPN headquarter. But this cannot guarantee sustainable authority and budget for TF studies of IPN.

Strategic direction for implementing TF studies by IPN could be suggested based on the results of SWOT analysis. Firstly, IPN should strengthen TF capability quickly by hiring talented experts and cooperating with other promising organizations such as FUMEC, ProMexico and private consulting firm by internalizing and accumulating TF capability. Secondly, for having sufficient TF capability quickly and taking a

lead in competition, IPN should use exploratory methodology for TF studies at the beginning and then IPN should shift its focus to use of normative methodology for deriving desirable technology for socio-economic growth of Mexico. Finally, IPN should actively have an effort to extrapolate the result of TF studies to R&D resource allocation in IPN and to influence a national R&D policy planning by disseminating the outcomes of TF studies.

4. Korean Experience of Technology Foresight

4.1. Institutional System for Technology Foresight in Korea

Korea has various organizations that conduct the TF studies, such as a central government, regional governments, government-funded research institutes, and public research institutes and private companies. Specifically, the central government has conducted and presented the national science and technology foresight study on national priorities of technology investment every 5 years since 1994. It conducts the study to establish the national science and technology strategy, under the control of the Framework Act on Science and Technology. The Ministry of Science and ICT (Information and Communication Technology), the managing department of scientific technology promotion at the national level, announced the fifth results in 2016. After the Ministry of Science and ICT has performed investigation for science and technology foresight, the other departments that mainly invest in the research and development, such as the Ministry of Industry, the Ministry of Environment, the Ministry of Health and Welfare, the Ministry of Land, Infrastructure and Transport, conduct TF studies.

The central government establishes laws, and the regional governments establish municipal ordinances and rules, to accomplish the legal basis to safely conduct the TF studies. The government-funded research institutes and the public research institutes have no duty to conduct TF studies based on the articles of association like the regional governments. However, many government-funded research institutes and the public research institutes conduct TF studies of the related fields of technologies as one of their activities to establish a mid-and long-term development strategy in every 3 to 5 years. Especially, the government-funded research institutes propose the mid-and long-term development strategy during the approval process of management performance plan by the government during 3- to 5-year term of the chief of the institutes. Also, each government-funded research institute conducts TF studies to explain their roles and functions to the public during change period of government regime or every 10 years. Like the government-funded research institutes and the public research institutes, the private companies also conduct TF

studies of related fields of technologies as one of their activities to establish a mid- and long-term development strategy or to find a new business or a new field for investment.

The Ministry of Science and ICT, the national level ministry in charge of TF studies, conducts the study based on Articles 13, 14, and 27 of the Framework Act on Science and Technology as the legal basis. KISTEP (Korea Institute of Science and Technology Evaluation and Planning) is the main agent to conduct the study. Also, other ministries, such as the Ministry of Industry, the Ministry of Environment, and the Ministry of Health and Welfare, conduct TF studies. Each of them has a quasi-government affiliated R&D institutions to conduct TF study. For example, the Ministry of Industry regularly conducts TF studies of the related fields of technology by KIAT (Korea Institute for Advancement of Technology), the Ministry of Environment by KEITI (Korea Environmental Industry and Technology Institute), the Ministry of Land, Infrastructure and Transport by KAIA (Korea Agency for Infrastructure Technology Advancement).

The regional governments, which have high volumes of research and development investments, conduct TF studies through the quasi-government affiliated organizations managing R&D or the municipal organization for the industrial development like the central government. For example, The Seoul Metropolitan Government conducts TF studies on each of its strategic industries or technologies with SBA (Seoul Business Agency), Gyeonggi province with GTEP (Gyeonggi Institute of Science and Technology Promotion), The Busan Metropolitan Government with BISTEP (Busan Institute of Science and Technology Evaluation and Planning).

In the government-funded research institutes and the public research institutes have each department that plans a mid-and long-term strategy, such as a department of strategic planning or a department of technology policy. And these departments take a role in conducting TF studies. In private companies, a department that plans a mid-and long-term strategy and finds a new business and a new field of investment, conducts the study.

The Ministry of Science and ICT is the line ministry for the national science and technology foresight study. And KISTEP performs the study for the ministry. KISTEP has its own department exclusively for TF studies. It has around 5 experts who directly conduct TF studies. However, the Ministry of Industry, the Ministry of Environment, the Ministry of Health and Welfare, the Ministry of Land, Infrastructure and Transport, and other central departments or regional governments, government-funded research institutes and public research institutes, assign a task of TF studies in each department to 1 or 2 supervisors. And they conduct the study through contract-based outsourcings to private consulting firms. Also, private companies, which have

a high priority on security, have their own departments that have experts who can directly conduct the study.

The central government, regional governments, the government-funded research institutes, the public research institutes and private companies, draw outcomes from TF studies. And they actively get feedbacks to establish science and technology strategies of each institutions.

In the central government, the Ministry of Science and ICT, the national department for TF studies; and its results of the national science and technology foresight study are included in establishment of the national science and technology strategy. First, the ministry discloses the result of TF studies to the public. And every 5 years, the national framework plan on science and technology reflects the result of TF studies as a duty. Also, it reflects the result on establishment of national technology roadmap manifesting the strategy and directions for technology development addressing future problems such as societal issues and improving quality of life which established by the Ministry of Science and ICT. Furthermore, the central government uses the results as an important review criterion for coordination and budget allocation or the feasibility study on the national research and development program for verifying the appropriateness of government investments prior to funding the Ministry of Industry, the Ministry of Environment, the Ministry of Land, Infrastructure and Transport, or each ministry that the central government promotes.

Likewise, the Ministry of Industry, the Ministry of Environment, the Ministry of Health and Welfare, the Ministry of Land, Infrastructure and Transport, and other ministries and the regional governments of the central government reflect the result of TF studies on establishment of the national strategy for science and technology, national technology roadmap, new national research and development program on the field of strategic technologies for each department.

The government-funded research institutes and the public research institutes reflect the result of TF studies on more than 5-year mid- to long-term development strategy or 3- to 5-year term of business performance plan, government/government-funded research and development business plan. And it uses the result as the base data to secure the research and development budget of the Ministry of Science and ICT or other ministries. Similarly, private companies also use the result of TF studies as the base data to secure the budget for the department of finance or investment for establishment of a mid-and long-term development strategy or a new business project plan.

4.2. Technology Foresight Studies at the National Level

This session introduces 2 cases of TF studies at the national level. One is the National Science and Technology Foresight Study made by KISTEP on the charge of the Ministry of Science and ICT. The other is “Technology Foresight 2040: Land, Infrastructure and Transport” made by KAIA on the charge of the Ministry of Land, Infrastructure and Transport.

4.2.1. The National Science and Technology Foresight Study

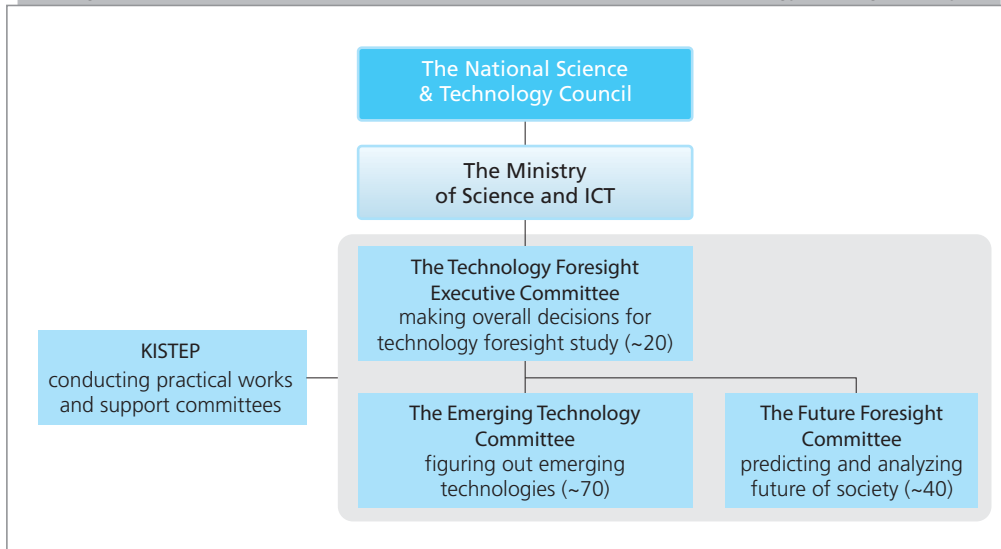
KISTEP has performed the National Science and Technology Foresight Study for establishing the National Science and Technology Strategies every 5 years since 1994. It completed the final fifth study in 2016. KISTEP conducts the national science and technology foresight study to identify emerging technologies in the consideration of their economic and social impacts, and finally explores effective nationwide countermeasures by analyzing growing trends in science and technology and science- and technology-driven changes in the future society.

KISTEP identifies the time of realization, its importance, effective measures for realization of the emerging technologies since the first study and identifies its tipping point of the emerging technologies in the fifth study.

The institutional structure for the fifth Science and Technology Foresight Study is explained in [Figure 1-6]. KISTEP supports and supervises the practical works in general, the Future Foresight Committee analyzes prospects of the future society on Stage 1, then the Emerging Technology Committee draws and predicts the future technology of Stage 2. The Executive Committee revises and examines overall science and technology foresight study.

The Future Foresight Committee has 3 departments, and each department has around 12 experts in science and technology and social science. The Emerging Technology Committee has 6 departments and has around 12 science technology experts in each department. And the Technology Foresight Executive Committee has high-level experts of science and technology and social science who are socially influential. And each director of committees participates as the official members of the Executive Committee.

[Figure 1-6] Institutional Structure for the National Science and Technology Foresight Study



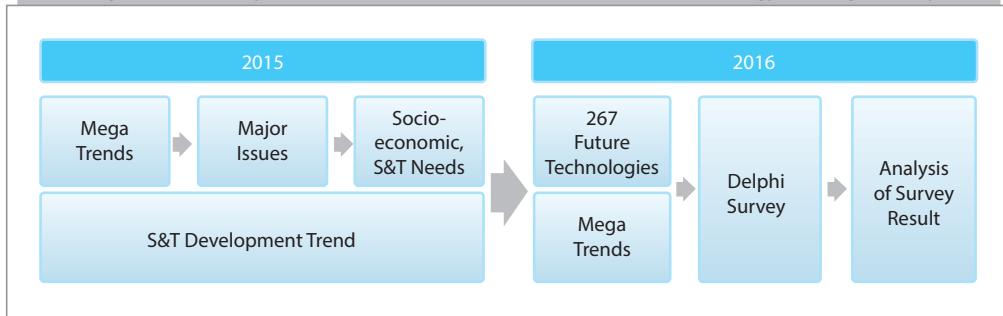
Source: KISTEP (2016).

The Future Foresight Committee draws socio-economic needs by examining the analysis results of KISTEP where it seeks to draw the main issues of each trend based on examination of outcomes from trend analysis. The Emerging Technology Committee appoints the candidate groups of future technologies based on main issues, needs, and development of science and technology. Also, they adjust and confirm the candidate groups. The Technology Foresight Executive Committee examines the conclusions of prospects of future society and technologies. Then it selects a subject to analyze tipping point of future technologies. Then it examines and revises the results of the National Science and Technology Foresight Study.

Usually, the Future Foresight Committee performs science and technology foresight study by 2 stages. At the first stage, it draws the needs of science and technology to resolve national level issues based on analysis of mega trends, and science and technology development trends. In the second stage, based on the result of the first stage analysis, it draws the future technologies with high potentials. From these technologies, it identifies the time, importance, effective measures for realization, and its tipping point of future technologies using Delphi survey with experts.

In the Fifth Science and Technology Foresight Study, each stage takes 1 year to proceed, it has completed the first stage in 2015 and the second stage in 2016 as shown in [Figure 1-7].

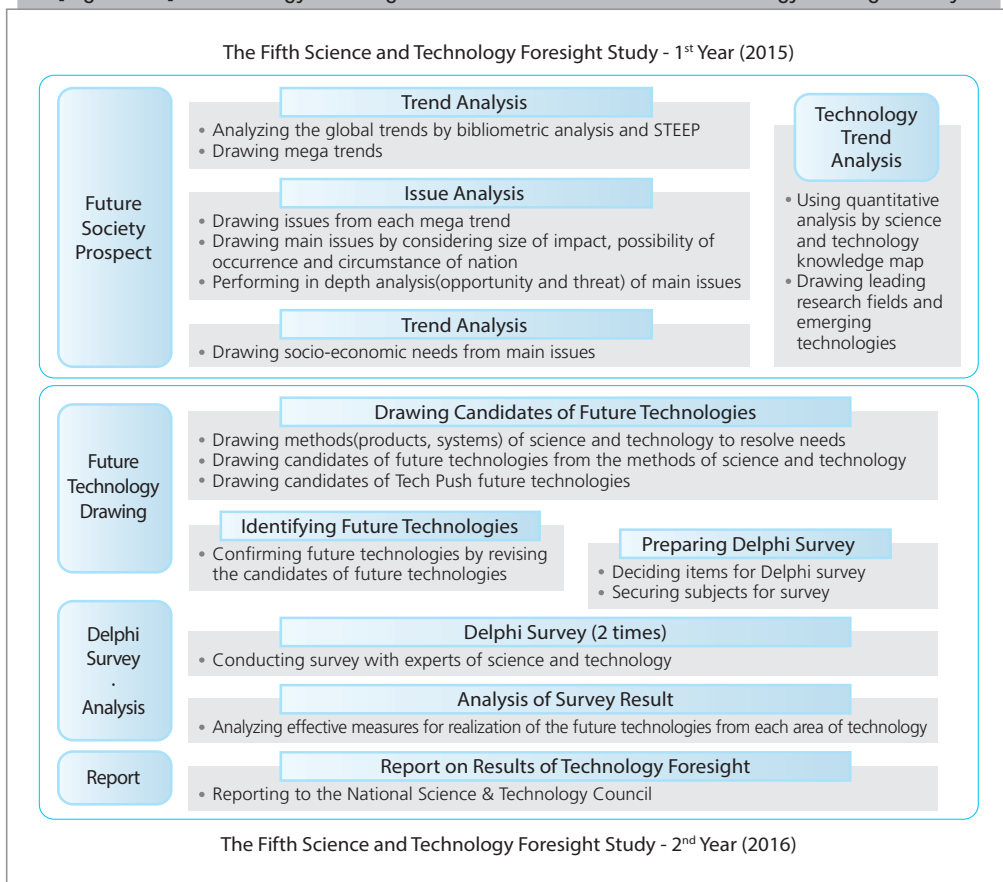
[Figure 1-7] Yearly Work Scope of the National Science and Technology Foresight Study



Source: KISTEP (2016).

Specific methodology and stage of the National Science and Technology Foresight Study is shown in [Figure 1-8]. In the first stage, it draws 5 mega trends, and 40 sub-trends, such as increase of life expectancy, hypoconnectivity technology, and

[Figure 1-8] Methodology and Stage of the National Science and Technology Foresight Study



Source: KISTEP (2016).

increase of natural disaster, based on surge analysis and STEEP (Social, Technological, Economic, Environmental and Political) analysis. With simultaneous analysis of mega trends, it draws a knowledge map based on academic journals from Web of Science and SCOPUS. Then it conducts network analysis of keywords from academic journals by each stage. It proceeds to divide each stage into 4 sections of past 20 years, from 1995 to 2014. Then it carries out time series analysis on the outcomes.

It draws out the main issues that the country must resolve based on the outcomes. The total number of issues are 40, which are 18 short-term issues, 14 short- or long-term issues, and 8 long-term issues. Examples of these issues are increase in speed of infectious diseases and emergence of new kind of infectious diseases, reform of logistics and traffic systems following the advent of autonomous vehicles and acceleration of convergence of industries and technologies. While it draws the main issues, it also includes the public opinions by online survey. Then it sorts technological keywords related to the key issues, recently emerged issues, and main issues by keyword to conduct keyword network analysis and natural language processing based on text mining from the 26,108,658 articles. It collects articles, which contain these issues, from websites of the major press.

Later, it draws out 231 scientific methods by the needs of science and technology to resolve 40 issues, such as constructing satellite-based national disaster management, grocery tracking system based on smartphones, technology of cerebral autoregulation by external stimulus, and central control system of autonomous vehicles.

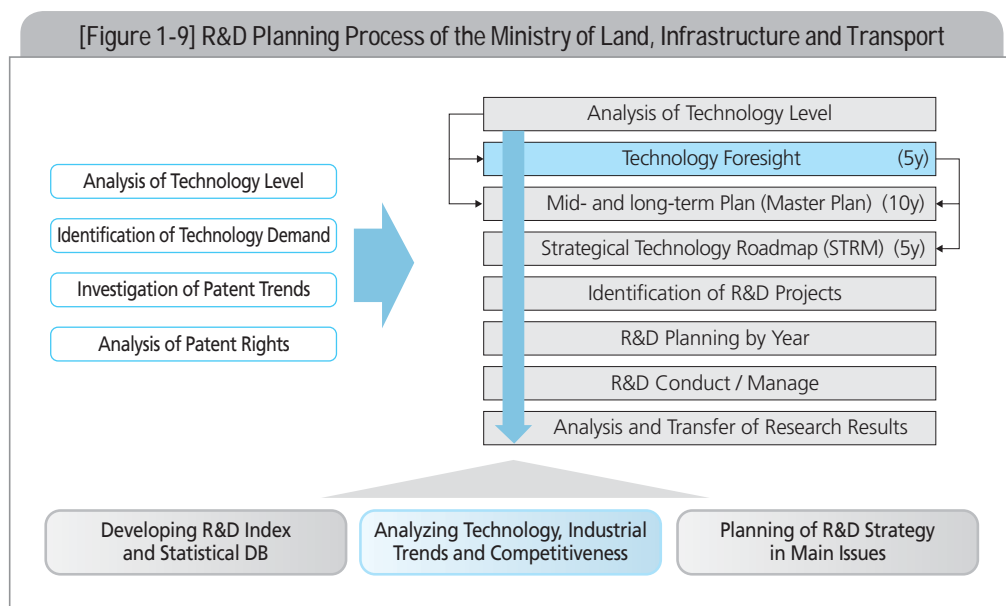
In the second stage, it draws out the 267 future technologies that will appear by 2040 along with demands change in the future and growth of the level of science and technology. Examples of these future technologies are artificial agri-food consumption foresight system, automatic ordering system, gas leakage warning system based on Internet of Things and 4K transparent flexible digital signage. Then it runs Delphi survey to draw realization time, importance and necessary government policy.

The experts respond to the survey on each technology. Especially among the 267 future technologies, it selects 24 main technologies that will have a great impact on the future society. And it conducts additional researches on tipping points of technologies to consider policy availability. The tipping point is when a technology rapidly spreads. It runs the Delphi survey in 2 rounds. The first round has 4,133 respondents, and the second round has 3,621.

4.2.2. Technology Foresight 2040: Land, Infrastructure and Transport

KAIA establishes a series of planning process. Also it periodically forms a rolling plan, which is 「TF studies → mid-and long-term strategy → Master Plan」 for systemic promotion of “The Infrastructure and Transportation Research and Development Program” under the Ministry of Land, Infrastructure and Transport. This process is shown in [Figure 1-9].

KAIA conducts TF studies to find emerging technologies in every 5 years. It analyzes future technologies and future trend and needs for future technology in the long-term view of 25 years to find the emerging technologies. Also, every 5 years, it establishes and complements a mid-and long-term strategy which orients phased technology development strategies and provision of research and development investment from the long-term view of 10 years. And every 5 years, it uses the master plan for finding or planning a new business and a research and development project of each department to develop plans to invest in core technologies every 5 years.

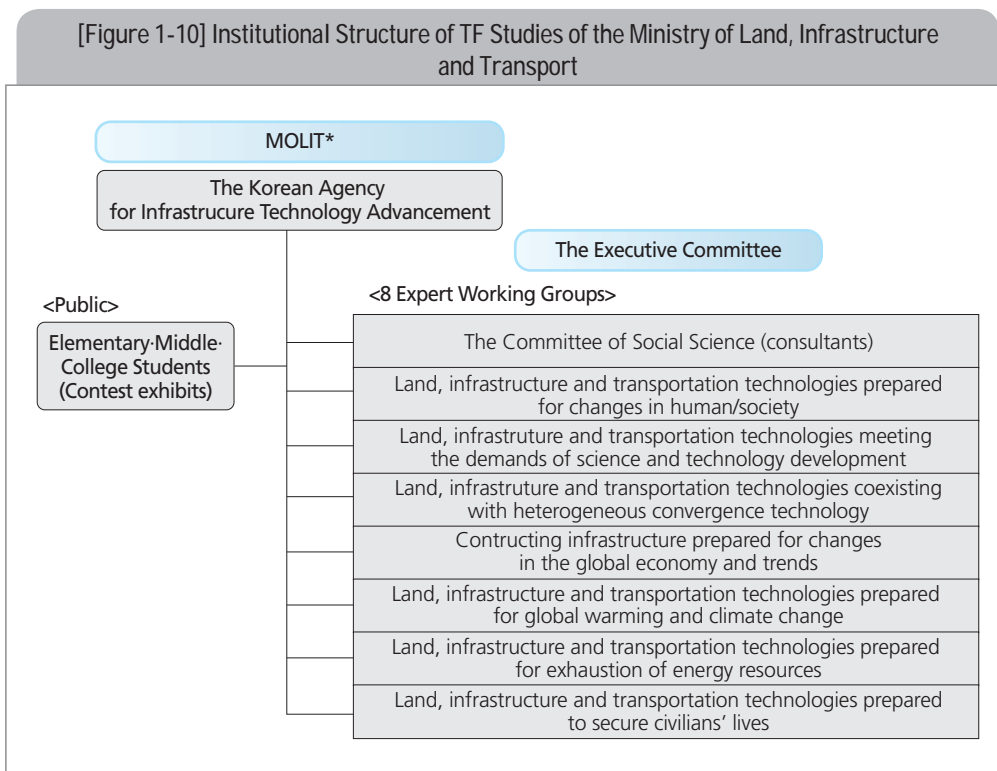


Source: KAIA (2013).

Institutional structure for TF studies on infrastructure and transportation technologies of KAIA is shown in [Figure 1-10]. The Ministry of Land, Infrastructure and Transport manages and KAIA supervises. It has the Executive Committee and the working group of 8 experts.

The experts in the working group can communicate with other experts having different specialties without limitation of their own professions. Each mega trend has 7 departments, the experts are gathered from the various fields of expertise, thus they can openly discuss their opinions on future trends. Also, other than infrastructure and transport, it composes the Social Science Committee which includes economics, business management, and social sciences. And it performs as a consultant to orient the vision of future and technical review.

The head of each committee compose the Executive Committee to put opinions together and to coordinate common issues. And it performs the final examination on the trends, the outcomes of Delphi survey, and the prospects of future. Also, during the TF studies, it runs the event that the public can add their imaginations, so it can include the ideas about the needs for future technology related to infrastructure and transportation from the students of elementary school, middle school, and college. This makes it possible to add the opinions from the public besides the opinions of scientists or engineers.



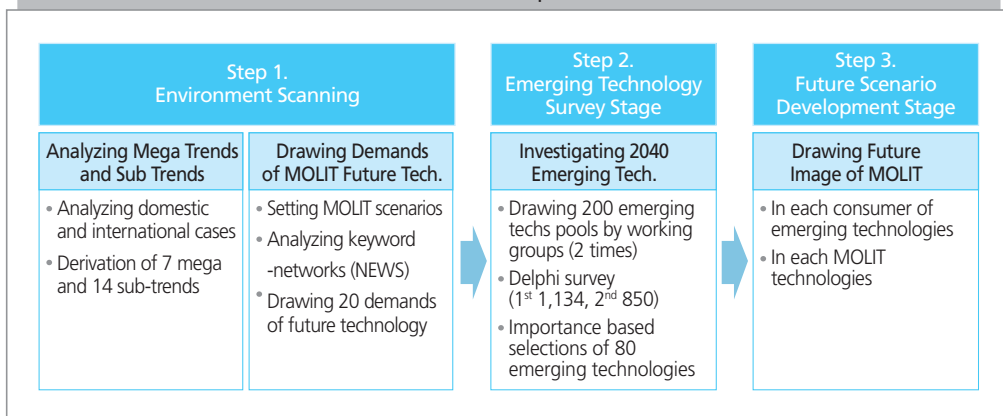
Source: KAIA (2013).

KAIA promotes the TF studies into 3 stages as shown in [Figure 1-11]. The first stage is the environment scanning stage where it draws the needs for future technology related to infrastructure and transportation. The second stage is the emerging technology survey stage where it draws Delphi survey. The third stage is the future scenario development stage where it draws the future scenario of infrastructure and transportation.

More specifically, the first stage, the environment scanning, grasps the 7 mega trends and related 14 sub-trends of infrastructure and transportation. This step is completed by analyzing the changes of external environments based on the variety of domestic and international cases of TF surveys based on the STEEP standards. Then it draws the important keywords of 14 sub-trends and collects news that includes any keywords of them from 2010 to 2012 to perform network analysis, to identify the rate of increase of keywords and the exposure rates by data mining. The outcomes of this analysis are 20 needs for future technology related to infrastructure and transportation.

In the second stage, the emerging technology survey stage, it provides 20 needs for the future technology related to infrastructure and transportation to the 8 working groups of experts. The experts draw future technologies throughout 2 workshops. They examine the overall ideas from the public from the workshop which includes the students from elementary school, middle school, and college, and the future technology of infrastructure and transportation that the TF reference states. The experts draw 200 candidates of the 2040 emerging technology to fulfill the 20 needs for future technology related to infrastructure and transportation.

[Figure 1-11] Methodologies and Stages of TF studies of the Ministry of Land, Infrastructure and Transport



Source: KAIA (2013).

It draws the emerging technology of 2040 based on the outcomes of Delphi survey from the emerging technology candidates. It conducts the Delphi survey online and asks around 10,000 experts from each department related to infrastructure and transportation. The first survey has 1,134 respondents, and the second survey has 850. The Delphi survey examines the time of realization, its importance, feasibility of technology development, level of technology, necessity for public investment of the emerging technology candidates. Specifically, it examines the importance of technology by 3 standardized strategies, which are the importance of scientific and technological advancement, the importance for society and the economy, and the importance of national strategy. Then it draws final 80 emerging technologies by analyzing the priority of the emerging technology candidates based on the result of responses in which the 3 standards of the technological importance were adopted.

The third stage, the future scenario development strategy, it draws the illustrated depictions of various circumstances to deliver how the emerging technologies that the survey identifies can bring changes into our environments from the point of view of customers by technology.

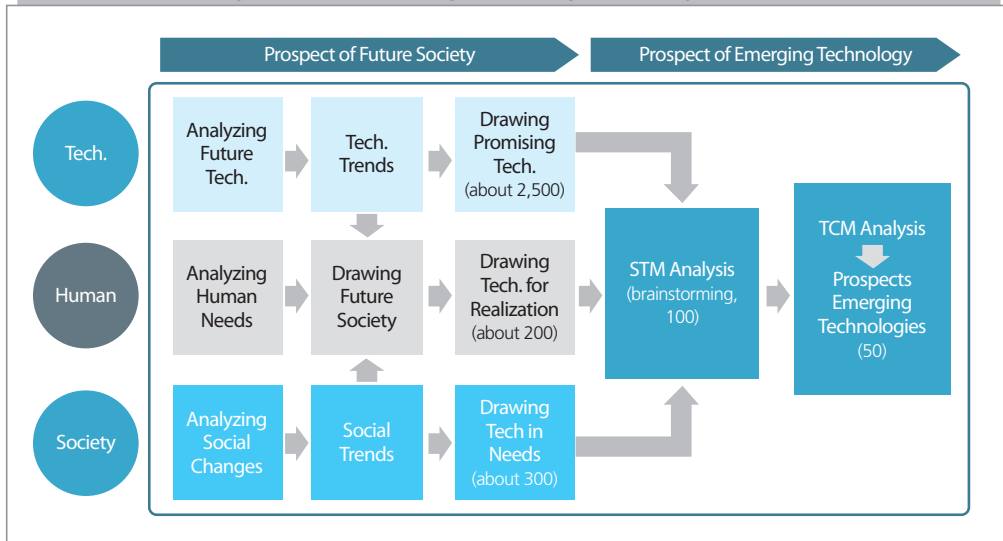
4.3. Technology Foresight Studies at the Research Institute Level

This section introduces a case of TF studies at the research institute level. It is TF studies that Electronics and Telecommunications Research Institute (ETRI) has executed yearly since 1993. ETRI is a government-funded research institute founded in 1976. It focuses on R&D, commercialization of its technologies in the information, communications, electronics, broadcasting, and its convergence technology fields.

The Future Technology and Strategic Research Laboratory in ETRI has the Future Technology Research Department. It foresees the future technologies. ETRI announces the emerging technologies that they should develop on their own or by the national level based on their foresights. For this purpose, the Future Technology Research Department of ETRI has developed a method for TF, "The Ecosight Based Technology Foresight".

ETRI has developed "The Ecosight based Technology Foresight" by analyzing the future technology that encompasses engineering and social sciences of 2013 and its impacts to provide strategic research and development orientation of ICT and fusion technology. ETRI continuously evaluates and revises "The Ecosight Based Technology Foresight". The most recent version is 3.0 developed in 2017, and ETRI is still updating the system.

[Figure 1-12] Methodologies and Stages of Ecosight Based TF

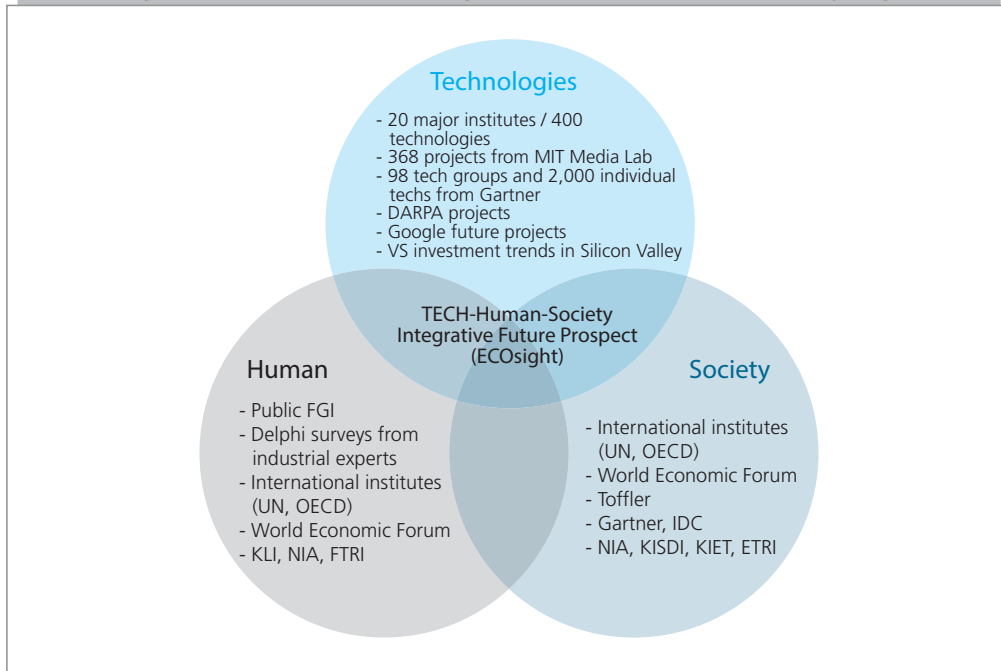


Source: ETRI (2015).

ETRI promotes “The Ecosight based Technology Foresight” in 2 stages, the Prospect of Future Society Stage and the Prospect of Emerging Technology Stage as shown in [Figure 1-12]. In the Prospect of Future Society stage, ETRI analyzes and diagnoses issues for the future that may occur in the global social change, ICT, and intersection of convergence technology. And the Prospect of Emerging Technology stage, ETRI foresees the future technologies of ICT and the convergence based on the core technologies of each area of engineering, human, and society.

Activities of each stage in the TF studies conducted in 2016 are as follows. First, the Prospect of Future Society Stage, ETRI draws the global and social changes and ICT, convergence technology changes by STM (Socio-Tech Matrix) analysis. Then ETRI depicts the possible future societal changes in the intersectional part of the social changes and the technology changes. More specifically, ETRI draws more than 2,500 future technologies based on the researches of the main TF institutes such as MIT, Gartner, the investment trends in Silicon Valley, the future projects of DARPA and Google, the outcomes of the paper analysis, and the patents (see Figure 1-13).

[Figure 1-13] Contents to be Investigated in the Prospect of Future Society Stage

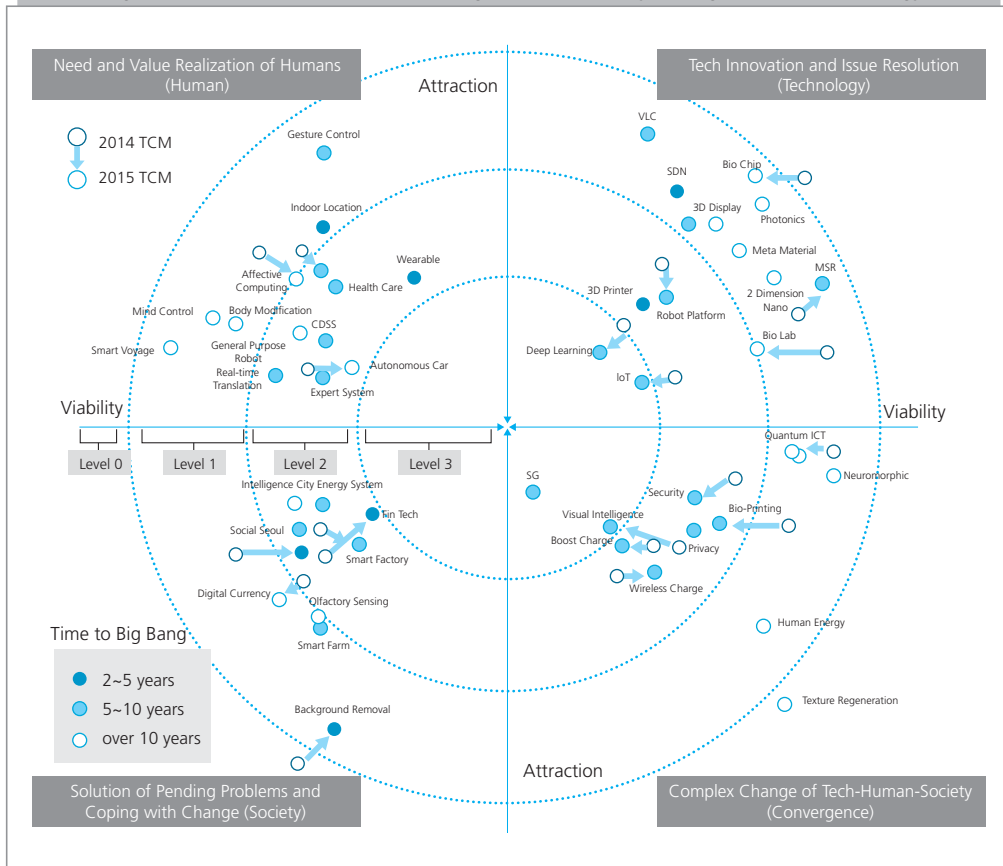


Source: ETRI (2015).

Also, ETRI draws about 300 technologies to solve the social issues based on the reports of the international organizations such as UN, and OECD, and the researches from domestic and international major institutes like Gartner, KISDI (Korea Information Society Development Institute), and the reference on opinions of experts. Also, ETRI draws around 200 technologies to realize the major needs of humans from the global social changes based on the FGI (Focused Group Interview) with experts and the public, and discussions with experts.

After, the technological experts make TCM (Tech-Contour Map) that foresees the potential and foresight time of each mega trend by brainstorming the attractiveness and viability of 100 ICT core technologies. Then with the TCM, they select core 50 future technologies and analyzes their main issues as shown in [Figure 1-14]. They consider originalities, market size, impacts on the attractiveness, conundrums, market structures and prices, social acceptability, and traits of regulations for viability.

[Figure 1-14] Core 50 Future Technologies Developed by Ecosight Based Technology



Source: ETRI (2015).

Finally, they choose the major 7 technologies that will have huge impacts on the future society. To select these technologies, the technology experts examine development speed of technologies, the potential of technical issue breakthrough, the effects on the technology ecosystems. Then with the 50 technologies and the 7 main technologies, they suggest 10 changes in trends affected by the technologies in the future society.

4.4. Implications for Technology Foresight in Mexico

There are some implications to develop implementation plan for TF system in TechnoPoli of IPN from analysis of TF studies in Korea. Most of TF studies in Korea are using trend analysis in the early stage for identifying technology needs and promising technologies. Also, they are using Delphi technique in the final stage for consensus building to identify the time of realization, importance of each technology. This tendency of preferring the exploratory methodology, especially Delphi technique is

mainly due to influence of Japan at the early establishment phase of TF studies in Korea. Also, it is due to preference to the objectivity and tendency to opinions of the majority for decision making in Korea. Furthermore, Delphi technique is more easy and straightforward to explain for a participant of survey and person who has an authority of decision making based on the result of TF studies. It will be also effective to use exploratory method, especially Delphi technique for successful introduction of TF studies in IPN.

All outcomes of TF studies in Korea have been used for national R&D policy planning and execution. Results of the national science and technology foresight study are used for establishment of national science and technology strategy. Also, all institutions such as ministry, regional government, and public research institutes should follow and refer to the TF study results for R&D program planning. Furthermore, result of technology foresight 2040 is used for the mid- and long-term R&D master plan of the Ministry of Land, Infrastructure and Transport. Finally, the “Ecosight Based Technology Foresight” by ETRI is also used for R&D planning of ETRI and is used as a fundamental material for ICT R&D program planning of the Ministry of Science and ICT. Like this, IPN should have endeavor to extrapolate the outcomes of TF studies actively by applying to R&D program planning and R&D resource allocation of IPN. Also, IPN should disseminate the results of TF studies nationally in Mexico and supporting the national R&D program planning and resource allocation with reference of the results of TF studies.

5. Suggestion of Implementation Plan of the Delphi Based Technology Foresight System

5.1. Directions for Technology Foresight in IPN

This section shows directions for development of implementation plan for TF system in TechnoPoli of IPN by analyzing the situation and cases of TF studies in Mexico and Korea.

Firstly, 5 years in the technology area related to the strategic industries for Mexico could be recommended as a time span for TF in Mexico. Usually time span and target technology area for TF studies in Korean cases is 40 years and all technology areas because goal of TF in Korea is to figure out not the key technology for the industry but the emerging technologies at the future. The reason why this is widely used is that in Korea the industry has technological competitiveness to key technology in the global market and there is a consensus about role of government as a facilitator of emerging technology development. But the urgent problem in the Mexican industry is recovery of technological competitiveness in the main industry and Mexican federal

government has been planning and implementing a series of industrial technology development policies for the strategic industries. As a deconcentrated entity of the Ministry of Public Education and its mission as an engine for Mexico's development by supporting the industrialization process and providing educational alternatives to society, IPN should have its own role to this mission. Therefore, the main goal of research institutes in IPN should be development of the key technologies useful for Mexican industry and they should focus on commercialization of R&D within 10 years. This is the reason why the time span of TF studies should be within 5 years and target technology areas for TF studies could be aligned with strategic industries for Mexico. If TF capability of IPN could be built-up enough and technological competence of industrial sector is competitive, time span of TF could expand from 5 years to 30~40 years gradually.

Secondly, with the same reason stated above, study on the future technology could be excluded and more focus can be placed on the potential technologies for problem solving for the industry and society in IPN and Mexico within 10 years. Also, sophisticated S&T trend analysis such as Big data analysis and advanced bibliometric analysis, scenario planning, expert panel could be also replaced by literature review. If TF capability of IPN could be built-up enough and technological competence of the industry is competitive, focus of TF also could be shifted gradually from the forecasting of science and technology trend to identification of desirable future technology to support economic and social goal of Mexico. Furthermore, sophisticated S&T trend analysis such as Big data analysis and advanced bibliometric analysis and normative method such as expert panel and scenario planning could be applied. As shown in previous section, Japan also shifted the focus of TF studies from forecasting of science and technology trend to identification of desirable future technology to support economic and social goal of Japan based on 30 years of TF studies history.

Thirdly, brainstorming and Delphi survey are necessary as methodologies to fully extrapolate the capability of Mexican participants and effectively use the outcomes of TF studies. As stated previous section, consensus building between stakeholders of IPN and Mexico R&D policy makers is very important to Mexico because there is no enough independent TF studies for R&D policy. Also, the final goal of TF studies is to be used in annual R&D program planning of IPN and in the decision-making process on the national R&D resource allocation. Therefore, TechnoPoli should invite as many science and technology experts and government officers from all of region of Mexico as possible to TF studies for brainstorming and Delphi survey. Also, these methodologies are more convenient than any normative methodologies to Mexican S&T experts and government officers because exploratory method such as trend analysis and Delphi method has been widely used at Mexico as mentioned in the previous.

Fourthly, the target technology area to be studied in foresight study will be intersection of competitive area between IPN and the national strategic industries. According to technology intelligence department in IPN, there are strategic technology areas of IPN to develop research capabilities of Mexico. It is consisted of food and agro-industry; IT connectivity; information and communication technology; energy; iron metal mechanic; chemical and petrochemical; electronic and electric; pharmaceutical; high technology manufacture; automotive; aerospace; business support; biotechnology; ecology and sustainable development; equipment and machinery; and textiles.

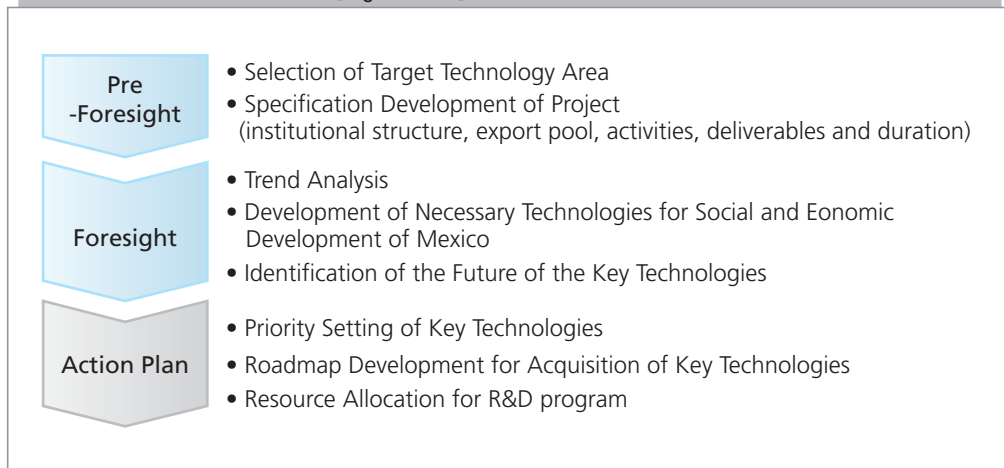
Fifthly, cooperation with Mexican consulting firms or other organizations in Mexico is suggested for capacity building and spillover effects. All employees of TechnoPoli of IPN have already own tasks and they can be overloaded with TF activities. Therefore, it is suitable that TechnoPoli carries out TF activities by cooperating with other private consulting firms. With this implementation structure, IPN could complete its previous role and new role, TF studies successfully and private consulting firms participating in the TF studies implemented by TechnoPoli could build up their own capabilities.

Finally, for sustainable resource acquisition of TF activity, TechnoPoli of IPN, should carry out TF studies and releases the outcomes not as one-time event or long-term periods but continuously and at least yearly. By these continuous efforts, TechnoPoli should verify that the outcomes of TF studies could be used one of the inputs to decision-making process by the research institutes and headquarters in IPN and be spilled over to the federal and state government and the industry. With these continuous efforts, TF studies could have accountability and authority for resource acquisition from IPN and the federal or state government of Mexico. It could be useful methodology for verification of its usefulness that IPN could carry out the survey to its customers like National Institute of Science and Technology Policy (NISTEP) of Japan. UNIDO say that NISTEP had carried out a survey of companies to assess how much use they made of the outcomes from the fourth Delphi exercise (UNIDO, 2005a). In survey from NISTEP, 59 percent of respondents had thought that the outcomes of Delphi exercise were "very important" and a further 36 per cent of respondents had thought that that the outcomes of Delphi exercise were "worthwhile".

5.2. Implementation Model for Technology Foresight Study

This section shows the implementation model of TF studies by TechnoPoli of IPN by internal discussion and brainstorming with the local consultant. The overall process of TF studies is shown in [Figure 1-15].

[Figure 1-15] Process of TF Studies



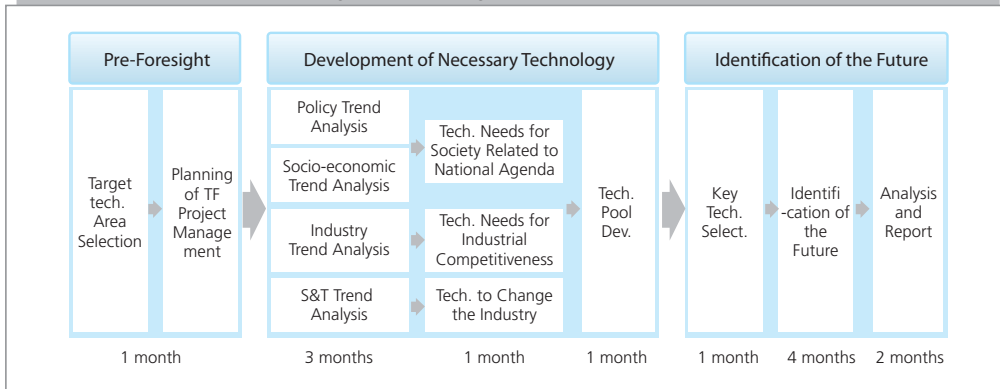
Source: Compiled by author.

As shown in [Figure 1-15], TF studies start from pre-foresight process. In the pre-foresight process, a series of activity for preparation of TF studies could be done such as selecting target technology area and planning of TF project management. Specifications of TF project management are design of institutional structure, expanding the expert pool, deliverables and duration of each activity.

Following process is foresight process. In this process, development of necessary technology for Mexico by trend analysis and identification of the key future technologies for Mexico are implemented. Finally, in the action plan process, extrapolation of result of TF studies is done. At first, identification of the key technologies for internal R&D is done by priority setting of the key technologies during TF studies. Finally, technology roadmap for prioritized key technologies is developed and R&D budget is allocated based on technology roadmap. It should be noted that action plan process in [Figure 1-15] is not a TF process but extrapolation process of TF studies. In other words, action plan process is taken into account for effective application of TF study results.

With more focus on TF study process such as pre-foresight and foresight process, stage model is recommended for successful implementation of TF studies by TechnoPoli of IPN as shown in [Figure 1-16]. The first stage is the pre-foresight stage. The second stage is a stage of necessary technology development and third stage is a stage of identifying future of technology. The first stage is explained briefly in the previous section. In the second stage, TechnoPoli of IPN should find a pool of necessary technologies to be developed for the economic and social development of Mexico. And then in the third stage, TechnoPoli of IPN should select the key technologies to be invested by IPN and draw a specific condition to be developed by technology foresight study.

[Figure 1-16] Stage Model for TF Studies



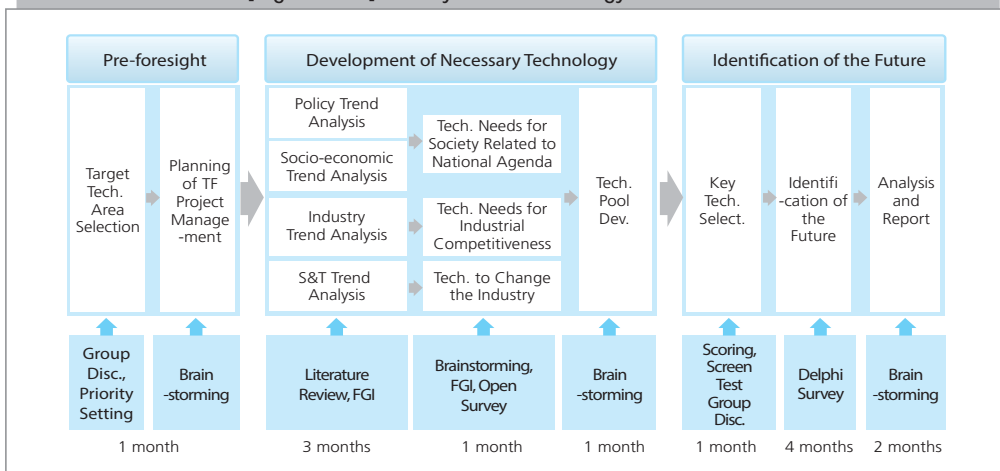
Source: Compiled by author.

This study suggests around 1 year as the period required for this TF study. The first stage could be implemented within less than 1 month. The second stage could be done within 5 to 6 months and the third stage also could be done within 6 to 7 months. In particular, technology foresight in the third stage could be completed within 3 to 4 months.

5.3. Activities and Methodologies for Technology Foresight Study

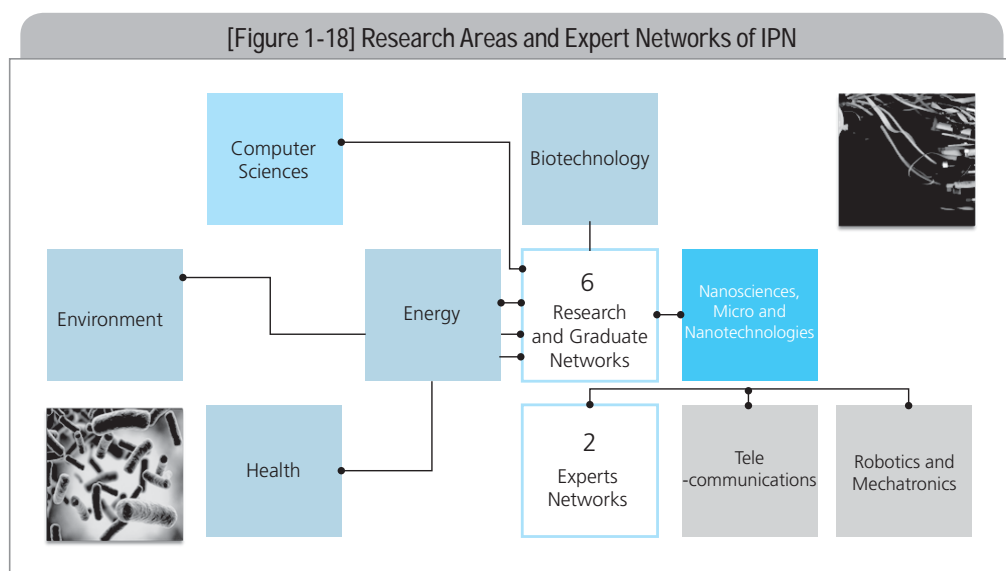
This section describes more detailed information for implementing the stage model of TF studies by TechnoPoli of IPN. [Figure 1-17] shows specific activities and methodologies to be applied in the stage model.

[Figure 1-17] Activity and Methodology for TF Studies



Source: Compiled by author.

At the first stage, which is pre-foresight stage, the first step is selection of target technology area. IPN should select the specific area of TF studies to be executed. This study also suggests that intersection of competitive area between IPN and national strategic industry such as Biotechnology, ICT (Information and Communication Technology) is suitable as a target technology area as stated in the previous section. [Figure 1-18] shows that research areas and expert networks of IPN. Most of these research areas are categorized by BT areas (Biotechnology, Energy, Environment, Health) and ICT areas (Computer Science, Telecommunication, Robotics and Mechatronics). IPN has enough capabilities and well-developed external expert networks in the Biotechnology and ICT areas. As a target technology area, intersection of competitive areas between IPN and national strategic industry is more favorable to get a budget for the TF studies and R&D investment in forecasted technologies. Also, this target technology area has another advantage of using DB of science and technology personnel already registered in IPN and motivating these experts to participate in TF studies.



Source: IPN (2017).

In the step of selecting a target technology area, methodology used for priority setting is generally applied for selection of 2 to 3 times technology areas for final selection of target technology areas by TechnoPoli of IPN. Group discussion for selecting target technology areas among the 2 to 3 times technology areas will be done. This study suggests 1~2 target technology area(s) to be selected in this step.

Specific activities of the second step at the first stage, planning of TF project management are explained enough in the previous section. Related to the development of expert pool in this step, it is more important to getting information of enough number of experts in each technology area. For gathering information of experts, DB of expert pool used by TechnoPoli, UPDCE and CIEBT should be integrated and classified by national technology classification scheme. Also, R&D experts participated in R&D project of IPN should be derived with cooperation of IPN headquarter and then should be merged to expert pool. Furthermore, related R&D personnel in Mexico should be derived by the courtesy of CONACYT at the selected technology area. Then, IPN can develop the full set of expert pool to be participated to technology foresight and should contact each expert in pool to update the contact information, to introduce the TF studies, and to confirm the willingness of participation.

At the second stage, development of necessary technology stage, the first step is trend analysis of policy, society, economy and target technology area related industry and science and technology. Primary goal in this step is building-up the future of Mexico in each category after 5 years. Literature review for PEST (Political, Economic, Social and Technological) analysis should be executed at first for the identification future of society and industry and future image of science and technology development. If the outcomes of PEST analysis could be within the range of reliability by the judgement of TechnoPoli of IPN, FGI (focused group interview) with opinion leader or experts of each field of analysis could be executed to complement the outcomes of literature review. It is suggested that IPN could co-work with private consulting firm or external institution such as FUMEC, ProMexico.

The second step at the second stage is derivation of needs for technology development and technology seeds to be developed based on the outcomes of the first step at the second stage. More specifically, technology needs for development of society could be derived from the policy and socio-economic analysis and technology needs for sustaining the industrial competitiveness could be derived from the industry analysis. Also, future technology to change the industry and society could be derived from the science and technology trend analysis. These activities could be executed by brainstorming of TechnoPoli of IPN and FGI (focused group interview) with opinion leader or experts of each field of analysis. To complement the outcomes of brainstorming and FGI, open survey using semi-constructed questionnaires to peoples of Mexico having interest in these issues could be executed by web-based survey system. In this step, unit of technology is product, system or facility for the fulfillment of social, economic desires of humans. More specification and narrow-down of technology for development should be done at the action plan phases.

Finally, a pool of necessary technologies could be developed for the economic and social development of Mexico by collecting and merging the technology needs and future technologies based on brainstorming.

In the third stage, identification of the future stage, the first step is selection of key technologies for TF. In this step, methodology used for priority setting and group discussion could be applied also. Importance for social or economic prosperity of Mexico, resource capability, probability of success could be used for selection of key technologies. If number of technologies in the pool of necessary technologies are bigger, a screen test could be applied to narrow the number of technologies before applying the methodology used for priority setting and group discussion. Information system for the efficient selection of key technology could be applied. Technology is selected within each technology committee and confirmed by the executive committee.

Identification of the future characteristics of selected key technologies by using Delphi method is executed within 3 to 4 months using the web-based survey system in the second step. At first, questionnaire should be developed and also validity of the questionnaire should be tested by using the pilot test. Pilot test of questionnaires could be done with approximately 10 persons in each technology area.

Questionnaires consist of attributes of key technologies to be forecasted such as importance, global competitiveness, time of realization and so on as shown in <Table 1-8>. If questionnaire is completely developed, web-based survey system should be developed by the transformation of off-line questionnaires into on-line questionnaires. Respondents of TF survey could be selected by DB of science and technology personnel from IPN, external network of IPN and CONACYT.

〈Table 1-8〉 Example of Questionnaire for Technology Foresight

1. Design of the Questionnaire on the R&D Characteristics		
Project	Definition	Option
Importance	Comprehensively considering the importance from science, technology, and societal perspectives	Select one from Very high/High/Low/Very low.
Uncertainty	R&D process involves several stochastic elements that need to tolerate failures and consider multiple approaches.	Quantize response and calculate scores (Very high: 4; High: 3; Low: 2; Very low: 1).
Discontinuity	R&D results are not an extension of the current state, with market-destructive and innovative characteristics.	
Morality	Morality and societal acceptance need to be considered during the R&D process.	
Global Competitiveness	Enabling Japan to exhibit global competitiveness over other countries.	
2. Design of the Questionnaire on the Predicted Time of Realization		
Project	Definition	Option
Technology Realization	When a technology is expected to be realized (somewhere in the world, including Japan); when a technological environment is ready, such as the achievement of anticipated performance (e.g., when the prospect of technology development becomes clear during the R&D process in a laboratory); and when a theory or phenomenon becomes scientifically established in the case of fundamental science.	Select one from Realized/To be realized/ Not realized/Not sure.
Social Realization	When it is applied in Japanese society or internationally led by Japan; when the realized technology is available to be used as a product or service (or when it is widely available); and when a framework, ethical standard, value, or societal consensus is established in the case of non-science and technology topics.	If "To be realize" is selected, then the additional question will involve asking the subject to identify the year between 2015 and 2050 when the technology will be realized.

Source: Shenkai et al. (2017).

If all these initial settings for TF studies are ready, a series of Delphi survey could be executed by the respondents. At first, e-mail for survey participation is delivered to each of experts. Then, the survey is circulated to the same set of respondents at least twice (UNIDO, 2005a) by e-mail and access of respondents to a web-based survey system.

To promote the exchanges of opinions and information and to see how far their foresight and expectation of each respondents, outcomes of previous round survey is provided. And the chance for respondents to modify their judgement is offered with the same set of questions. Finally, Delphi survey could be ended if the reliability of specific question such as importance index and realization time is within the stability. Usually, it is suggested that coefficient variation in each questionnaire item is less than 0.8. Also, response rate by final round should be bigger than 60%. It is known that response rate of other countries is as follows; U.S. 50~60%, Japan 70%, Korea 80%. For effective Delphi survey, co-work with private consulting firm or external institution such as FUMEC, ProMexico is suggested.

Final step of the third stage, analysis and report is the stage of reporting the outcomes of TF. The report of the outcomes of TF is written and reported to executive and technology committees. Then, summary of the outcomes of TF studies is released to headquarter of IPN, opinion leader in Mexico and public. For more effective usage of the outcomes of TF studies, holding a public hearing of the outcomes of TF is strongly recommended. Also, co-work with private consulting firm or external institution such as FUMEC, ProMexico is suggested for the analysis of survey outcomes.

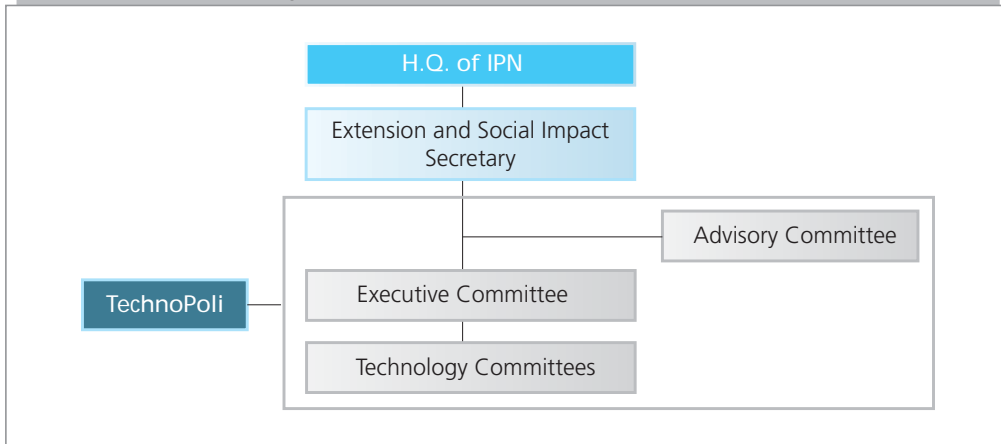
5.4. Institutional Structures for Technology Foresight Study

The session shows the overall institutional structures which include each responsible entity and its relationship between each entity to execute the TF studies of TechnoPoli of IPN by internal discussion and brainstorming with local consultant. Also, this session shows the suitable number of staff or experts in each organization.

[Figure 1-19] shows the institutional structure of TF studies by TechnoPoli of IPN. It consists of headquarter of IPN, extension and social impact secretary, TechnoPoli, and 3 committees. Headquarter of IPN could have a role of final confirmation of outcomes of TF and supporting the activities of TechnoPoli. Secretary of Extension and Social Impact could have a role of supporting the activities of TechnoPoli and providing the appropriate information and budget for TF studies. TechnoPoli has a main role of development of necessary technology and support the operations of 3 committees.

In [Figure 1-19], there are 3 committees; Advisory Committee, Executive Committee, Technology Committees. Advisory Committee should be set up to getting a legitimacy for TF studies and support of execution of TF studies and extrapolation of outcomes of TF studies. Opinion leader in science, technology and innovation in Mexico such as the senior-level of S&T related association, public media, CONACYT is recommended as a member of the Advisory Committee.

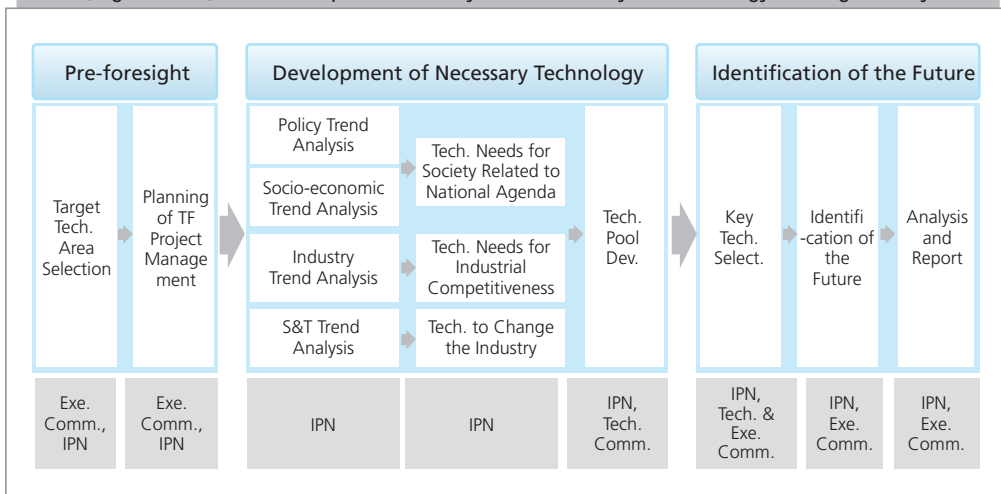
[Figure 1-19] Institutional Structure for TF Studies



Source: Compiled by author.

The Executive Committee will have a role of making an important decision at each stage of TF studies and confirming of the outcomes of TF studies. Finally, the Technology Committees will be set up along with target technology areas. Senior S&T personnel in Mexico are recommended as a member of the Executive Committee while young and qualified S&T personnel in Mexico are recommended as a member of the Technology Committee.

[Figure 1-20] Role of Responsible Entity in each Activity of Technology Foresight Study



Source: Compiled by author.

In [Figure 1-20], this study shows the role of each entity at each stage and step for TF study. The Executive Committee has a role of selecting target technology area and key technologies for technology foresight. The Technology Committee has a role of development of pool of key technology mainly and also role of selection of key technologies for technology foresight.

5.5. Resources and Infrastructures for Technology Foresight Study

In this section, this report shows the budget per year and required facilities such as information system to be installed in TechnoPoli for effective TF studies implementation of TechnoPoli of IPN by internal discussion and brainstorming with the local consultant.

More than \$150,000 is recommended as a budget for TF studies in each target technology area. It includes all costs to be incurred during TF studies such as operation cost of 3 committees, operations cost of activities of TechnoPoli by the dedicated human resources, operation cost of web-based survey system, etc.

Finally, there is no further need of any information system acquisition because TechnoPoli has a sufficient internal information service system for business and technology intelligence and also has external network for information services.

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the National Polytechnic Institute of Mexico

Chapter 2

R&D Priority Setting for Strategic Technology Planning

1. Introduction
2. Theory of R&D Priority Setting
3. Practice of R&D Priority Setting in Korea
4. Review of the S&T System and Capacity of Mexico
for R&D Priority Setting
5. Conclusion

R&D Priority Setting for Strategic Technology Planning

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Summary

Growing attention has been devoted to the issue of technology planning to enhance the accountability, effectiveness, and efficiency of R&D investment of public resources. Mexico is also trying to establish an effective technology planning system that is suitable to the country's own situation. The Mexican government hopes to learn lessons from Korea's experience in technology planning. The National Polytechnic Institute (IPN) is a higher education and research organization interested in contributing to achievement of national S&T goals. IPN wants to make technology foresight, a technology roadmap (TRM), and priority setting that can improve the efficiency of limited R&D resources.

The purpose of this project is to strengthen IPN's capabilities of technology planning. It is expected that the efficiency and effectiveness of R&D investment will be enhanced if IPN's strategic technology planning capability is increased. This project therefore aims to help Mexico's socio-economic development by enhancing the quality of R&D results. In order to reach these goals, this study has 2 following objectives: firstly, to understand the aim, structure, practice, and application of Korean R&D priority setting and draw from them policy implications and lessons; secondly, to provide suggestions to Mexico for a more advanced practice of R&D priority setting in order to enhance the efficiency and effectiveness of research and technology development activities in IPN through g detailed information and

Keywords: R&D Priority, Technology Planning, IPN, R&D Investment, Technology Roadmap (TRM)

knowledge based on the Korean experience.

To accomplish the above-mentioned objectives, this study consists of 4 modules. The first is a theoretical review of R&D priorities. The second is to summarize the policy implications and lessons from Korea's experience. The third is to understand Mexico's S&T system and R&D priorities. It is essential to understand Mexico's S&T system and R&D activities in order to propose policy suggestions for Mexico. Finally, it provides some suggestions to set up the R&D prioritization system for IPN in the Mexican environment of S&T. The study, therefore, covers the 4 following tasks: Theory of R&D Priority Setting; Experience and Lessons of R&D Priority Setting in Korea; Review of the S&T System and Capacity of Mexico for R&D Priority Setting; Suggestions and Solutions for Mexico.

The analytical framework used in this study is an overarching meta-evaluation framework. Each Priority Setting (PS) system can be regarded as being composed of 5 main areas: i) paradigm, ii) resources, iii) implementation, iv) utilization, and v) environment. According to this framework, this report proposes principles and suggestions for a more advanced PS. The report also provides an advanced PS model for IPN according to this framework.

In Korea's case, there are a few lessons to be learned in order to effectively set priorities. First of all, there needs to be an effective system and efficient procedures to set priorities for a clear purpose. Second, strategic technology planning is a matter of resource allocation, which means resources are concentrated on promising areas rather than on equal research support. Therefore, the continued interest and support of top decision makers is very important. If not, planning will be difficult to actually execute. Third, it is necessary to build an independent organization to take charge of strategic technology planning. Researchers involved in individual research and development are likely to represent their own interests. It is therefore desirable to have an independent and professional organization free from conflict of interest issues. Fourth, there are many considerations for prioritization. Theoretically, it cannot reflect all of the many influencing factors. Therefore, it is very important to use various methods integrally; in other words, "One does not fit all." Fifth, priority should be set based on the scientific method and data as much as possible. However, it is also the product of political negotiations among the people involved, so that the result is not an absolute standard. In the end, reaching a consensus is important for stakeholders to fully accept and actively cooperate with the plan after R&D priority has been set.

IPN needs to reach a consensus on key research fields with a top-down approach, taking its missions into consideration. At the national level, it is necessary to establish an adjustment system of R&D investment for technology foresight, TRM, and setting

priorities. R&D management and resource allocation policies based on performance-based management (PBM) should be established at the IPN level, and this work should be steadily promoted for at least 5 years.

In order to increase the acceptability of IPN for differentiated resource support, there is a need for mutual agreement among the members to ensure that sufficient compensation will be provided for IPN research units and researchers with excellent performance.

It is necessary to establish a department to analyze, coordinate, and evaluate IPN's research activities as a whole so that the planning, execution, and evaluation activities of R&D can be carried out in a comprehensive and systematic manner. If it is hard to start right away, a temporary organization (task force team) should be organized. It is also necessary to establish a coordinating body (committee/council) within IPN to deliberate and make decisions on budget adjustment and prioritization. In this case, the Director General of IPN needs to lead the committee.

A data collecting and sharing system is needed to objectively analyze R&D investment, evaluation information, investment priorities, activities, outputs and benefits for beneficiaries. If a research fund costs more than a certain amount, it is obligatory to submit a technology development plan report. Relevant laws and regulations must contain provisions that define specific actions for strategic technology planning and evaluation.

It is necessary to invest about 5% of IPN's total research expenses in activities related to technology planning, such as technology foresight, roadmap, and priority setting. In 2018, some dedicated personnel (4-5 individuals) will need to be deployed to implement the actual strategic technological plan.

The results of the proceedings should be reported directly to the Director General of IPN. It takes about 1 year for a pilot project, but it may take 6 months to accelerate the accumulation of experience by working more intensively. It could be necessary to set detailed priorities for the 6 sectors for the current Mexican economic development.

Therefore, concrete and detailed implementation plan for how can we achieve the goal needs to be presented. The figure could be a frame of IPN for setting priorities. Results should never suggest just directions, but should be specific enough to allocate resources accurately. Strategic implementation of budget execution for years should follow the priority setting. It is required to monitor, assess, and provide feedback on the effect of the strategic investment allocation.

1. Introduction

1.1. Background

1.1.1. Necessity of R&D Priority Setting

As the importance of science and technology for socioeconomic development increases, government expenditures on R&D and innovations in many countries have been substantially enhanced during the past few years. Given this growing investment, policy makers want to ensure that this investment is sensibly allocated and is yielding the expected return. Many countries, therefore, are making efforts to measure the performance of their S&T organizations with accuracy.

However, a more important activity is strategic technology planning. As always, the government is under financial pressure. In other words, governments have a lot of work to develop technologies with limited public funds. Many countries and companies try to invest in research and development to secure future growth engines, but there is always a lack of available resources. To overcome this situation, a goal-oriented technology plan is needed to achieve the desired result more efficiently. Growing attention has therefore been devoted to the issue of technology planning to enhance accountability, effectiveness, and efficiency of R&D investment of nations, companies, and institutes.

1.1.2. R&D Priority Setting Experiences with Mexico as a Case Study of KSP

Mexico is interested in securing national competitiveness through science and technology, and is trying to establish an effective technology planning methodology that is suitable to the situation in Mexico. In particular, national science and technology research and higher education institutions such as the IPN will contribute to the achievement of national goals. IPN wants to make technology foresight, a technology roadmap (TRM), and priority setting for research and development (R&D) that can improve the efficiency of limited human and financial resources. In the process, the Mexican government hopes to learn lessons from Korea's experience in technology planning and development.

Korea has developed rapidly in the past decades with rapid economic growth. The Ministry of Economy and Finance of Korea wants to share Korea's experience in science and technology development with the Mexican government through the Knowledge Sharing Program (KSP). In particular, science and technology is one of the areas that provides the intellectual foundation of national development, and it is expected to bring very promising results in that it is the most outstanding

development field in Korea.

As a result, IPN will contribute to Mexico's science and technology development and economic development through systematic technology development and richer research results.

1.2. Purpose and Scope of Work

1.2.1. Purpose

The main project is entitled, "Strategic Technology Planning for the National Polytechnic Institute of Mexico." The purpose of this project is to strengthen IPN's capabilities of technology planning. It is expected that the efficiency and effectiveness of R&D investment will be enhanced if IPN's strategic technology planning capability is increased. This project therefore aims to help Mexico's socio-economic development through enhancing the quality of R&D results.

The project will support the development of strategic technology planning in IPN by implementing 3 sub-topics. The first topic is about technology foresight. Technology foresight is an important methodology of technology intelligence which is required for decision making of R&D investment and direction. We are mainly aiming to develop a technology foresight system that is suitable for Mexico, focusing especially on cases of technology foresight using the Delphi Survey. The second topic is how to effectively create a TRM. TRM is a guide for developing and securing technology. TRM will enable more systematic acquisition of technology. The third topic is how to prioritize R&D investment for strategic technical planning. In other words, when a core technology or a technology path is determined through technology foresight or a technology roadmap, the R&D priority setting is a decision as to whether the investment can be effectively focused on a certain research or not.

Among these topics, the order of technology road mapping and prioritization can be reversed as in this report.

- Topic 1: "Development of Technology Foresight System"
- Topic 2: "R&D Priority Setting for Strategic Technology Planning"
- Topic 3: "Technology Roadmapping"

This study is about the second topic and has the following objectives:

- To understand the aim, structure, practice, and application of Korea R&D priority setting and to draw policy implications and lessons
- To provide suggestions to Mexico for a more advanced practice of R&D priority

setting in order to enhance the effectiveness of R&D activities in IPN through detailed information and knowledge based on the Korean experience

In other words, this study will try to answer how to develop a more advanced and suitable technology intelligence and decision making system for the efficiency and performance of research and development in IPN.

1.2.2. Scope of Work

To accomplish the above-mentioned objectives, this study consists of 4 modules. The first is a theoretical review of R&D priorities. The second is a summary of the policy implications and lessons from Korea's experience. The third is an explanation of Mexico's S&T system and R&D priorities. It is essential to understand Mexico's S&T system and R&D activities in order to propose policy suggestions for Mexico. The final module is suggestions to set up the R&D prioritization system for IPN in the Mexican environment of S&T. The study therefore covers 4 tasks as follows:

- Theory of R&D Priority Setting: The meaning of the Priority Setting; Logic and Approaches of Priority Setting
- Experience and Lessons of R&D Priority Setting in Korea: Institutional basis related to Korea's PS; Framework and Steps; Detailed process of PS in Korea; Lessons from the Korean experience
- Review of the S&T System and Capacity of Mexico for R&D Priority Setting: A Short Analytical Review of S&T system in Mexico; Technology Planning Activities including R&D Priority Setting in IPN; Capacity and Readiness of Mexico (IPN) for R&D Priority Setting
- Suggestions and Solutions: The applicability of Korean Experience to Mexico; Policy Suggestions and Practical Solutions; Next Steps

The followings are the key questions that will be dealt throughout the 4 tasks:

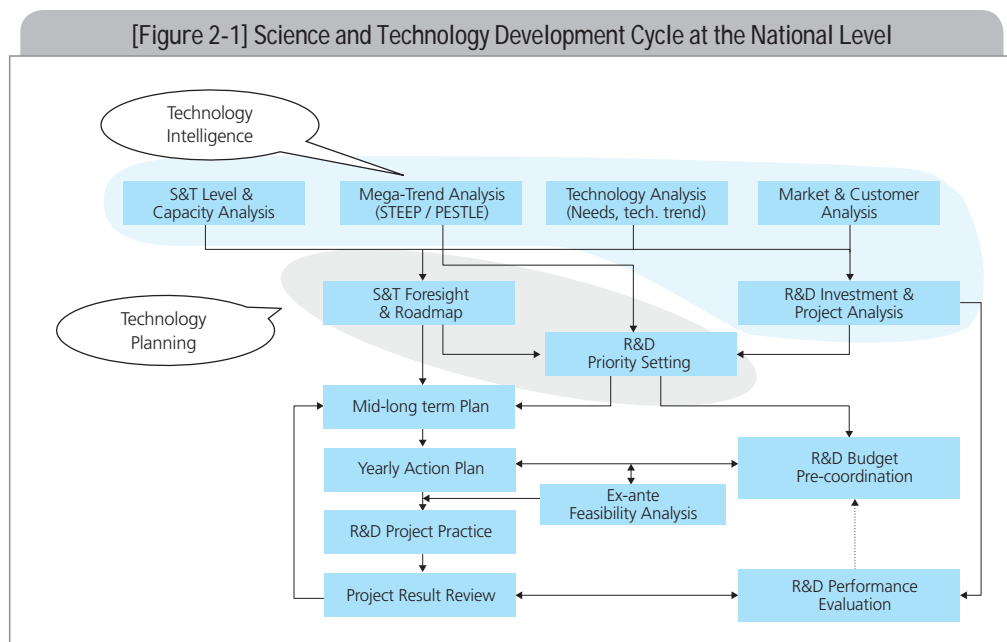
- How is PS of S&T applied in Korea?
- Why do they conduct R&D priority setting of S&T organizations?
- Which examples are best applicable in Mexico? What are the best benchmarking points?
- How does IPN of Mexico conduct setting priorities? Who requires PS of S&T? Who performs PS? What methodology is used for the PS? What is the process of PS? What are the results of PS and who are the users of these results?
- What is the necessary condition to carry out PS in IPN?
- What lessons can be learned from Korea's experience and how to apply it in order to develop an advanced PS system in IPN?

1.3. Analytical Framework and Research Method

1.3.1. Analytical Framework

The goal of technology planning is to review the socioeconomic needs and policy considerations based on technology information, and to decide the goal, subject, cost, and timing of the technology to be developed. Prioritization of R&D is therefore a critical step in the process of strategic technology planning for the efficient use of limited resources. Strategic technology planning could be divided into a few stages: technology intelligence, technology foresight, priority setting, and technology roadmap. For example, [Figure 2-1] shows the process of technology planning, R&D investment and program evaluation, and R&D investment in Korea at the national level. In this process, technology intelligence includes S&T level analysis, R&D capacity analysis, STEEP (Social, Technological, Economic, Environmental and Political) analysis, and market analysis. Technical planning includes S&T foresight, TRM, and R&D priority settings, which are covered in this project. In order to achieve a good result of priority setting, preliminary analysis of social, technological, national strategic and economic aspects should be conducted effectively.

Technology intelligence (TI) involves collecting and analyzing technology-related information needed for technology and business decision making in companies and organizations. TI aims to capture and disseminate the technological information



Source: Oh (2014).

needed for strategic planning and decision making. Because of the speed of technology change and the changing global business environment, TI has been becoming increasingly important. At the national level, TI includes S&T level and capacity analysis, mega-trend analysis, market analysis, and R&D investment analysis.

Technology foresight is a process of comprehensively examining the future of science and technology and the socio-economic change from a long-term standpoint in order to select research areas that are expected to produce the greatest socio-economic benefits (OECD, 1996). It is also a means for presenting the mid- to long-term vision of technology and deriving the problem to be solved from the technological point of view, which is based on the needs of future society.

R&D priority setting refers to compiling of R&D promotion rankings or resource allocation plans by comprehensively considering the competence of the technology development entity, given circumstances, technological importance, and the socio-economic ripple effect of technology. In the case of government research, public concern or interest of technology is one of the most important factors in setting priorities, and whether it helps to overcome market failures is another important criterion.

The technology roadmap (TRM) is a kind of guide map for developing and securing core technologies. It is a tool to effectively integrate and express various viewpoints of strategy, technology, and products, and to effectively eliminate functional barriers that are placed between each technology. TRM is often classified as both a market-driven model and a technology-push model. A market-driven model expresses the path of market, product and technology as a roadmap. Market needs are very important in this case. As for the technology-push model, the new technology creates a new market by taking the path of technology, product and market.

Among these steps, the procedure of technology roadmapping and prioritization may be reversed. In the first case, we can plan TRM first and then set priorities. We can then make a TRM based on the future that we anticipate. We then set the R&D priorities according to our capabilities and resources. On the other hand, there could be another case that prioritization is conducted first, and then the TRM could be made. In other words, technology foresight determines the technology to be developed in the future. After that, core technologies should be strategically selected in terms of the strategic goals of the technology, urgency of the technology, technology level, and technology development capacity. TRM could then be drawn according to those priorities including technology acquisition means, performers, time, product, and resources.

1.3.2. Research Methods

Research methods are as follows: literature review, expert meetings, case studies, brainstorming, and cooperation with local experts. Literature review was conducted through various sources such as books, papers, reports, and websites for data analysis. For example, the following data are the subjects of literature analysis:

- Policy documents, papers, reports, and websites on R&D priority setting, technology planning, technology strategy, business strategy with technology development plan, etc.
- Korea's R&D priority report, government plans and guidelines
- Report on Mexico's national science and technology planning, R&D areas, S&T government system
- Analysis of various statistical data on science and technology, research and development, budget, economic activities by field, etc.

Expert review is also a good tool for case studies. It is an effective means to develop meaningful insights and feedback from the cases that were done in Korea. A series of expert reviews and interviews on the priority setting practices of Korea were conducted to provide greater insights into the design of an appropriate priority setting system in Mexico. This study includes experts in related fields, such as science technology prioritization, technology foresight, and technology roadmap. In particular, the following experts are targeted:

- Mexico: IPN, Mexico experts, civil servants and related specialists
- Korea: The Ministry of Science and ICT, The Ministry of Economy and Finance, Korea Institute of Science and Technology, Korea Agency of Infrastructure Advancement, Korea Institute of S&T Evaluation and Planning, National Assembly Legislation Research Institute, etc.

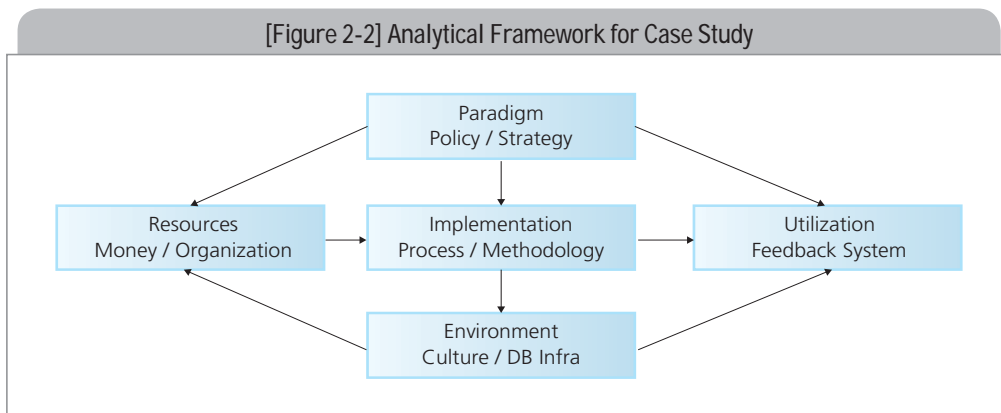
It was also important to work with local experts to diagnose accurately the system and situation of S&T in Mexico. Local experts are responsible for analyzing the practice of R&D prioritization the science and technology system, and the experience and competence of IPN in Mexico.

1.3.3. Analytical Framework for This Case Study

The analytical framework used in this study is an overarching meta-evaluation framework. Each PS system can be regarded as being composed of 5 main areas: i) paradigm, ii) resources, iii) implementation, iv) utilization, and v) environment. According to this framework, this report proposes principles and suggestions for a more advanced PS. The report also provides an advanced PS model for IPN according

to this framework.

- *Paradigm* includes the philosophy, purpose, principles, policies, and scope of PS. For example, “What is the policy context for setting R&D investment priorities?” could be an important question. It is very important to identify paradigm which is pursued in PS practice because the paradigm provides basic direction.
- *Resources* include the players, in other words, human resources (participants, peers, experts, and stakeholders), material and organizations resources (money, time, and organization for PS), etc. Effective PS is not possible without good players and resources. In order to make an advanced PS system, therefore, sufficient resources should be secured.
- *Implementation* includes the process, object, and methodology of PS. Once paradigm and resources are determined, PS procedures and methods are fixed accordingly. PS methods and procedures are very diverse. Actors of PS should therefore formulate a workable PS plan that takes available resources into account. Sometimes it is necessary to use a number of methods, and PS is likely to fail when the PS plan is too an ideal one.
- *Utilization* means the feedback mechanism. It is also to identify the 1st or 2nd user of PS findings. If there is no feedback on PS results, the PS is useless. The construction of an active PS feedback system is a very important element in PS activities.
- *Environment* means the infrastructure of PS. This includes related rules and acts, IT infrastructure, information systems, culture, education for stakeholders, openness to foreign experts. The establishment of advanced PS culture is a very important issue in the long term. Scientific analysis is very crucial for objective PS. In addition, it is very important to remove paternalistic attitudes in the scientific community in order to prevent a conflict of interest among stakeholders.



Source: Compiled by author.

2. Theory of R&D Priority Setting

2.1. Meaning of the Priority Setting: Definition and Purpose

There is always a problem of selection, which is a priority setting in order to use limited resources efficiently. R&D prioritization is a key part of strategic technology planning that determines what to do and who is to perform to achieve maximum performance through the efficient use of resources.

Prioritizing R&D has also complex political processes among various stakeholders. It is not a one-sided choice but a process of compromise that is appropriate for technology push and market demand pull. Ultimately, prioritization cannot be separated from resource allocation. For example, at the national level, R&D priority is a broader process that includes selection of target areas, portfolio coordination, science and technology competence and capability assessment, budget allocation, and research project selection.

Prioritization involves 3 important questions: What should we develop first? This question has a strong point in emphasizing mutual linkage between R&D actors and focusing on internal logic and the development direction of science and technology. Second, there is a structured prioritization method that focuses on the question of “how to develop”. This emphasizes the formation of interaction among the various participants in science and technology, and focuses on economic and social needs and political demands. “Who should be the player of research and development” is also an important question. The question includes detailed questions as follows: Should we develop this technology on its own? Will we secure or obtain this technology from outside? Will this study be conducted through collaborative research with external researchers (including international cooperation)?

2.2. Logic and Approaches of Priority Setting

2.2.1. Prioritization Model

There are a few models used for priority setting: user-based decision model, insider decision model, and political decision model. The user-based model utilizes the user’s preference on behalf of the researcher or stakeholders, so that the technology development direction can be planned according to the market needs. However, since users are not directly involved in the technology development field, it is difficult to grasp the importance of strategic R&D in the long term.

Also, there is the disadvantage that additional aspects of R&D such as education and infrastructure can be overlooked.

The insider decision model is a way to prioritize R&D based on the importance of technology as determined by scientists and engineers. It has the advantage that the policy direction can be determined with clear recognition of the importance of the technology. However, scientists and engineers are likely to judge that their own fields of study are more important. The results could therefore be distorted. In other words, there is the disadvantage that conflict of interest occurs inevitably.

The political decision model is a way to set the direction of R&D by prioritization from a viewpoint of organization. This is the way the government, which promotes R&D, often prefers. In a democratic society, the result of prioritization can change very often. As a result, this approach has the disadvantage that the scientific basis of prioritization may be weak.

2.2.2. Priority and Resource Allocation

After determining the R&D priority, it is important for us to decide how to allocate and invest the resources that we have. At the national level, it is a question of how to share the total resources of a country for various purposes: the direction of science and technology policy, the direction and scale of investment, and the size of resources for national strategic fields. Once national priorities are determined at the ministerial level, role assignment of each ministry, investment scale, strategic investment items, and policy tools should be considered. After determining priorities at the government and ministry levels, we must consider resource allocation at the program level. Allocation of resources at the program-level, experts in the relevant field are actively involved in prioritization.

After determining the allocation of resources at the macroscopic and intermediate levels, it is necessary to consider resource allocation at the microscopic level. We should consider how to allocate resources for similar R&D projects. Efforts should also be made to eliminate redundant investments. At the stage of prioritizing research projects, we must decide on specifically who will conduct what tasks, and at what scale.

2.2.3. Logic of Resource Allocation

There are various opinions on how to allocate resources. First, according to socio-economic logic, distribution of R&D resources should be decided by economic and social benefits and values of results that could be obtained by investment. This is to determine priority and resource allocation based on a relative comparison of

cost and revenue. In other words, this is a method of determining the appropriate investment scale from the balance between the cost of technology development and revenue. However, this approach has the disadvantage of it being difficult to grasp the cost and profit of investment for technology development. Also, it's hard to acquire generic technology or accumulate technological potential.

However, there is a technological approach that is determined by scientific and technological value. This approach focuses on the goals, excellence, and importance of technology itself. This is a way of allocating resources within a given available resource. Therefore, people criticize supply-oriented method because it does not consider industrial demand.

Ultimately, a complementary approach is needed to rationally allocate resources and develop promising technologies. The rational allocation of resources, such as taking a policy mix approach to solve a problem, requires a balance of social and economic benefits and technological excellence.

2.3. Methods of Priority Setting

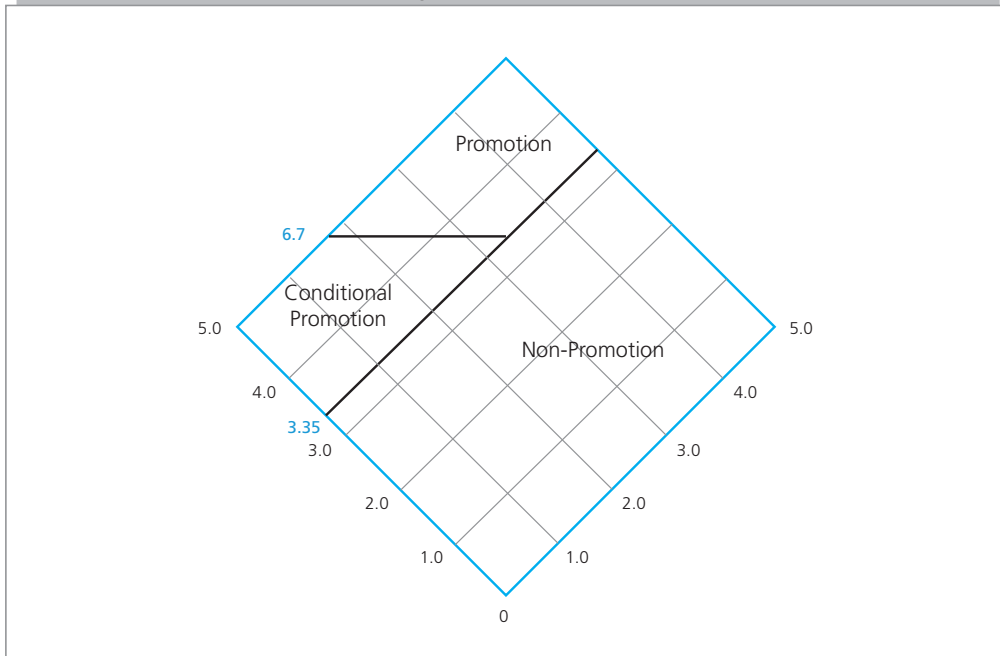
2.3.1. BMO

BMO analysis is often being used for deriving core technologies. BMO is a kind of 2x2 matrix based on attractiveness and feasibility.

The evaluation procedure of the BMO consists of 3 steps: Attractiveness Evaluation → Feasibility Evaluation → Total Evaluation. The first step is to prioritize the attractiveness of the business item or technology. If the attractiveness is more than 3.35 out of 5, we then proceed to the 2nd step. Step 2 assesses the feasibility of technology development. Step 3 predict the probability of success and determines the strategy of technology development with the attractiveness and feasibility scores. BMO analysis can simplify complex and diverse variables to feasibility and attractiveness.

- More than 6.7 out of 10 points: Promotion
- 3.35 ~ 6.7 points: Conditional promotion
- Under 3.35 points: Non promotion

[Figure 2-3] BMO Model



Source: Kim, Oh, and Yoo (2016).

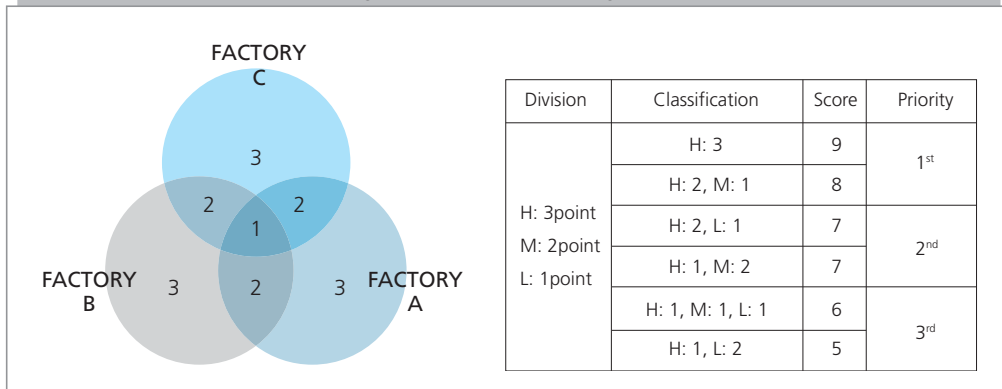
2.3.2. Three Factoring

Three factoring analysis is a priority setting method that assigns low, normal, and high ratings through relative comparison. It considers 3 strategic judgment criteria at the same time: public benefit, technological attractiveness, and strategic importance. Public benefit asks how much the technology is related to public interest. Technological attractiveness refers to the ripple effects of technology and technological excellence. Technological attractiveness refers to items that are intended to reach the business and policy objectives. Of course, the 3 criteria in this method can vary depending on the purpose of setting priorities.

- Public Benefit: Relevance to the public interest
- Technological Attractiveness: Ripple effect and excellence of technology
- Strategic Importance: Correlation with business and policy objectives

Of course, the evaluation criteria used in Three Factoring depends on the priority to be sought. For example, in the process of selecting future strategic industries by the Korean Ministry of Commerce, Industry and Energy, 3 factors were suggested as follows: leadership in technology, economic impact, and relevance to national strategy.

[Figure 2-4] Three Factoring Model



Note: 1) Result. High-3points, Middle-2points, Low-1point

2) 9-8points : 1st / 7points : 2nd / Under 6: 3rd

Source: Kim, Oh, and Yoo (2016).

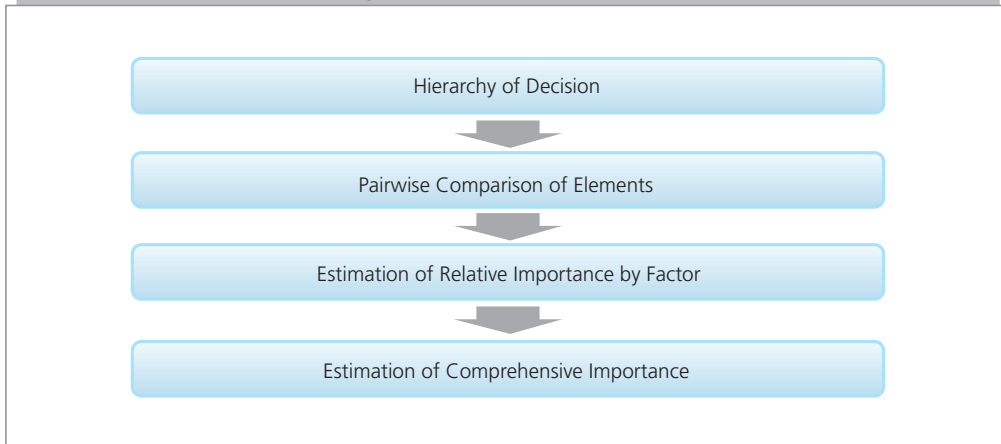
2.3.3. AHP

AHP means “Analytic Hierarchy Process” or “Hierarchical Analysis Method.” It is a technique to classify multiple attributes hierarchically and select the optimal alternative by grasping the importance of each attribute.

Key principles of AHP include *expectation* (Include all the objectives in decision making in the hierarchy), *dependence* (Factors at the same level are dependent on adjacent upper level factors), *reciprocal* (pairwise comparison matrix takes a reciprocal form centered diagonally) and *homogeneity* (Importance is expressed by a defined scale within a limited range). AHP has various uses (public, private, and various topics) and provides a final estimate of the alternatives.

AHP requires specialists to respond to each issue. It needs consistency of logic. The disadvantage of this method is that as the number of comparison objects increases, the number of comparison pairs increases too much. It is very hard to use AHP when many objects are being compared.

[Figure 2-5] AHP Process (4 Steps)



Source: Compiled by author.

2.3.4. Delphi Survey

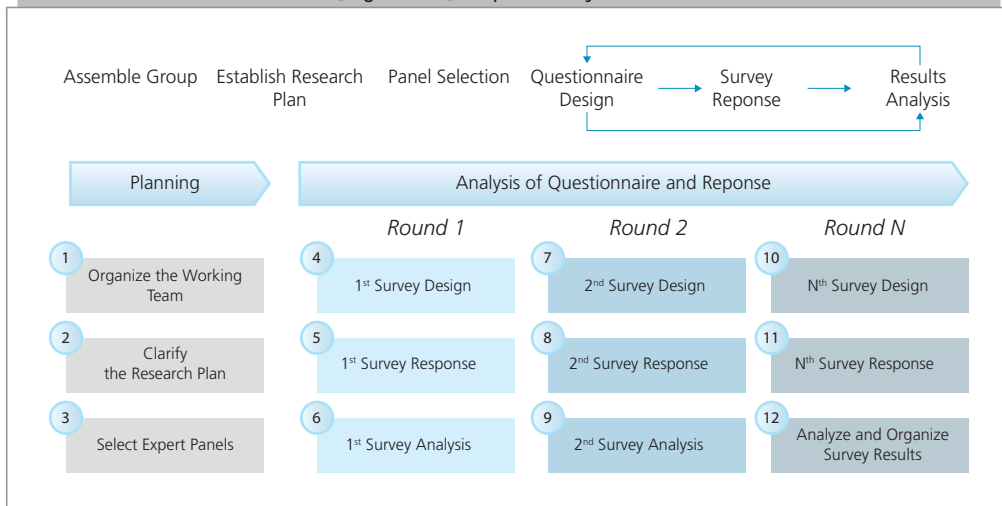
The Delphi survey is often called “Expert Consensus Law.” It is a technique to repeatedly perform questionnaires based on the experience and knowledge of experts in related fields to solve problems and derive priorities.

Key principles of Delphi method *include* 1) *Anonymity of experts who participate in survey*, 2) *Repeatability of the questionnaire* (repeat 3 surveys on average), 3) *Controlled feedback* (most common comments should be reflected in the next design), 4) *Unrestricted expert agreement*, and 5) *Independent opinion*.

Merits of this method includes the following: 1) Opinions of various experts related to the topic are objectively and freely induced to produce reasonable results, 2) Utilizing abundant professional expertise in any area, 3) Respond freely without being influenced by the pressure or the biased strong claim of a specific person.

The followings are drawbacks of the Delphi method: 1) Requires a lot of time and effort (usually 3 to 4 months), 2) High level of expertise and effort required to make questionnaire, 3) If a group of experts is selected incorrectly, it is likely to lead to narrowed and distorted results.

[Figure 2-6] Delphi Survey Process



Source: Compiled by author.

2.3.5. QFD

QFD means “Quality Function Deployment”. It is a structured approach to integrate the voice of the customer into the product development process. This translates the consumer’s requirements into the design characteristics of the product and then translates them back into component specifications, process characteristics, and finally specifications for production.

At the heart of the QFD structure is how to design and produce products and services to meet customers’ needs and what they require. In other words, it is structured by using matrices that represent objects and means in relation to each other (purpose-means matrix). This is to maximize customer satisfaction by making sure that consumer needs are fully reflected in products and services at every stage from product design, parts planning, process planning, and production planning. The expected effects of QFD can be summarized as follows:

- Reduced product development time by saving time from concept to production
- Substitute characteristics (design variables) of customer demand (true quality)
- Strong cooperation between related departments and promotion of teamwork
- Ultimate Customer Satisfaction

The QFD usually uses a matrix of purpose-measures to form a quality table called the House of Quality (HOQ) that represents the customer’s needs (objectives), technical characteristics (means) and competitiveness. With the HOQ as a starting

point, quality function development can be divided into design stage, parts stage, process stage, and production stage. Thus, QFD is not easy to apply to the R&D priorities of the public sector because it has been developed as a means to increase customer satisfaction in private companies. It is not a study for research, but it helps to clarify what the final product (product or service) of R&D will actually provide to the people. It also provides important information to specify the characteristics of the end product of R&D. For example, NASA in the United States has been using QFD to pursue technical planning to enhance the effectiveness of NASA's R&D.

3. Practice of R&D Priority Setting in Korea

The Ministry of Land, Infrastructure and Transport (MOLIT) conducts many tasks that promote S&T in the area of land, infrastructure, and transport such as setting up science and technology plan for the Ministry, R&D project funding, technology roadmap, technology trend analysis, and technology foresight. In line with these tasks, many strategic technology planning activities are implemented in MOLIT. For instance, "Research on the establishment of the core facilities and acquisition strategies for national infrastructure" was carried out as a technology priority setting activity with legal and institutional basis. This report introduces it as the subject of case study.

3.1. Framework and Steps

3.1.1. Institutional Basis

At the national level, the Ministry of Science and ICT (MSIT) is in charge of setting priorities in public R&D expenditure. Korea Institute of S&T Evaluation and Planning (KISTEP) implements technology foresight, conducts R&D program evaluation and priority setting of government R&D investment under the umbrella of MSIT. KISTEP has more than 250 experts to analyze, plan, set priority, and evaluate public R&D expenditure of Korean government.

At the ministry level, MOLIT has established a specialized agency that is responsible for the planning and management of R&D for the development of construction and transportation technology. Korea Agency for Infrastructure Technology Advancement (KAIA) is responsible for technology foresight, technology trend research, performance analysis, research project planning, research project management, and setting R&D priorities. The Division of Future Strategy is dedicated to the task of R&D and technology planning. In accordance with the priority setting by the Division of Future Strategy, each department in KAIA is in charge of research management and evaluation. Departments of R&D management in KAIA make a

contract research projects with research institutes, universities, and companies and provide research funds to researchers.

3.1.2. Legal Basis

The Korean government has the Framework Act on Science and Technology to encourage government ministries to conduct diverse activities to promote scientific technology. According to this act, S&T related ministry should carry out foresight of scientific technology, plans for development of scientific technology, and evaluation of R&D performance. Each ministry also implements diverse policies to promote R&D activities in its administrative areas. MOLIT, for example, has its own act and committee to implement S&T planning, R&D investment coordination and project management.

3.1.3. Policy Environment and Direction

The Korean government has steadily expanded its support to construction as a major industry along with steel, shipbuilding, semiconductors, automobiles and mobile phones. It is also recognized that government should promote safety and convenience of public facilities. As the government requires high-tech solutions for more advanced facilities, the government should select promising core facilities that can capture Korea's technological superiority in domestic and overseas markets. And the government has to establish strategies for how to develop them. KAIA as a professional agency for MOLIT therefore has tried to establish a technology acquisition strategy through selecting promising core facilities and establishing R&D investment plan according to R&D priorities.

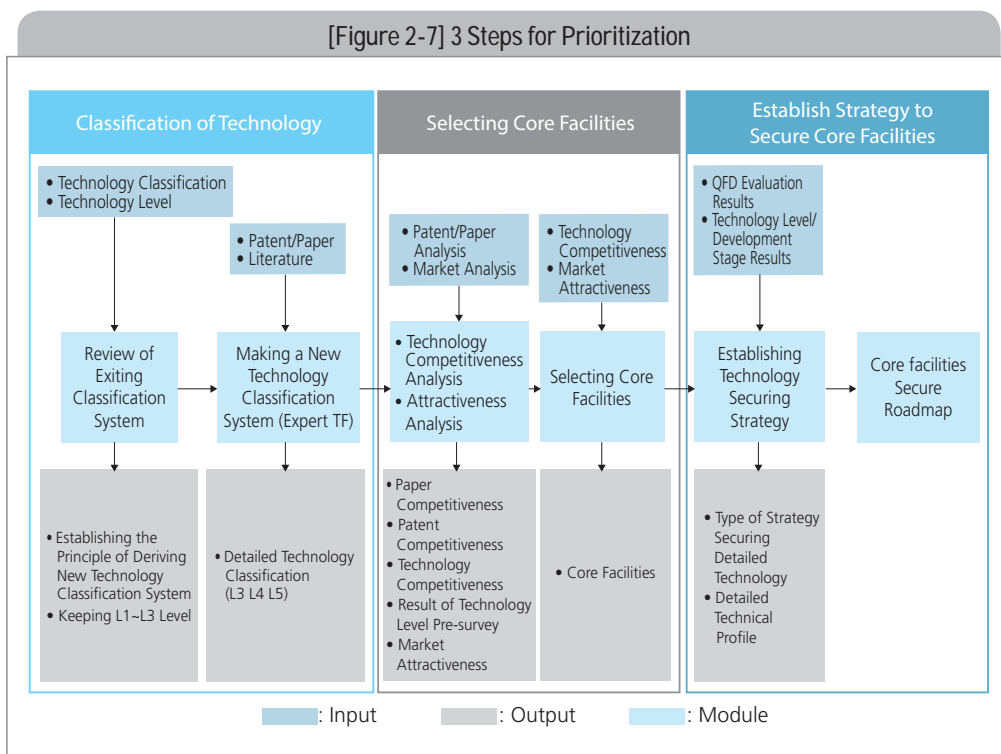
3.1.4. Input: Resources

KAIA has put \$400,000 and 10 researchers into the project in order to select key facilities and set priorities of them. Hundreds of experts (industry -academia-institute) have been consulted for about a year. KAIA placed an order to Korea Institute of Construction Technology (KICT) to carry out the project. The institute's role in the project is to provide research methods, STEEP analysis, technology intelligence (including market trends and technology analysis), and experts who have special knowledge on infrastructures and facilities. The research team spent about 6 months and had a number of discussions for collecting ideas and opinions coordinated among stakeholders and related experts.

3.1.5. Activities: 3 Steps for Prioritization

This research has several steps to prioritize core facilities and create a technology roadmap for securing promising technologies.

- Classification of Technology
 - Review of existing technology classification system
 - Establishing detailed technology classification system of target facilities
 - Making technology profile of each facility
- Selecting Core Facilities
 - Analysis of market attractiveness
 - Technology competitiveness analysis and technology level investigation
 - Selecting core facilities for securing strategy
- Establishing strategy to secure core facilities
 - Classification of technology securing strategy
 - Establishing technology securing strategy and prioritization
 - Establishing technology roadmap



Source: Compiled by author.

3.1.6. Output: Usage of Result

The project aims to answer the following questions: What facilities are important and attractive? What technologies are needed? How to get those technologies? What is the most efficient and effective strategy in order to get key technology for securing core infrastructure? Based on the strategies, MOLIT can make a plan for specific and detailed research project. In other words, the result of the project was used as a blueprint of core facility building plan of MOLIT.

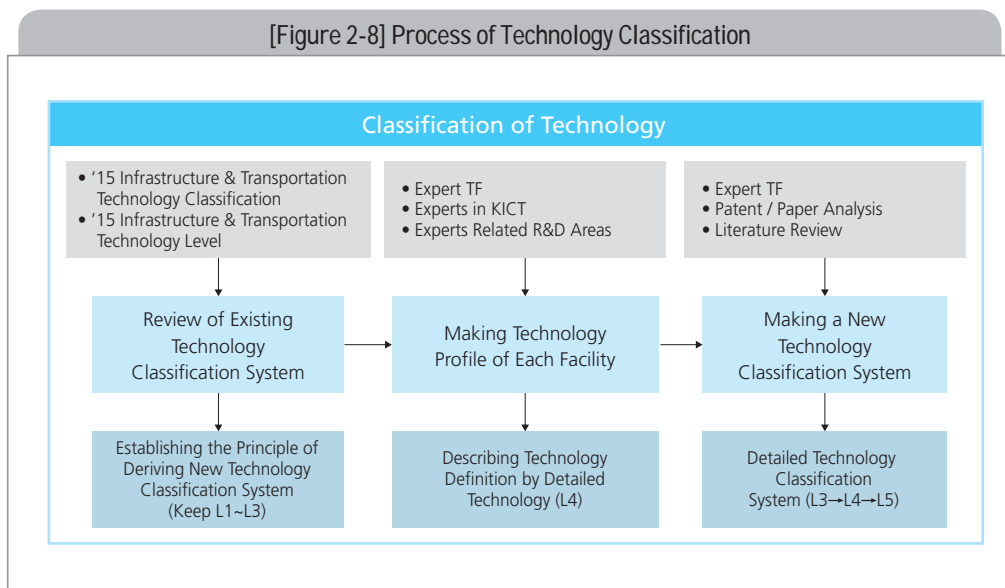
If specific research projects are selected, KAIA makes Request for Proposal (RFP) and provides to researcher. Researchers submit proposals for research projects according to RFPs. The core facility project thus serves as a compass for detailed research project planning and implementation.

3.2. Detailed Process

3.2.1. Classification of Technology

3.2.1.1. Review of the Existing Technology Classification System

First of all, the project reviewed existing technology classification system of domestic and foreign land transportation sector in order to benchmark them. The existing classification of MOLIT is composed of 5 levels from Level 1 to Level 5. It is thought that MOLIT's technological classification system is well defined in Level 1



Source: Compiled by author.

and 2 for facilities. Therefore, the researchers found that the technology tree is well structured. Therefore, it was decided to keep the whole framework of technology tree. However, at the level of detail of L3 ~ L5, it was decided that it did not reflect current technological change and decided to make corrections and modifications. In summary, Level 1 and Level 2 used in the existing MOLIT's classification system remained unchanged in order to maintain consistency with previous studies and technologies in level 3 ~ 5 were modified.

3.2.1.2. Establishing Detailed Technology Classification System of Target Facilities

The project operated a special task force to establish a detailed technology classification system for facilities. In this project, the detailed technology classification of L4 and L5 level was established considering the scope, scale, mutual redundancy as sub-categories of L3. As a result, the technology classification system including 38 subdivisions (L4) and 434 detailed categories (L5) was fixed under 18 sub-categories (L3).

〈Table 2-1〉 Technology Classification (Level 1 ~ Level 5)

L1	L2	L3	L4	L5
C. Facility	C1. Bridge	C12. Concrete bridge	Green / Low Carbon Concrete Bridge Technology	HVMA (High volume Mineral Admixture) high-strength concrete technology
				HVMA (High volume Mineral Admixture) self-charging concrete (SCC) technology
				Alkali-active slag concrete (cementless concrete) technology
				CO ₂ reduction cement technology using non-plastic binder
				Green and low-carbon concrete structure design & construction technology
			Technology to Shorten Construction Period of Concrete Bridges	Curvature-compatible precast bottom plate production or rapid construction technology
				FRP-based floor plate design, production, construction technology
				Modular design and rapid construction technology of upper structure of concrete bridge
				Technology for design, manufacture and rapid construction of prefabricated bridge piers
				Three-dimensional shape measurement and quality control technology of built-up member
				Rapid production and construction technology of short bridge (within 20m)
				Camera-based visualization technology for precise construction of built-up member
		

Source: KAIA (2017).

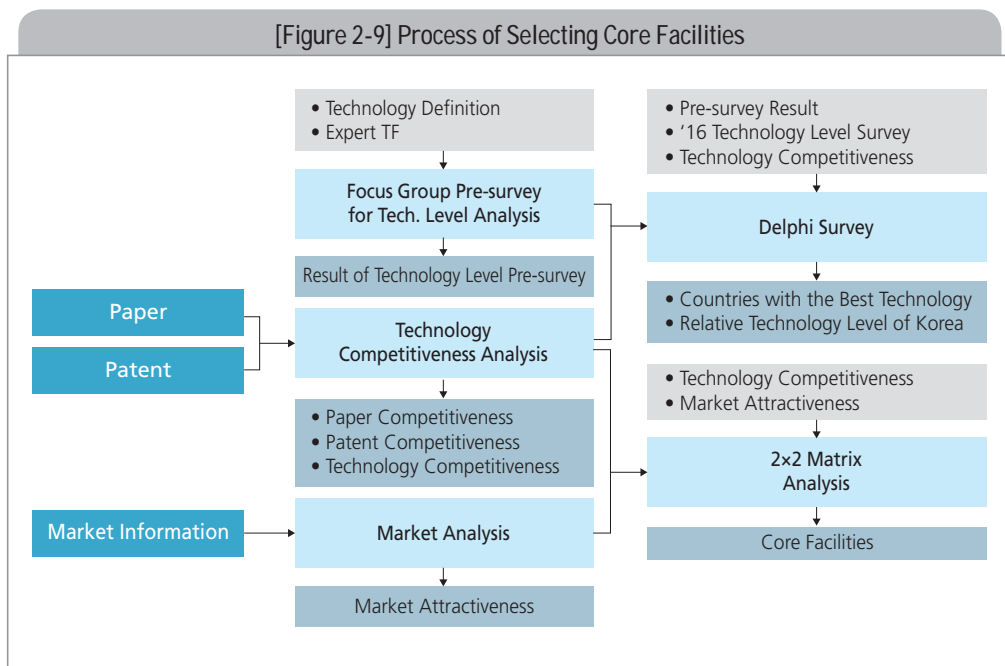
3.2.1.3. Making Technology Profile of Each Facility

The project has created a technology-specific profile that includes the contents and scope of the detailed technology in consideration of the purpose, contents, and functions of the technology. The profile includes definition, function, main content and configuration of subdivision technology, and keyword by level 4 technologies (38 technologies). A brief description of the technology, including definition, needs, and expected benefit finally was made in 434 detailed technologies (L5). Each of them is the unit of priority setting.

3.2.2. Selecting Core Facilities

3.2.2.1. Analysis of Market Attractiveness

Market attractiveness is defined as the magnitude of the potential profit that domestic technology can achieve in the global market, considering current and future market size. First, the research team looked at global market trends at the L2 level and Korean companies' market share in overseas markets. Based on the survey results, research team estimated the future prospects at the L3 level and examined the market attractiveness of the L4 level facilities through expert evaluation. In order to increase the reliability of evaluation of market attractiveness, the team conducted



Source: Compiled by author.

surveys for domestic and overseas specialists in the field of facilities, and marketing teams for overseas construction in Korean companies.

3.2.2.2. Technology Competitiveness Analysis and Technology Level Investigation

In order to derive the competitiveness of the papers and patents, the research team examined papers and patents of the last 5 years ('12~ '16) at the L3 level. They analyzed the paper competitiveness and patent competitiveness at L3 level using SCOPUS DB and KIPO DB. In addition, they set up search keywords at L4 level to analyze the papers and patent in more detail. Finally, the expert Delphi survey investigated the technology level of L4 and L5 to derive technology competitiveness. In other words, based on the results of quantitative analysis of papers and patents, the 2-round Delphi survey was conducted to set the level of technology and technology development in L5 units. Unlike other Delphi surveys, the Delphi survey conducted a preliminary selection of experts who could respond. Therefore, the response rate was very high at more than 50%. This is much higher than the 10% response rate of a typical Delphi survey that randomly selects experts. This has positively influenced the reliability of the results.

3.2.2.3. Selecting Core Facilities Before Strategy Building

The research team selected core facilities at the L4 level based on market attractiveness and technological competitiveness in order to expand overseas competitiveness of Korean companies. In order to establish a technology strategy, facilities with high potential in the global market were selected as core facilities at the L4 level. The L4 facilities selected here are the key facilities that are urgently needed to secure detailed technology. To summarize, the research team selected the key facilities to be secured through the 2x2 matrix analysis, which consists of L4 technology competitiveness and market attractiveness.

[Figure 2-10] Identify Core Facilities with 2X2 Matrix



Source: KAIA (2017).

3.2.3 Establishing Strategy to Secure Core Facilities

3.2.3.1. Classification of Technology Securing Strategy

The research has typed method and player to acquire the L5 level detailed technology in order to effectively establish the core facility acquisition strategy. Considering Korea's technology level and development stage of L5 level technology, it distinguished between the technology to be developed by R&D and the technology to acquire from outside.

- If the level of domestic technology is high, regardless of the stage of technology development, technology is acquired through domestic independent R&D
- If the domestic technology level is dependency or non-technical level and the technology is in the introduction period and growth period, technology is acquired through international joint research
- If domestic technology level is low or dependency level and the market is already well formed due to maturity of technology, technology is acquired from outside including technology purchase

In order to determine who will lead the technology development, the research analyzes not only technology benefit but also R&D risk. The QFD questionnaire conducted by the expert task force was used for analyzing the benefits of technology and the risk of technology development. Questions for QFD appraisal include the utility of acquiring skills, increased demands for entering into overseas market, technical risk, clarity of demand, and time and efforts. The scores of each question item were given exponentially (e.g. 1-3-9) instead of being equally spaced (linear, e.g. 1-2-3) to improve the discrimination power of each item.

- Private sector lead: Technology with high risk of technology development and high technology benefits
- Public sector lead: Technology with high R&D risk, but low benefit
- Cooperation of public and private sector: Technology with high benefits/high risks or low technology benefits/low risk

〈Table 2-2〉 QFD Analysis

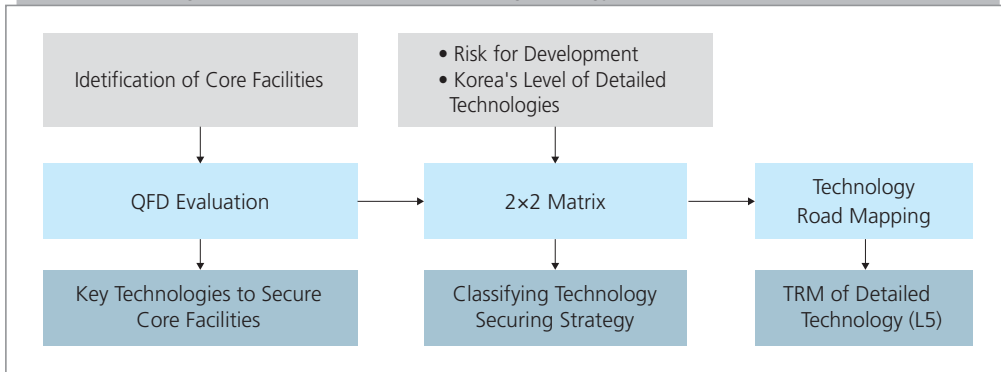
Priority	Technical Name	QFD Appraisal							Total Score
		The Utility of Acquiring Skills	Increased Demand for Overseas Market Access	Demand for Entry into New Overseas Markets	Increase in Profitability	Technical Risk	Clarity of Demand	Input Time and Effort	
1	Tangible Material Technology for Floating Structures	3.483	0.1134	0.496125	0.363825	0.453375	0	-0.069316	4.840
2	Structural Technology of Supersize Concrete Structures	2.709	0.0756	0.441	0.202125	0.272025	-0.136617	-0.207948	3.355
3	Float Stability Improvement Technology	2.322	0.00756	0.441	0.202125	0.18135	-0.409851	-0.069316	2.743
4	Floating Portion Fixation and Anchoring Technology	1.7415	0.08505	0.275625	0.202125	0.272025	-0.136617	-0.034658	2.405
5	Rapid Manufacturing Technology of Super Large Float	1.548	0.04725	0.275625	0.3234	0.18135	-0.136617	-0.17329	2.066
6	Bonding Technology of Large -Scale Module	1.548	0.10395	0.275625	0.1617	0.18135	-0.136617	-0.17329	1.961
7	Wave-Structure Interaction Analysis Technology	0.9675	0.02835	0.165375	0.121275	0.272025	-0.409851	0	1.145

Source: KAIA (2017).

3.2.3.2. Establishing Technology Securing Strategy and Prioritization

After selecting core facilities, the research team established a strategy to secure L5 level technology. In order to secure the competitiveness of the core facilities, the team sorted out the subject and method of securing the detailed technology, and defined the present level of technology and the target level of the technology to be secured. Then, the team presented the definition and scope of the core facilities to be secured, and strategies for securing detailed technology (L5) after sorting current issues such as trends, market attractiveness, technology level, and competitiveness. Priority was given to each L5 unit, which was made available for reference in R&D promotion for securing the technology through QFD evaluation.

[Figure 2-11] Process of Establishing Strategy to Secure Core Facilities



Source: Compiled by author.

3.2.3.3. Establishing Technology Roadmap

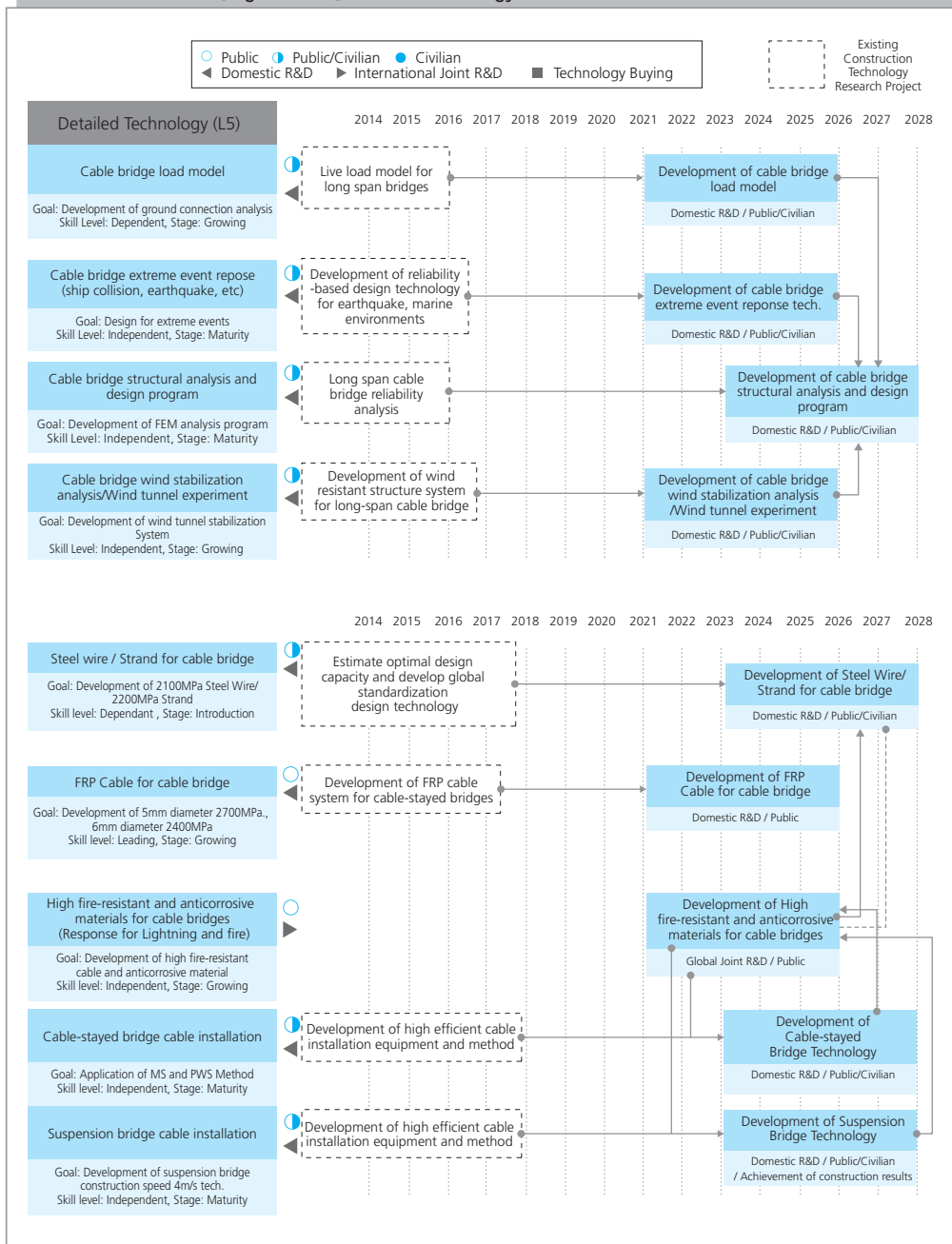
Finally, the research team summarized the research activities that should be pursued to secure core facilities in L5 units. The team presented a roadmap to intuitively identify future activities, target markets, R&D targets and strategies.

〈Table 2-3〉 Result of Strategy to Secure Core Facilities

Technology	Securing Strategy	Player
Cable bridge load model (L)	Domestic R&D	P/C
Cable bridge extreme event response (ship collision, earthquake, etc.) (I)	Domestic R&D	P/C
Cable bridge structural analysis and design program (SW) (I)	Domestic R&D	P/C
Cable bridge wind stabilization analysis (I)	Domestic R&D	P/C
Steel wire for cable bridge (L)	Domestic R&D	P/C
Construction of concrete high-rise tower of cable bridge (L)	Domestic R&D	C
FRP cable for cable bridge (D)	Global Joint R&D	P
High fire-resistant and anti-corrosive materials for cable bridges (D)	Global Joint R&D	P
.....

Note: L: leading, I: independent, D: dependant, P: public, C: civilian
Source: KAIA (2017).

[Figure 2-12] Result of Strategy to Secure Core Facilities



Source: KAIA (2017).

3.3. Lessons and Policy Implications

In Korea's case, there are a few lessons to be learned in order to effectively set R&D priorities. These are summarized according to the analytic framework as follows:

3.3.1. Paradigm

First of all, it needs to establish a clear purpose for an effective system and efficient procedures to set priorities. If the goal is unclear, then the prioritization methodologies as well as the results are not sound.

Strategic technology planning is a matter of resource allocation, which means that resources are concentrated on promising areas rather than on equal research support. Therefore, the continued interest and support of top decision makers are very important. If not, it will be difficult to actually execute the plan.

There are many considerations for prioritization. Theoretically, it cannot reflect all of the many influencing factors. Therefore, it is very important to use various methods integrally. That means that "One does not fit all."

Priority should be set based on scientific method and data as much as possible. However, this is also the product of political negotiations among the people involved. Therefore, the result is not an absolute standard. In the end, it is very important to reach a consensus so that stakeholders can fully accept and actively cooperate for the plan after R&D priority has been set.

3.3.2. Environment

Prior to setting priorities, data collection and analysis system (DB) should be built to analyze market size, growth rates and level of technology. In the process of prioritization, it is important to gather opinions from many experts, so that it is necessary to create an appropriate number of expert pools considering the field.

Priority refers to the differential allocation of resources. Therefore, it is very important to have a culture in which the members of the organization or the related parties are able to accept the results of prioritization. Acceptance of results depends on how scientific and reasonable the prioritization methodology is. It is also a matter of fair-play spirit that accepts adverse results. Therefore, prior to starting the priority setting, it is necessary to announce the purpose and method of the priority setting and how to use the results. By doing so, the people involved can readily accept the priority results.

3.3.3. Resources

It is necessary to build an independent organization to take charge of strategic technology planning. Researchers involved in individual research and development are likely to represent their own interests. It is therefore desirable to have an independent and professional organization free from conflict of interest issues.

If it is difficult to create an independent organization for prioritization, it is desirable to create task forces for a limited time or to assign priorities to external independent organizations. It could be a good idea to have a steering committee within the organization to deliberate and coordinate the results of prioritization.

3.3.4. Implementation

It is desirable that the qualitative method and the quantitative method are appropriately used in the priority setting. As shown in the case study, various methods such as BMO, AHP, Delphi method, and QFD were used in Korea.

6 months to 1 year is most appropriate for setting the priority. Since resource allocation is an important issue, it is good to carry out plans with sufficient time. However, if there are problems with the time and resources required to set priorities, and if the study period is too long, the results will be less timely. Since the surrounding environment related to the priority also changes, it is desirable to consider the priority setting as a kind of rolling plan and modify it according to the environment changes. Most plans in Korea set investment priorities as rolling plans each year after establishing investment directions for 5 years.

3.3.5. Utilization

Unused priorities have no meaning. It is important to ensure that all those involved know when, where, and how priorities will be used. KAIA's core facility project was provided as a reference for project planning at the L5 level. In this way, specific R&D projects have been planned according to the facilities and technologies presented in the core facilities project. In the planning of individual R&D projects, details such as the size of the task, the detailed technical development goal, the development method, and the subject of development have been determined, and studies are being conducted based on these.

Prioritization should be integrated with TRM to derive the results. Since it is difficult to design an actual technology development path by presenting only the priority, it is desirable to prepare a report combining the priority and TRM.

4. Review of the S&T System and Capacity of Mexico for R&D Priority Setting¹⁾

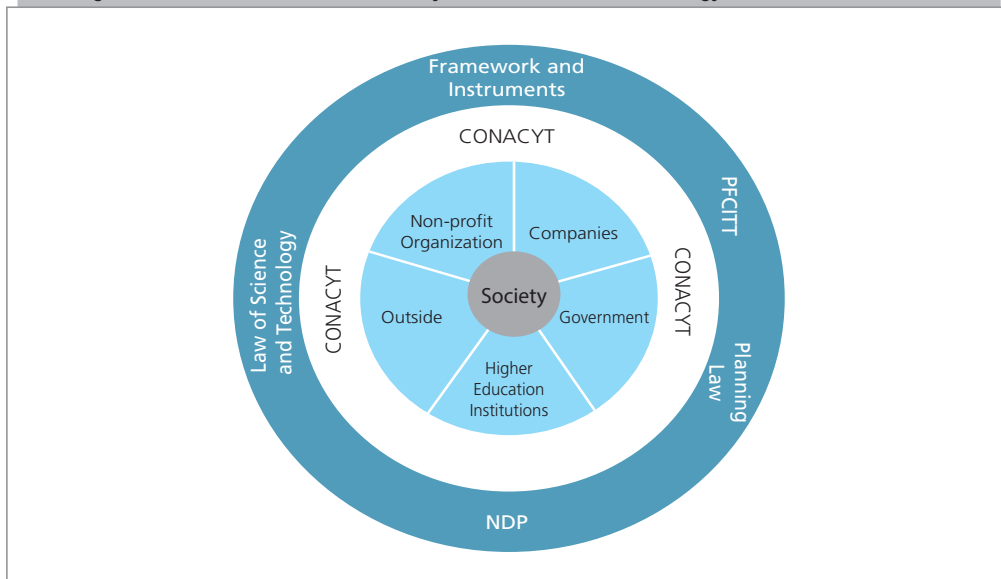
4.1. Analytical Review of S&T System in Mexico

Each country is trying to produce knowledge and know-how and to make more effective national science, technology, and innovation systems. Public research organizations as innovation drivers in NIS (National Innovation System) are responsible for responding to the needs of the society.

In Mexico, various efforts are being made to form an innovation system that involves all the factors in continuous and sustainable processes in order to carry out the competition on the basis of innovation (Congress, 2011).

The National System of Science, Technology and Innovation (SNCTI by its Spanish acronym) is made up of the instruments of government, public policy, and planning, and by a set of actors: the public sector at its 3 levels, the academic and research sector, and the set of companies with Science, Technology and Innovation (STI) activities. The following are important actors that permit to understand the infrastructure of the SNCTI in Mexico, which were shown in [Figure 2-13].

[Figure 2-13] Actors of the National System of Science, Technology and Innovation (SNCTI)



Source: CONACYT (2014).

1) This chapter is mainly prepared by local consultant, Ms. Alexandra Ortiz Guzman.

Currently, the National Council of Science and Technology (CONACYT by its Spanish acronym) is serving as the coordinator and it is the articulating axis of the STINS. The system has solid links between Higher Education Institutions (HEI) and Public Research Centers (PRC). In contrast, other types of links, such as HEI and PRC with the productive sector, they are still small (CONACYT, 2014).

Since 2003 Mexico has a legal framework that helps to impulse STI in the country in which CONACYT has an active role (CONACYT, 2017).

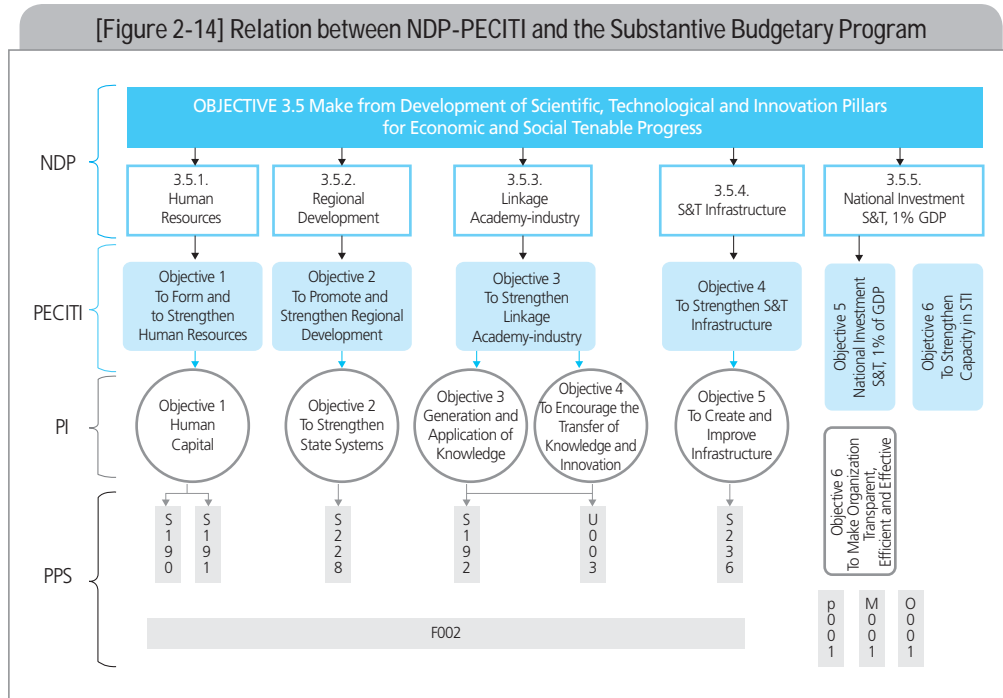
- Law of Science and Technology
- Organic Law of CONACYT
- Reform of the Law on Income Tax Relative to Tax Incentives
- Scientific and Technological Advisory Forum
- Inter-Ministries Committee for the Integration of the Federal Consolidated Budget of Science and Technology
- General Council of Scientific Research and Technological Development headed by the head of the Executive
- CONACYT as a non-sectorized entity dependent on the Executive, with functions of sectoral coordination and administrator of a budget branch for Science and Technology
- National Committee of Science and Technology as a coordinating body between the offices and councils of the states and CONACYT to promote scientific and technological decentralization
- Publication in the Official Gazette of the Federation of the “Decree by which article 9 bis of the Science and Technology Law is added”, dated September 1, 2004
- Agreement of the National Treasury Commission to create the Branch 39 and channel resources to the States to promote scientific and technological activities

4.1.1. CONACYT

CONACYT was established on December 29, 1970, as a decentralized organization. It is the council in charge of designing and coordinating STI policy in Mexico to promote scientific and technological development in the country. To achieve this, CONACYT pursues several strategic objectives through various instruments and tools for planning and public policy (CONACYT, 2017).

Its objectives and strategies are reflected in the guiding planning documents: the Special Program of Science, Technology and Innovation 2014-2018 (PECITI by its Spanish acronym) and the Institutional Program 2014-2018 (PI by its Spanish acronym). This translates into lines of action that are specified through the different

Substantive Budgetary Programs (PPS by its Spanish acronym) administered by the Council (CONACYT, 2015).



Source: CONACYT (2015).

4.1.2. Law of Science and Technology

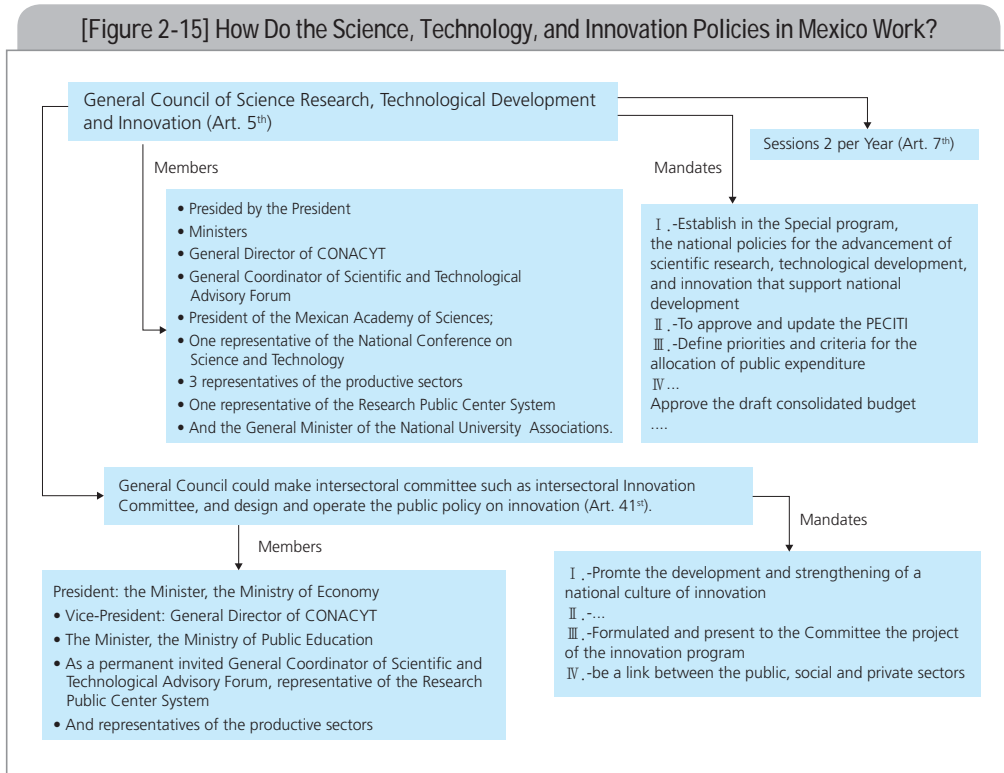
In its article 3rd, the law consolidates state policy for scientific, technological and innovation activities and promoting coordination, specifically the STINS (Mexican Government, 2015).

Besides, the article 3rd indicates that the SNCTI is integrated by:

- State policy on science, technology, and innovation defined by the General Council
- PECITI as well as the sectoral and regional programs in terms of science, technology and innovation
- The guiding principles and legal, administrative and economic instruments to support the scientific research, technological development, and innovation established by this law and others ordinances
- The Federal Public Administration and its affiliated entities that carry out activities of scientific research, technological development and innovation or support for them, as well as institutions of the social and private sector

and governments of the states, through the procedures for coordination, coordination, participation and connection in accordance with the laws applicable

- The National Network of Groups and Research Centers and scientific research activities of universities and institutions of higher education, in accordance with its applicable provisions



Source: Mexican Government (2015).

4.1.3. Planning Law

The planning law gives the basic norms and principles according to which the NDP will be done (The latest Planning Law reformed in 2016, Art.1st).

Through planning, objectives, goals, strategies, and priorities will be established as well as criteria based on cultural feasibility studies; resources, responsibilities, and times of execution, actions to be coordinated, and results to be evaluated as follows.

- The Ministry of Finance and Public Credit is in charge of coordinating the activities of the NDP (Art. 14th) and prepare the National Development Plan,

taking into account the proposals of the Federal Public Administration, its affiliated entities and state governments, the approaches that be formulated by the social groups and the indigenous peoples and communities concerned as well as the gender perspective.

- The programs derived from the National Development Plan must keep congruence in what corresponds with the horizon of 20 years (Art. 21st).
- The plan indicates the sectoral, institutional, regional and special programs which must be elaborated. These programs are observed the congruence with the plan, and its validity will not exceed the constitutional period from an aspect of government management in which they are approved, although their forecasts and projections refer to the longer term.
- The National Development Plan must be prepared, approved, and published within a term of 6 months counted from the date on which the President of the Republic takes office (Art. 21st).

4.1.4. National Development Plan 2013-2018

The Public Federal Administration's programs are necessarily aligned to the National Development Plan 2013-2018 (NDP or PDN by its Spanish acronym). NDP is the working document that presents the road that Mexico government has to trace to realize Mexico's maximum potential.

The Mexican legal framework establishes the obligation to carry out democratic planning where the broad participation of Mexicans takes place so that aspirations and demands of society can be collected and incorporated into the NDP. With this in mind, a broad consultation process was established on the occasion of developing the NDP (Mexican Government, 2013).

It is important to mention that the NDP does not describe a strict methodology that must be followed; as for the Delphi survey or hierarchical analysis method; however, the NDP 2013-2018 performed a consultation procedure as an important piece to develop and complement the NDP.

In the development of the NDP, the website pnd.gob.mx was made available to the public for the reception of proposals in digital archives and through which interactive surveys were carried out. In parallel, windows of physical reception of proposals were opened throughout the Mexican Republic.

Additionally, 397 consultation actions were carried out, including the holding of 5 National Forums (one for each national goal) with 31 discussion panels, 7 Special Forums with 40 discussion panels, and 32 State Forums with 160 discussion panels.²⁾

2) In the National Forums, specialists and officials delineated the objectives and strategies that each of the National Goals must include. The President participated in these forums.

122 sectorial dialogues with specialists and various groups of interest were also held.³⁾ There were a total of 228,949 participants; 129,299 people answered the interactive survey, the Forums and Sectoral Tables had 61,779 attendees, and there were 37,871 physical and electronic proposals. The different inputs of the consultation process contributed to the design of goals, objectives, strategies, and lines of action of the present NDP (Mexican Government, 2013).

〈Table 2-4〉 Consultation Process of the National Development Plan

Consultation Measure	Contributions to NDP	
Citizen Online Survey	National Goals and Objectives	National Development Plan 2013-2018
Physical and Electronic Proposals by Citizen		
5 National Forums with 31 Panels	Objectives and Strategies	
7 Special Forums with 40 Panels		
32 Statal Forums with 160 Panels	Strategy and Actions Lines	
122 Sectorial Dialogues		

Source: Mexican Government (2013).

The NDP 2013-2018 has 5 national goals: a peaceful Mexico, an inclusive Mexico, a Mexico with quality education, a prosperous Mexico, and a Mexico with global responsibility. It also suggests 3 transversal strategies; democratizing productivity, closer and modern government, and gender perspective.

〈Table 2-5〉 National Development Plan 2013-2018

General Objective	To realize Mexico's maximum potential				
5 Goals	I. Mexico in Peace	II. Inclusive Mexico	III. Mexico with Quality Education	IV. Prosperous Mexico	V. Mexico with Global Responsibility
3 Transversal Strategies	i) Democratize Productivity				
	ii) Closer and Modern Government				
	iii) Gender Perspective				

Source: Mexican Government (2013).

3) Sectorial dialogues or working tables called for groups and citizens interested in contributing proposals and discussing specific public policies.

In the “Mexico with Quality Education,” “Making scientific, technological and innovation development pillars for sustainable economic and social progress” is included as a general objective, along with 5 strategies related to science, technology, and innovation (CONACYT, 2014).

The STINS is linked with this goal, objective, and strategies, and has a direct impact with the development of S&T priority setting, which is described in the next topic.

〈Table 2-6〉 Strategies and Objectives of the Goal “Mexico with Quality Education”

National Goal	Objective of the National Goal	Strategy
III. Mexico with Quality Education	3.5. Making scientific, technological and innovation development pillars for sustainable economic and social progress	To contribute to the national investment in scientific research and development technology by expanding investment annually and reaching a level of 1% of GDP
		To contribute to the formation and strengthening of high-level human capital
		To promote the development of vocations and local scientific, technological and innovation capacities to strengthen sustainable and inclusive regional development
		To contribute to transfer and use of knowledge, linking HEI and research centers with the public, social and private sectors
		To contribute to the strengthening of the country's scientific and technological infrastructure

Source: CONACYT (2014).

Once the NDP is done, sectoral programs are developed according to this plan. And the forum, panels, and sectorial dialogues have an impact on the preparations of the sectoral programs. The sectoral programs developed in the current government 2013-2018 are presented in the next table.

〈Table 2-7〉 Sectoral Programs

Sectoral Program	Line Ministry
Innovative Development Program	The Ministry of Economy
Sectoral Program of Communications and Transportation	The Ministry of Communications and Transportation
Sectoral Program of National Defense	The Ministry of National Defense
Sectoral Energy Program	The Ministry of Energy
National Program Law Enforcement	Prosecution of Justice
Sectoral Development Program of Agriculture, Fishing and Food	The Ministry of Agriculture, Livestock and Rural Development
Sectoral Program of Environment and Natural Resources	The Ministry of Environment and Natural Resources
Sectoral Program of Health	The Ministry of Health
Sectoral Program of Education	The Ministry of Public Education
Sectoral Program of Social Development	The Ministry of Social Development
Sectoral Program of Governance	The Ministry of Interior
Sectoral Program of Agrarian, Land and Urban Development	The Ministry of Agrarian, Land, and Urban Development
Sectoral Program of Tourism	The Ministry of Tourism
Sectoral Program of Foreign Affairs	The Ministry of Foreign Affairs

Source: Compiled by author.

4.1.5. PECITI

The PECITI's contents and its general process of elaboration are established in the current Science and Technology Law, Article 3, as a Special Program and as one of the fundamental pieces of the SNCTI (CONACYT, 2014). Likewise, the Law articulates that the PECITI must include a long-term vision and projection for up to 25 years, with updates made every 3 years, coinciding with the start of each new Legislature of the Congress of the Union.

This special program has been prepared by CONACYT with consideration of the proposals of other affiliated entities and organizations. It highlights participation in forums and meetings of the Academy of Engineering (AI), the Mexican Academy of Sciences (AMC), the National Academy of Medicine (ANM), the Science council of the Presidency of the Republic (CCC), the National Association of Universities and Educational Institutions Superior (ANUIES), in addition to the National Network of

State Councils and Organizations of Science and Technology A.C. (REDNACECYT), with the last one constituted by the ministries and CONACYT. Many representatives of universities, research centers, and business associations participate in the forums (CONACYT, 2014).

Even though the PECITI program is a good instrument that helps respective institutions, universities and organizations align their goals with science and technology priority setting, as the NDP, the PECITI does not mention a complete methodology that describes the method, software, or tools that were used step by step.

The objective of the NDP goal 3.5 states to “Making scientific, technological and innovation development pillars for sustainable economic and social progress” and the strategies stated in in <Table 2-6> are detached and specify the public policy actions of the sector. These policy lines are the guiding objectives of the PECITI, whose principal purpose is to guide the transition of the country towards a knowledge-based economy (CONACYT, 2014).

First of all, there is a need to achieve national investment in Scientific Research and Experimental Development (IDE by its Spanish acronym) that represents at least 1% of GDP, which is considered as the turning point for sustainable development (CONACYT, 2014). In this sense, the objectives of the PECITI also have a linkage with the diverse objectives of the sectoral program shown in <Table 2-7>.

In the same way, specific opportunity areas have been identified that require attention and specific public resources. All these opportunities have a transversal, multidisciplinary nature, generate positive externalities, serve different elements of STI, and require the participation of different sectors. These are opportunities that belong to sectors with degrees of uncertainty regarding the results that can be obtained in an investigation; focusing on these issues favors the addition of investment (CONACYT, 2014).

〈Table 2-8〉 Priorities in Science, Technology and Innovation

Area	Priority
Environment	<ul style="list-style-type: none"> • Integrated water management, water security and the right of water* • The oceans and their use • Mitigation and adaptation to climate change* • Resilience against natural and technological disasters* • Use and protection of ecosystems and biodiversity
Knowledge of the Universe	<ul style="list-style-type: none"> • Studies on astronomy and cosmology • Studies on physics, mathematics, chemistry and its applications • Study on geosciences and their applications
Sustainable Development	<ul style="list-style-type: none"> • Food and its production* • Standard aspects for institutional consolidation • Cities and urban development* • Public policy and foresight studies*
Technological Development	<ul style="list-style-type: none"> • Automation and robotics • Development of biotechnology* • Development of genomics • Development of advanced materials* • Development of nanomaterials and nanotechnology* • Computer connectivity and development of information technologies, communication and telecommunications* • Engineering to increase the added value in industries • High-tech manufacturing*
Energy	<ul style="list-style-type: none"> • Sustainable energy consumption* • Development and use of renewable and clean energy* • Prospecting, extraction and exploitation of hydrocarbons
Health	<ul style="list-style-type: none"> • Human behavior and prevention of addictions* • Emerging diseases of national importance* • Preventive medicine and health care • Development of bioengineering
Society	<ul style="list-style-type: none"> • Fight against poverty and food security* • Public communication of science • Knowledge economy • Society and digital economy* • Humanities • Migrations and human settlements* • Prevention of natural risks* • Citizen security*

Note: The priority settings marked with an (*) are the most important priorities.

Source: CONACYT (2014).

Specifically, the PECITI aims to ensure that Mexican society takes ownership of scientific and technological knowledge and uses it to be more innovative and productive. This requires a much more robust SNCTI prepared to help Mexico face its most pressing realities. The above demands properly combine the diversity of local approaches and properly assess their capabilities and vocations to build from these a

national system that takes better advantage of the efforts by all its actors, a system that is not only closer to society, but also much more connected with the global knowledge market (CONACYT, 2014).

4.2. Technology Planning Activities in IPN

Planning in IPN identifies the needs of the organization, its reason to be, and its objectives to later orient resources and activities towards the achievement of its vision through strategies and tactics in the long, medium, and short terms.

The data collected for this case study were developed in line with the following analytical framework.

4.2.1. Infrastructure

The Strategy Management Department (SMD) is the administrative unit in charge of developing the necessary methodological instruments to integrate and articulate the planning, organization, budgeting, and evaluation of the Institute. The SMD has 2 crucial areas (IPN, 2017):

- Planning Direction: In charge of coordinating in an integral way the strategic planning processes of medium and long term.
- Evaluation Direction: Responsible for planning, designing, directing and operating the Institutional Assessment and Information Systems in accordance with the applicable regulations.

Furthermore, for strategic planning, IPN considers different programs as part of the infrastructure and legal framework, some of them were described in the previous topic, and were taken for the Guide for Updating the Institutional Development Program (PDI by its Spanish acronym) 2018.

- NDP by the Ministry of Finance and Public Credit
- PECITI by CONACYT
- Innovative Development Program 2013-2018 by the Ministry of Economy
- Sectoral Program of Education in charge by the Ministry of Public Education
- The Planning Law

The programs mentioned above are at the national level. Almost every public education institute must follow these programs. In addition, the programs described below are parts of the IPN framework for the strategic planning. Some of them are described with more detail in this report.

- Organic Law of the National Polytechnic Institute
- Internal Regulations of the National Polytechnic Institute
- Regulation of Social Integration of the National Polytechnic Institute
- Planning Regulation of the National Polytechnic Institute
- Institutional Development Program 2013-2018
- Institutional Development Program 2015-2018
- Medium-term Institutional Program 2013-2015
- Medium-term Institutional Program 2016-2018
- Guide for Updating the Institutional Development Program (PDI) 2018
- Diagnostics of the National Polytechnic Institute

Even though IPN has an adequate number of programs that are claimed to be used as a guide for the selection of the priority settings, these programs fail in mentioning the methodology necessary for development of the strategic axes that will be adopted by the current administration. Furthermore, there is no description of how these axes will be traced or who will conduct it.

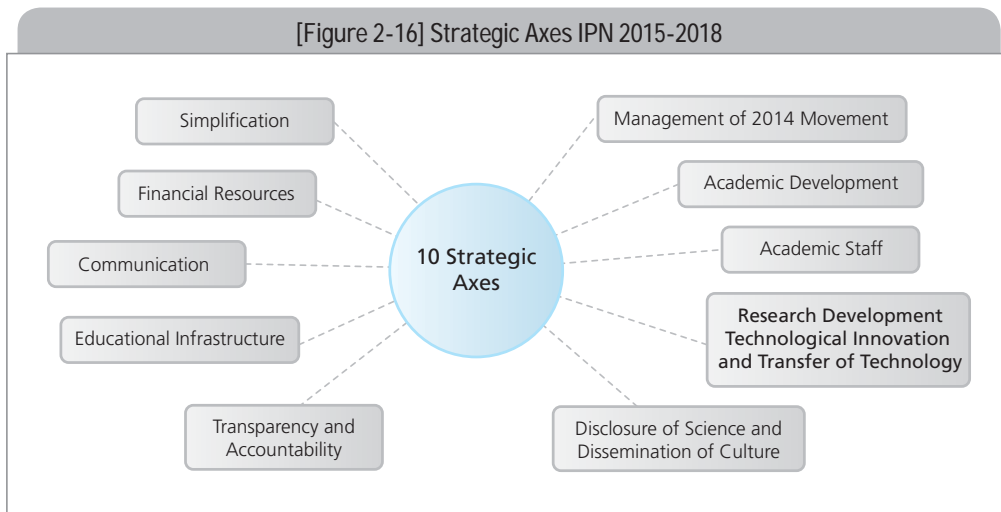
The planning and setting activities of IPN go through 3 principal programs.

- *The Institutional Development Program* (IDP or PDI by its Spanish acronym) mandates the participation of IPN in the fulfillment of the national and sectoral objectives and goals, and has its basis in accordance with 3 principal instruments: the NDP, the sectoral programs, and the PECITI.⁴⁾
 - Through its structural correlation and functional alignment, it proposes action frameworks for the institutional task and the definition of commitments for a 6-year period (IPN, 2017). The PDI has a 3-year validity, the most recent being for the period 2015-2018, and it should be updated in the first quarter of 2018.⁵⁾ (In the annex section B, the strategic axes of the 2015-2018 program)
 - Once the PDI is ready, it is developed into the PIMP.
- *The Medium Term Institutional Program* (MTIP or PIMP by its Spanish acronym), derived from the PDI, is part of the strategic planning process. Its purpose is to focus the tasks of IPN in a concerted and comprehensive manner to conduct academic and administrative management during a 3-year period (IPN, 2017). The MTIP, an operative program, gives the alignments, strategies and goals to different activities.
- *The Medium Term Strategic Development Program* (MTSDP or PEDMP by its Spanish acronym) of each polytechnic unit considers the PIMP as a conceptual,

4) It is as a Special Program and as one of the fundamental pieces of the National System of Science, Technology and Innovation (CONACYT, 2014).

5) It is important to consider that 2018 is an election year in Mexico for that reason when the government will be changed, it will be necessary to do a new PDI and for then other PIMP and PEDMP that were aligned with the new NDP.

methodological, and operational reference. Every department or affiliated institute of IPN has its own PEDMP that is aligned with the PDI.



Source: IPN (2015).

4.2.2. Input

Hundreds of experts from academia and the Industry are consulted through different tools, discussion panels, forums and sectoral tables for development of the NDP and the PECITI. The experts were not mentioned as having been consulted for the realization of the IPN programs as PDI, PIMP, and PEDMP.

However, it is important to note that IPN is working in an active way for the STINS; for that reason, it could be understood that IPN is aware of the principal issues of the country regarding S&T. Unfortunately, this knowledge is not always reflected in its strategic planning.

Also, it is imperative to consider that the strategic axes developed by the SMD try to cover all the necessities of IPN. This involves students, docents, and researchers, and they are not only specific for R&D, nor do they have a specific axis for R&D. However, it is possible with a right strategic technology planning and with the inclusion of R&D priority settings, technology foresight, and technology roadmap to achieve axes that have a direct impact in Science, technology and Innovation.

The resources used to develop the strategic axes are not always the same and depend on the administration in charge in the period that the programs are made

in IPN (PDI, PIMP, and PEDMP). For example, the SMD in charge in 2015 hired an external consultant to develop the PDI for the years 2015-2018. However, this external consultant did not have the right professional profile, and on occasion made incorrect analyses of IPN. Therefore, the General Director of the IPN highlighted only the priority axes (Calva, 2017).

〈Table 2-9〉 Working Program 2017-2020

Budgetary Programs	Axes Name
<ul style="list-style-type: none"> • Educational Services: Medium Higher • Educational Services: Higher Education and Postgraduate Cultural Development 	1. Quality of Pertinent Education
<ul style="list-style-type: none"> • Educational Services: Medium Higher • Educational Services: Higher Education and Postgraduate National Program Scholarships 	2. Coverage
<ul style="list-style-type: none"> • Educational Services: Medium Higher • Educational Services: Higher Education and Postgraduate • Science Research and Technology Development 	3. Knowledge to the Solution of the National Problems Axis
<ul style="list-style-type: none"> • Educational Services: Medium Higher • Educational Services: Higher Education and Postgraduate Cultural Development • Science Research and Technology Development 	4. Accomplishment of the Social Commitment Axis
<ul style="list-style-type: none"> • Educational Services: Medium Higher • Educational Services: Higher Education and Postgraduate • Administrative Supporting Activities 	5. Governance and Institutional Management
<ul style="list-style-type: none"> • Educational Services: Medium Higher • Educational Services: Higher Education and Postgraduate 	T1 Sustainability
<ul style="list-style-type: none"> • Educational Services: Medium Higher • Educational Services: Higher Education and Postgraduate 	T2 Gender Perspective

Source: SMD-IPN Website.

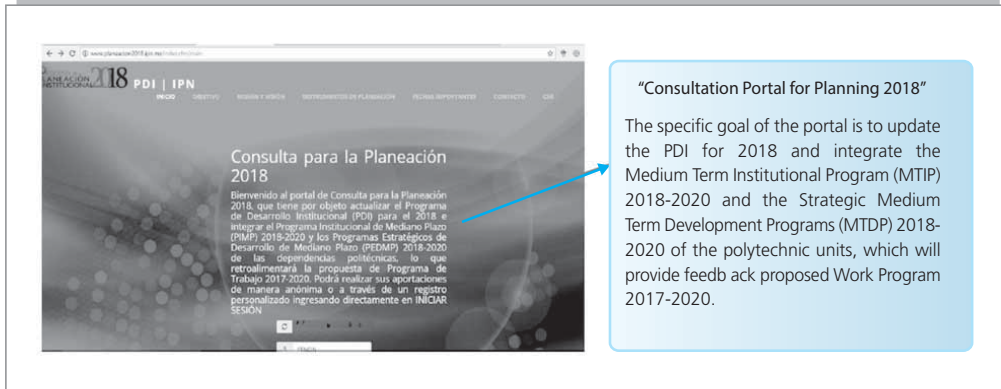
In the 2017-2018 administration of the SMD led by Dr. Calva, a group of 6 persons started with the diagnostics of IPN as part of the new strategic planning that will be integrated in the next PDI, PIMP, and PEDMP.

Also, another tool was developed with the goal of making principal actors involved directly in the strategic planning in order to be accepted by the IPN community.

For that reason, an open portal called “Consultation Portal for Planning 2018” was created, in which docents, teachers, researchers, students or ex-students could give their opinions on issues like missions, visions, SWOT, strategic axes (priority

settings), and transversal axes (Calva, 2017). This is a sort of learning process for the IPN.

[Figure 2-17] Consultation Portal for Planning 2018



Note: The platform was opened until February 18th 2018.
Source: SMD-IPN Website.

4.2.3. Throughput

It is complex to discuss the specific prioritization in R&D of IPN because of how the priorities setting developed for the SMD are more focused on solving institutional problems that are not always part of R&D. For that reason, there is currently no classification of technology in priorities settings in IPN.

Alternatively, the SMD is making some efforts to achieve a better strategic plan and to have better focus and realistic strategic axes. The first piece of this complex puzzle started with the first complete diagnostic review of IPN, which was elaborated upon in 2017. With this diagnostic review and with the use of the NDP, PECITI and the sectoral programs, it will be possible to improve the priority axes (Calva, 2017). For the diagnostics, it was necessary to develop corrects indicators, though IPN had more than 400 indicators. For that reason, 5 macro-indicators, called "Supra indicators", had to be designed.

〈Table 2-10〉 Supra-Indicators

<p>Institutional Diagnostic</p> <p>↑</p> <p>Supra-indicators of IPN</p>	<p>1. Learning Quality</p> <p>It is understood as the conciliation between “work” and “duty”, so that the education focuses on its students.</p>
	<p>2. Research Productivity</p> <p>It permits the measurement of effective research in order to achieve the economic and social goals and to identify programs that will train future generations.</p>
	<p>3. Technological Development Advances</p> <p>It focuses on the generation of new products, services, designs, methods, or organizations, and to increase value in those that already exist.</p>
	<p>4. Institutional Impact on the Social Development of the Country</p> <p>It is regard as the way that IPN links its services and projects with the environment.</p>
	<p>5. Institutional Infrastructure Conditions</p> <p>It measures the adequate infrastructure and equipment needed for the development of education and research.</p>

Note: Each supra indicator is conformed to other indicators. For example, the 2nd indicator is conformed by: Quality and Quantity to the research, citation index, impact research projects, researcher level, participation of docents in SNI and level of SNI research (National System of Researchers).

Source: IPN (2017).

The proposed IPN supra-indicators will allow IPN to be comparable with other institutions at the national or international level. In addition, homogeneous and relevant information to the polytechnic community and society in general about its educational quality supports its decision-making, promotes good management practices and, above all, contributes to compliance with the social responsibility that the Institution has (SMD, 2017).

Aligning a relationship between different variables, the IPN supra-indicators have advantages, such as establishing a comparable and objective basis to improve institutional performance and facilitating the understanding of an item due to the breadth of their perspectives. Their value is in observing the results in aggregate terms, providing specific information about a situation in time, and ensuring that information with the activities oriented to the fulfillment of the mission and institutional vision (SMD, 2017).

The supra-indicators give the institutional diagnostic data, with a score for each indicator demonstrating derivative goals and objectives for improvement (Calva, 2017). In 2017, 5 strategic axes and 2 transversal axes that are aligned with the supra-indicators were developed.

〈Table 2-11〉 Strategic Axes

1	<p style="text-align: center;">Quality and Pertinent Education Axis</p> <p>1.1. Institutional educative model 1.2. Pertinence in academic programs 1.3. Quality educational assurance 1.4. Culture and sport 1.5. Directives and docent workers with education support</p>
2	<p style="text-align: center;">Coverage Axis</p> <p>2.1. Consolidation of new educational spaces 2.2. New Academic Programs 2.3. Articulation between type and educational levels 2.4. Online and distance education 2.5. Equity in the access and scholarly trajectory</p>
3	<p style="text-align: center;">Knowledge to the Solution of the National Problems Axis</p> <p>3.1. Technology research and development 3.2. Technology innovation 3.3. Incubating technology-based companies¹⁾ 3.4. Technology observatory</p>
4	<p style="text-align: center;">Accomplishment of the Social Commitment Axis</p> <p>4.1. Relation with the social and the private sector 4.2. Institution with social impact 4.3. Mobility and internationalization 4.4. Broadcast to the polytechnic activity through its TV channel and IPN radio</p>
5	<p style="text-align: center;">Governance and Institutional Management Axis</p> <p>5.1. Strategic planning of short-, mid- and long-term goals 5.2. Statistical analysis 5.3. Processes simplification 5.4. Strategic implementation for the safe to the IPN community</p>

Note: The so-called Technology-Based Companies (TBCs) are small and medium businesses that are characterized by having a platform of knowledge focused on innovation.

Source: SMD-IPN Website.

Even though there was no strict methodology for prioritization in R&D, with the diagnostic data it is possible to detect some of the core facilities of IPN and work on them by aligning research projects with the core facilities of the IPN that were exposed already.

4.2.4. Output

Once the supra-indicators were developed and their data collected, along with the information processed in the consultation portal, the PECITI, NDP, and other instruments, as part of the 2013-2018 Innovative Development Program the Sectoral Program of Education, was able to develop the IPD 2018-2020, which was completed in February as the first step of the strategic planning (SMD-IPN Website).

The second step involved new contributions through the portal for the MTIP. MTIP 2018-2020 aligns with NDP 2018-2024 and the sector programs, and it must be updated every year. It was completed in April 2018 (SMD-IPN Website).

The third step, once MTIP has been elaborated, will begin to ensure that each institute in IPN does its own MTPD, and it was completed in May 2018 (SMD-IPN Website).

It is important to note that the programs are still developing, and with the supra indicators elaborating the strategic axes, each axis has a direct impact on at least one of the supra indicators. In this step, the SMD establishes a working program that includes every axis aligned with a budgetary IPN program. This working program is for the period of 2017 to 2020 (annex section D), but will be updated in 2018. As part of the results, the IPN has to evaluate the supra indicators and the programs at least every 3 months (Calva, 2017). There is a dedicated team within the SMD for evaluation, and the reports made every 3 months will be evaluated by this evaluation team with the help of the Institutional Control and Performance Committee (COCODI by its Spanish acronym) and the Internal Management Commission (CIDA by its Spanish acronym). The purpose of COCODI is to:

- Contribute to timely compliance with institutional objectives and goals
- Contribute to the management of institutional risks
- Establish and update the Institutional Internal Control System
- Promote compliance with programs and cross-cutting (transversal) issues
- Add value to institutional management with the approval of agreements that translate into commitments to solve the issues that arise

The objective of CIDA is to support the evaluation tasks and institutional coordination in order to contribute to achievement of its objectives and goals, as aligned with the NDP and programs derived from it, all under the terms and provisions of the Planning Law (IPN, 2017).

The data since 2017 is collected with respective results, and if IPN cooperates with the correct information and updates data accordingly, it will receive financial resources (Calva, 2017).

4.2.5. Policy

There are different programs and public funds that the government is developing in order to meet participation needs of institutions, universities, and companies in research, development, and innovation. All of them have to be in the eye of IPN and also in its strategic axes.

- **PEI**

It is a support program for companies that invest in research projects, technology development, and innovation, aimed at the development of new products, processes, or services. It is addressed to Mexican companies registered in the National Registry of Scientific and Technological Institutions and Enterprises (RENIECYT), which carries out Research, Technological Development and Innovation (IDTI by its Spanish acronym) activities in the country, either individually or in conjunction with public or private Higher Education Institutions (IHS by its Spanish acronym) and/or Research Centers and Institutes (CI by its Spanish acronym). CONACYT is in charge of Proinova.

- **PROSOFT**

It is a program for development of the software industry and innovation. Being a program of the Ministry of Economy, it is a public policy that encourages the Information Technology (IT) sector in Mexico and innovation in strategic sectors.

- **ProMexico**

ProMexico is the Mexican Federal government agency, a subdivision of the Ministry of Economy, which promotes international trade and investment.

- **Insignia Projects**

The Insignia Projects are strategic projects chosen for the IPN. They demonstrated great success in 2015 thanks to an excess in the budget of the Chamber of Deputies. The selection of the projects did not follow a specific methodology, even though they were conducted with help of Elsevier experts. Because these developments need the bigger budget of IPN, it is expected that the projects will be desegregated. The research and postgraduate department is in charge of evaluating the Insignia Projects, and their first report is expected to be released in 2018. The government is also working to promote the area of science and technology through the generation of chambers and different associations.

- **FUMEC**

The United States-Mexico Foundation for Science (FUMEC) is a binational non-profit organization whose mission is to promote binational collaboration in science and technology in order to contribute to solving problems of common interest, especially for those that support the economic and social development of Mexico.

- **ANUIES**

The National Association of Universities and Higher Education Institutions (ANUIES by its Spanish acronym) is a non-governmental organization that includes 152 public and private higher education institutions in Mexico. The association is involved in development of programs, plans, and national policies for higher education, as well as establishing agencies aimed at fostering the development of higher education in the country.

5. Conclusion

Prioritization is a very important process in strategic technology planning. Prioritization is a matter of strategic investment. This study examines the logic, framework, and methodology of R&D priorities and draws policy implications and lessons through cases from Korea. Based on the analysis of the mission, capacity, and experience of Mexico, especially IPN, this study has tried to suggest practical solutions for R&D priority setting to be pursued by IPN. The study has focused not only on the logical completeness of, but also feasibility of the method and approach in the proposal of solutions and suggestions. There are hopes that IPN will actually set its R&D priorities in order to lay the foundation for efficient and effective use of the R&D budget. In addition, it is expected that the proposed approach will help to create best practices for strategic technology planning in the Mexican context.

- **Paradigm**

At the national level, it is necessary to establish an adjustment system of R&D investment for technology foresight, TRM, and setting priorities. As we can see from the Korea case, it is necessary to specify administrative actions on the technology planning and R&D priorities in science and technology related laws. In other words, science and technology legislation needs to specifically answer the following questions: What activities should government agencies such as CONACYT do in relation to setting up technology planning and investment priorities at the national level? What should be included in the science and technology plan? What is the national R&D investment direction over the next several years? How much will R&D investment increase? What are the most critical and important areas?

IPN is currently conducting research in accordance with the research interests of researchers. There are references to some important areas such as energy, agriculture, environment, and nanoscience, but there is no blueprint for what resources to invest in those areas. In other words, there is no concentration of investment according to level of technology and research direction of IPN. Therefore, the continued interest of the government and top decision makers is important in order to adjust investment priorities by adjusting IPN-level research resources. IPN needs to reach

a consensus on key research fields with a top-down approach, taking its missions into consideration. R&D management and resource allocation policies based on performance-based management (PBM) should be established at the IPN level. This work should be steadily promoted for at least next 5 years.

Another key point is the acceptability of stakeholders in IPN. In order to increase the acceptability of IPN for differentiated resource support, there is a need for mutual agreement among the members to ensure that sufficient compensation will be provided for IPN research units and researchers who demonstrate excellent performance.

- **Infra**

It is necessary to establish a department to analyze, coordinate, and evaluate IPN's research activities as a whole, so that planning, implementation, and evaluation activities of R&D can be carried out in a comprehensive and systematic manner. If it is hard to organize a permanent department, it could be a good option to set up a temporary unit (task force team). If technology planning and R&D priorities set by the TF increase the research performance and social value of IPN as a whole and it is proved to be a worthwhile activity, then a regular organization can be created.

It is also necessary to establish a coordinating body (committee/council) within IPN to deliberate and make decisions on budget adjustment and prioritization. In this case, the Director General of IPN needs to lead the committee.

A data collecting and sharing system is also needed to objectively analyze R&D investment, evaluation information, investment priorities, activities, outputs, and benefits for beneficiaries. If a research fund costs more than a certain amount, it is obligatory to submit a technology development plan report. As mentioned above, relevant laws and regulations must contain provisions that define specific actions for strategic technology planning and evaluation.

- **Resources (Input)**

It is necessary to invest about 5% of IPN's total research expenses in activities related to technology planning, such as technology foresight, roadmap, and priority setting. In 2018, some dedicated personnel (4 to 5 individuals) will need to be deployed to implement the actual strategic technology plan.

The results of the proceedings should be reported directly to the Director General of IPN. He needs to share the results with researchers at IPN, make adjustments to the research work being done in IPN, and provide feedback on the budget for the next year.

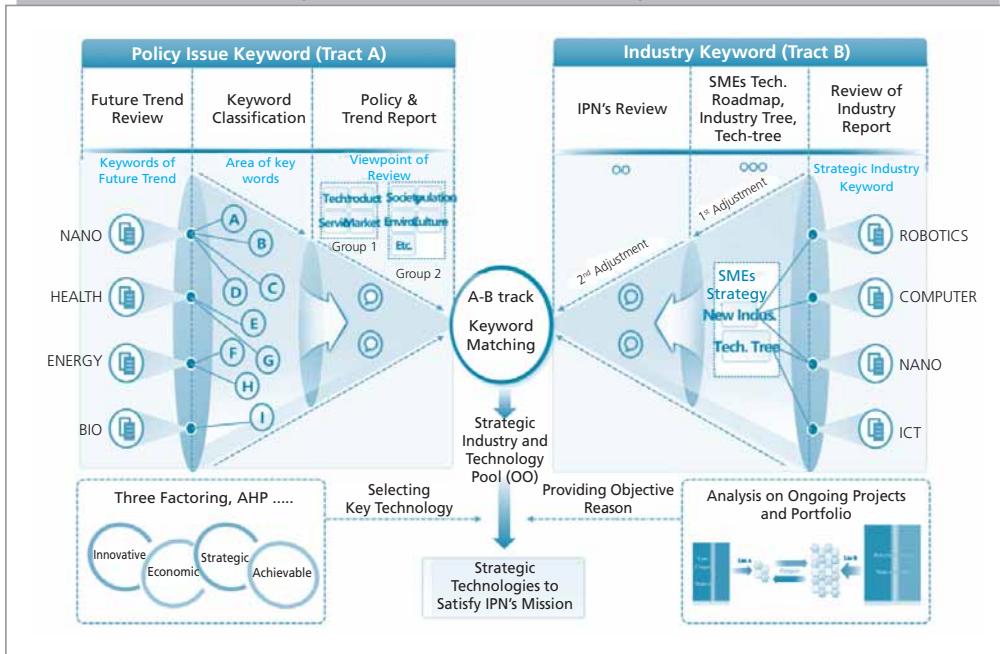
It takes about 1 year for the pilot project, but it may take 6 months to accelerate the accumulation of experience by working more intensively. The most important thing is to accumulate success cases related to R&D investment prioritization in the IPN even if it starts small. This means that a lean start strategy is needed (“fail fast, fail cheap”).

- **Implementation (Throughput)**

It is necessary to set detailed priorities for the 6 sectors for Mexico’s current economic development. Since the 6 sectors, including energy, food and automobiles, have been already established as strategic areas at the national level, it is necessary to present a concrete and detailed implementation plan for achieving the goals. [Figure 2-18] could be a frame of IPN for setting priorities. As shown in [Figure 2-18], the mega trends are identified through STEEP. It also conducts industrial and socio-economic keyword analysis through various reports (A track). On the other hand, Industry strategy reports analyze and future technology and industry prospects are carried out. Also, it is recommend to refer to existing technology trees or roadmaps in related fields and identify what technology meets socio-economic demands. Based on these technologies, topics are selected, which are to be believed to be propelling IPN (B track). As a result, the strategic industry and technology pool are created with keywords derived from both the A-track and B-track.

According to the Research and Expert Networks of IPN, computer sciences, environment, health, energy, biotechnology, nano and micro S&T, telecommunications, robotics, and mechatronics could be key areas as a starting point to make R&D priorities. This means that important research areas have already been identified. Therefore, either one of the tracks (A or B) can be omitted. In short, the core research areas can adopt the existing plans of IPN and proceed with selecting detailed research projects and setting priorities.

[Figure 2-18] Frame of IPN for Setting Priorities



Source: Compiled by author.

Once a pool of strategic technologies is created, 3-factoring method is used to derive strategic industrial technology topics that are appropriate for the key areas in Mexico (IPN). Three factors in this case could be leadership in industry and technology, economic impact, and strategic importance in the national agenda.

- **Leadership:** It is highly likely to create a new market with high technology penetration and connection.
- **Economic impact:** The market size should be large, and the growth potential and profitability of the market should be high.
- **Strategic importance:** It contributes to national competitiveness, have a high degree of incompatibility with national strategy, and have a great impact on the national economy including employment.

(Table 2-12) Three Factoring: Criteria for Selecting Key Projects with High Priority (Example)

Criteria	Detailed Criteria	Key Question
Technological Leadership	Technological Impact	<ul style="list-style-type: none"> • Is this technology likely to be a genetic or a standard technology? • How big is the spillover effect of this technology?
	Industrial Linkage	<ul style="list-style-type: none"> • How much is this technology related to the development of related industries? • Is this technology able to solve the most critical problems in the development of related industries?
	New Market Creation	<ul style="list-style-type: none"> • Does this technology provide the technical solution that the market needs? • Is this technology likely to create new markets?
Economic Impact	Marketability	<ul style="list-style-type: none"> • Is the industry related to this technology growing faster than the existing industry? • Is there a possibility that the industry applying this technology will form a large market in the future?
	Contribution to Economic Growth	<ul style="list-style-type: none"> • How much of this technology-related industry contributes to GDP?
	Profitability	<ul style="list-style-type: none"> • How much is the value added of this technology relative to other industries? • How does this technology have a positive impact on increasing the added value of the industry?
Strategic Significance	Relevance	<ul style="list-style-type: none"> • How does the development of this technology match the national industrial strategy and the IPN's mission? • What benefits do the proposed projects provide in solving the country's social and economic problems?
	Possibility of Success	<ul style="list-style-type: none"> • Given the technology development capabilities, such as technology level, how successful is this technology development likely to be?
	Contribution to Employment	<ul style="list-style-type: none"> • How much quality jobs can be created if the technology is applied to the industry?

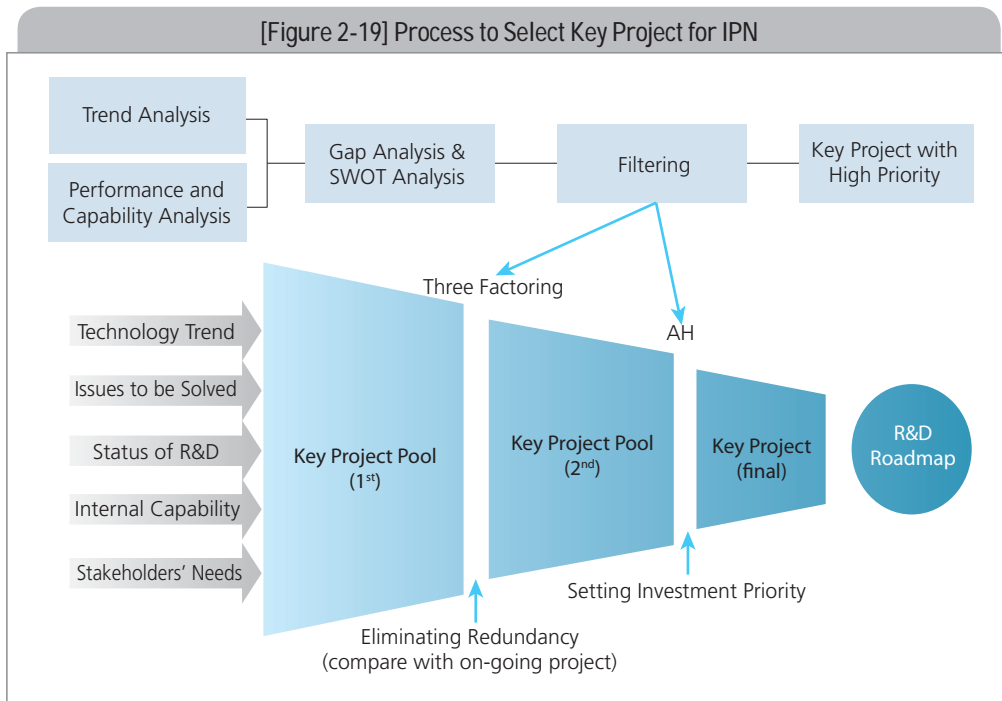
Source: Compiled by author.

• Utilization (Output / Feedback system)

Results should never suggest just directions, but should be specific enough to allocate resources accurately. Strategic implementation of budget execution for years should follow the priority setting. It is required to monitor, assess, and provide feedback on the effects of the strategic investment allocation.

For example, as shown in [Figure 2-19], once the priority is set, the process of finding a specific project is implemented. Specifically, the IPN mission, the research environment, the surrounding conditions, and the tasks and projects currently undergoing are reviewed in detail. It is necessary to analyze the gap with socio-

economic demand, to remove duplicate tasks (projects), to finally select the tasks (projects) that can be focused on, and to set a budget scale for them. The implementation plan of the research project dimension is finally expressed in the R&D roadmap.



Source: Compiled by author.

IPN strives to make a better planning program for more efficient R&D. It hopes that this project will help guide Mexican research institutions in the best way toward science, technology, and innovation, aligning IPN with the necessities of the country. This is part of the efforts of Technopoli to enhance the knowledge of R&D priority setting as a key piece in the development of strategic technology planning, at least in IPN.

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Abbreviations

CIDA	Internal Management Commission
COCODI	Institutional Control and Performance Committee
CONACYT	National Council of Science and Technology
GDP	Gross Domestic Product
HEI	Higher Education Institutions
IDE	Investment in Scientific Research and Experimental Development
IDP	Institutional Development Program (PDI Spanish initials)
KAIA	Korea Agency for Infrastructure Technology Advancement
MOLIT	Ministry of Land, Infrastructure and Transport
MOEF	Ministry of Economy and Finance
MSIT	Ministry of Science and ICT
KISTEP	Korea Institute of S&T Evaluation and Planning
KSP	Knowledge Sharing Program
MITP	Medium Term Institutional Program (PIMP Spanish initials)
MSTDP	Medium Term Strategic Development Program (PEDMP Spanish initials)
NDP	National Development plan (or PDN by its Spanish acronym)
IPN	National Polytechnic Institute
PECITI	Special Program of Science, Technology and Innovation
PI	Institutional Program
PPS	Substantive Budgetary Programs
PS	Priority Setting
R&D	Research and Development
SMD	Strategic Management Department
SNI	National System of Researchers
S&T	Science and Technology
STINS	Science Technology and Innovation National System
SWOT	Strengths, Weaknesses, Opportunities, and Threats
TRM	Technology Roadmap

2017/18 Knowledge Sharing Program with Mexico (I):
Strategic Technology Planning for
the National Polytechnic Institute of Mexico

Chapter 3

A Study on Implementation of TRM-based R&D Planning Methodology Customized for Mexico & IPN

1. Overview
2. Introduction to Technology Roadmapping
3. Current State of R&D Planning and Tech. Roadmapping in Mexico & IPN
4. Korean Experience of Technology Roadmapping
5. Suggestion of Technology Roadmapping Process Customized to IPN & TechnoPoli
6. Suggestion of Technology Roadmapping for IPN

A Study on Implementation of TRM-based R&D Planning Methodology Customized for Mexico & IPN

Dong Nam Kim (Veritanos)

Irving Munoz Lopez (Breakthrough IP Intelligence, Mexico)

Summary

- **Overview**

Throughout the years, Mexico has been growing as a production base for global companies in North America. However, due to increasing re-shoring and protectionism in major trading partners such as the United States, Mexico has come to face a situation in which it needs to reinforce its future industrial competitiveness. Therefore, in order to prepare for the 4th industrial revolution, Mexico needs to advance its science and technology innovation system to foster new growth engines and strengthen industrial competitiveness by introducing a sophisticated technology planning and R&D management systems.

Although IPN is making efforts to provide technical and market information through TechnoPoli, it still lacks the maturity in practical skill and experience for technical planning as a whole.

Therefore, this study shares the knowledge and experiences of R&D projects and methodologies based on the technology roadmap experience of Korea. Moreover, this study proposes a Technology Roadmapping (TRM) methodology that can be practically used.

Keywords: Technology Roadmap, R&D, R&BD, R&D Planning, Technology Planning System

- **Main Research Contents**

The purpose of this study is to introduce the technology roadmapping methodology reflecting Mexico's technology planning capability and conditions, so that the major R&D institutions in Mexico, such as IPN, can utilize it. It is intended to share TRM-based technology planning cases in the public and private sectors of Korea and pass methodologies and processes that can be used from a practical perspective on IPN.

This study is mainly composed of a theoretical review of technology roadmapping, case study of TRM applications in public and private sector in Korea and major industrialized countries, analysis of the technology planning capacity and situation in Mexico, and TRM-based technology methodology and suggestions.

According to a report by the local expert, Mexico's science and technology innovation system operates in relation to LCyT (Science and Technology Law) and PECITI (The Special Program for Science Technology and Innovation). The CONACYT, a committee under the Ministry of Education, serves as a control tower of science and technology innovation policy. On the other hand, there are very few examples of establishing science and technology policies and running technology roadmap-based technology planning systems in major institutions. Some institutions are trying to develop roadmaps, but the general judgement is that they lack systemicity, usability, and specificity.

The theoretical review section of the technology roadmap presents the concept and definition of technology roadmapping, importance of TRM for improving the system and efficiency of R&D investment, and the underlying process. This study proposes various types of and differences in technology roadmapping used in the public and private sectors by presenting many application cases of technology roadmapping in Korea and developed countries. Some examples of cases come from developed countries include National Aeronautics and Space Administration (NASA)'s Technology Roadmap and the EU's Energy Technology Roadmap. In the case of Korea, the National NBIC's Convergence Technology Map (2008) and the SMEs Technology Roadmap (2016) are introduced as examples in the public sector, and L's TRM case was introduced for the private sector.

Based on these cases, considering the reality and capability of IPN, TRM methodology and process are presented with examples and templates. The study concludes with policy recommendations to improve Mexico's technology plans.

- **Conclusions**

Taking into consideration the increasing complexity in technology trends and state-of-the-art technology in the age of the 4th Industrial Revolution, the national science and technology system should be strategically planned and create economic and social added value through convergence. Therefore, it is very important to create an R&D mechanism that can closely link science and technology policy planning, R&D investment, and R&D performance utilization.

Systematic technical planning, such as TRM, improves productivity of R&D investment and creates many jobs and competitive enterprises as guidelines for enhancing national R&D accountability.

In order to proliferate technology planning method, it is critical to make a policy effort, such as establishing law and institutional strategy, training professionals, and continuously implementing and encouraging learning. In particular, strategic investment is needed to enable IPN, the leading R&D institutions in Mexico, to rapidly increase its technology planning capabilities and to share with more diverse public and private R&D actors.

1. Overview

With the proliferation of the 4th Industrial Revolution, each country is reinforcing its efforts, such as expanding R&D investment, to enhance future industrial competitiveness. In particular, the government is preemptively trying to develop core source technologies to enhance global competitiveness of domestic companies through public R&D and to link them with innovative products and services of their own.

Throughout the years, Mexico has been growing as a production base for global companies in North America. However, due to increasing reshoring and protectionism in major trading partners such as U.S., Mexico has come to face a situation in which it needs to reinforce its future industrial competitiveness. It requires strategic R&D for promotion of new industries other than conservative approach taken by the Mexican government. Therefore, the Mexican government and IPN, as the core R&D institutions, need to conduct strategic R&D planning in an urgent manner, so that they can improve their implementation system.

Moreover, Mexico's R&D system lacks a strategic connectivity among "policy – R&D planning – funding/budget" and biased funding structure to short-term project without output/outcome, and even important R&D institutions such as IPN have not obtained the necessary information of strategic R&D planning. As a result, it affects

the lack of government and R&D institutions' investment and interest for enriched manpower and progress on strategic R&D planning. In conclusion, productivity of Mexico's R&D is still at a low level.

As a result, it becomes increasingly important to conduct strategic technology planning to increase efficiency of public R&D investment and enhance the strategic R&D system. Thus, Mexico must advance its R&D process through utilization of the technology roadmap for systematic upbringing of the strategic industry.

This study shares the knowledge and experiences of R&D projects and methodologies that were based on technology roadmap of major developed countries including Korea. Moreover, the study proposes a TRM methodology that can be practically used by IPN.

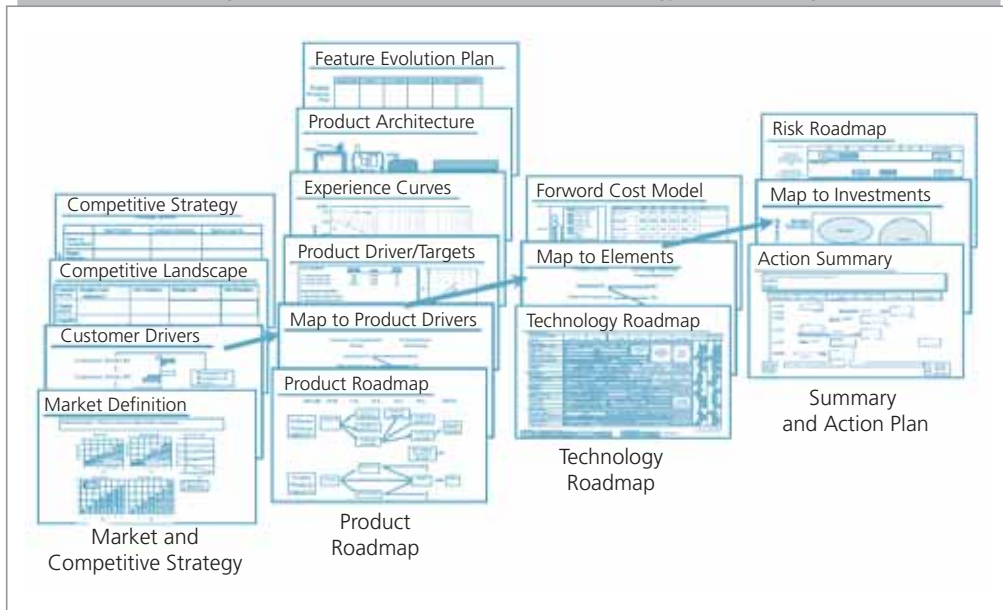
2. Introduction to Technology Roadmapping

2.1. Definition and Concept

The definition of Technology Roadmap (TRM) is "a dynamic set of technical, policy, legal, financial, market and organizational requirements identified by all stakeholders involved in its development" (IEA, 2014). These efforts will strengthen the foundation for sharing information about all related technology-specific R&BD (Research & Business Development) among participants. The goal is to accelerate the overall R&BD process in order to deliver an earlier update of the specific technology into the marketplace.

Technology roadmapping is "a planning process that gives decision-makers a means to identify, evaluate and select among strategic alternatives for achieving technological objectives"(Industry Canada, 2004). In other words, technology roadmapping refers to the planning process of products and technologies that meet market demand, and the result is a technology roadmap. Thus, technology roadmapping involves a series of processes that start with strategies for the market and customers and develop into product strategies, technology strategies and action plans for them.

[Figure 3-1] Development Process of Technology Roadmapping

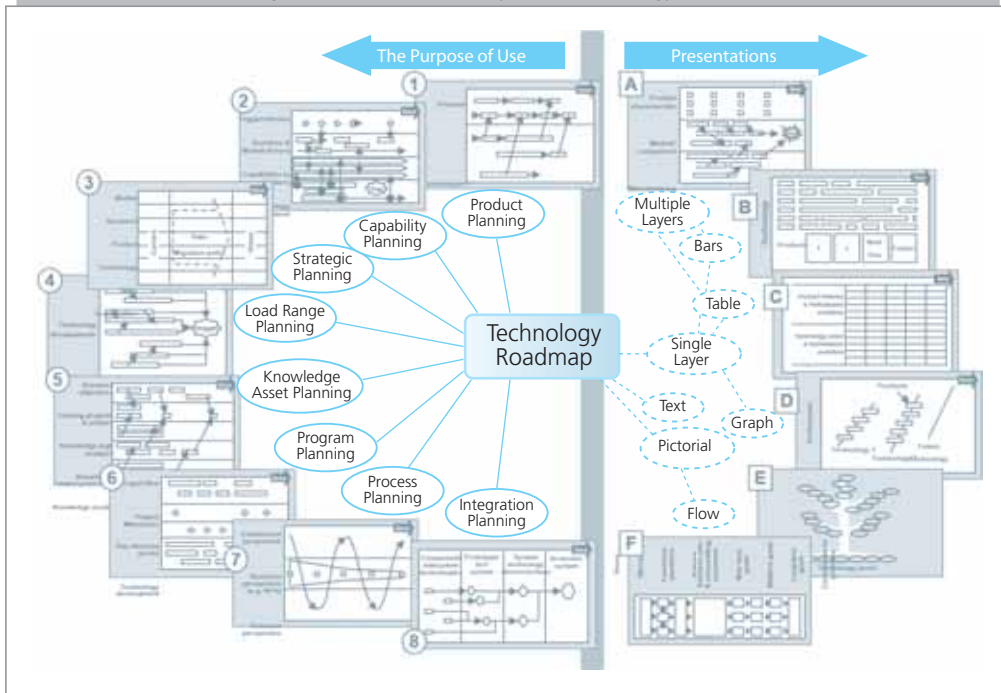


Source: The Albright Strategy Group (www.albrightstrategy.com).

Technology roadmapping differs significantly from other planning and analysis tools. First, it is driven by “market pull”, not by “technology push”(Industry Canada, n.d.). In other words, it is to develop and drive innovation to provide new services by predicting the future market rather than existing technologies. Second, it is based on a vision of the future direction of businesses and what technologies are needed (Industry Canada, n.d). Third, it provides a way for companies and institutions to achieve their visions by selecting and developing the technologies required to develop products that meet future market needs.

TRM can be expressed in a number of different types depending on the purpose of use and how it is expressed. For example, TRM can be established under a variety of circumstances, ranging from national R&D plans to establishment of plans for mass production of new products by companies.

[Figure 3-2] The Various Type of Technology Roadmap



Source: R. Phaal, C.J.P. Farrukh, D.R. Probert (2004).

2.2. Importance of Technology Roadmapping in R&D Planning

Companies face many challenges in today's global markets. Products are becoming more complicated and more customized. Time-to-market for products is shrinking and product life is shortening. R&D is expensive, and reduced budgets are making it impossible for individual companies to independently develop all the technologies they might need to meet future market imperatives.

TRM indicates the industry's consensus on a number of topics: vision of the industry at a set time in the future; new types of products (or services) that market will require; the enabling technologies to create those products; the feasibility of creating the needed technologies; the technological alternatives for achieving the needed technologies; and how to meet these technology needs through R&D. The roadmap addresses the role of an industry's suppliers in making the desired future, human resources needs, legal barriers, and other topics.

In general, the role of TRM contributed in the R&D innovation process is as follows:

- Predicting future technology of the market and product needs.
- Identifying the highly-potential technology area for the industry and key technologies that will be needed and the gap between what exists and what is needed.
- Defining the necessary pathways for successful competition in future markets.
- Providing guidance for decision making on technology development.
- Facilitating collaboration, knowledge sharing and new partnerships.
- Reducing investment risks in technology development.
- Providing opportunities to preempt future market.

In the era of the 4th Industrial Revolution, which is represented by Hyper-convergence and Hyper-intelligence, systematic planning and management of convergence R&D involving a variety of actors, is very important. TRM has the advantage of being a very important guideline for planning and managing such convergence R&D. TRM is expected to play a major role in improving the productivity of the country's R&D investment in areas such as IT, bio and aviation, which Mexico considers as a strategic industry.

2.3. Process of Technology Roadmapping

TRM can be divided into public (government, public institution) TRM and private (enterprise) TRM depending on the objective of planning. It can also be classified into product/service technology roadmap, emerging technology roadmap, and so on.

TRM in the public sector mostly consists of tech-push type TRM, which is usually used for designing and planning investments of governmental R&D program, public R&D institute, etc. On the other hand, the private sector TRM is generally characterized by a market-pull type that is used to identify core technologies and develop plans to create innovative products/services depending on business area of a company.

Public R&D aims to prevent market failure, such as basic research and source technologies, that cannot be done by the private sector to enhance national competitiveness. Thus, the purpose of TRM in the public sector is to identify promising technologies and share national and public development plan. Therefore, public TRM is relatively less specific than private TRM and technology-push.

In contrast, TRM in the private sector is very specific and focused on practice, with the priority placed on establishing a technology strategy for development of products/services to enhance a particular firm's business competitiveness.

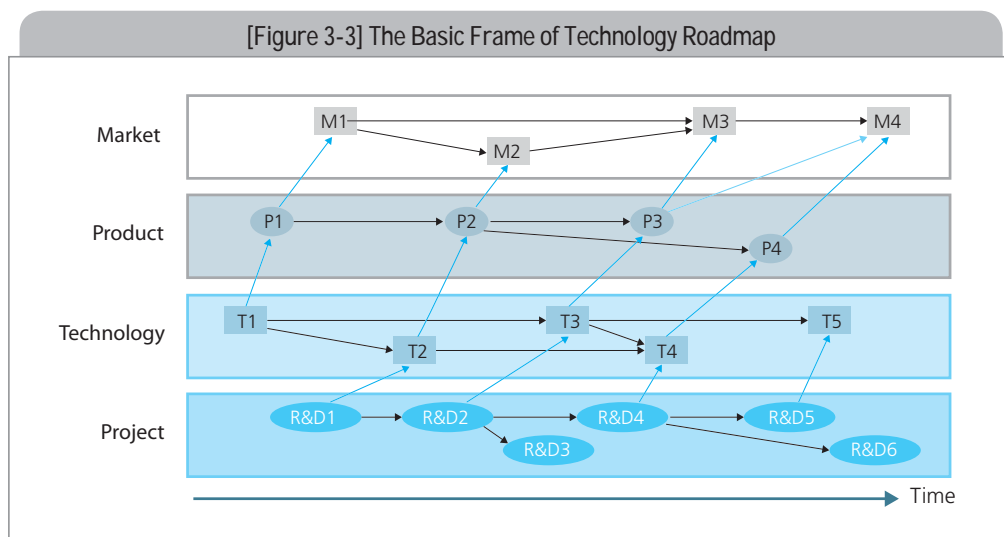
The concept and outcome of the technology roadmap are easy to understand. However, there are a lot of resources, manpower, complicated information required in order to systematically and strategically plan a project. Therefore, institutions without enough skills, capacity and experiences have a hard time to take their first steps.

Despite the vast difference in establishment and utilization of TRM between the public and private sectors, the process of technology roadmapping is very similar. Because they have similar purpose of establishing and using TRM.

2.3.1. General Process of Technology Roadmapping

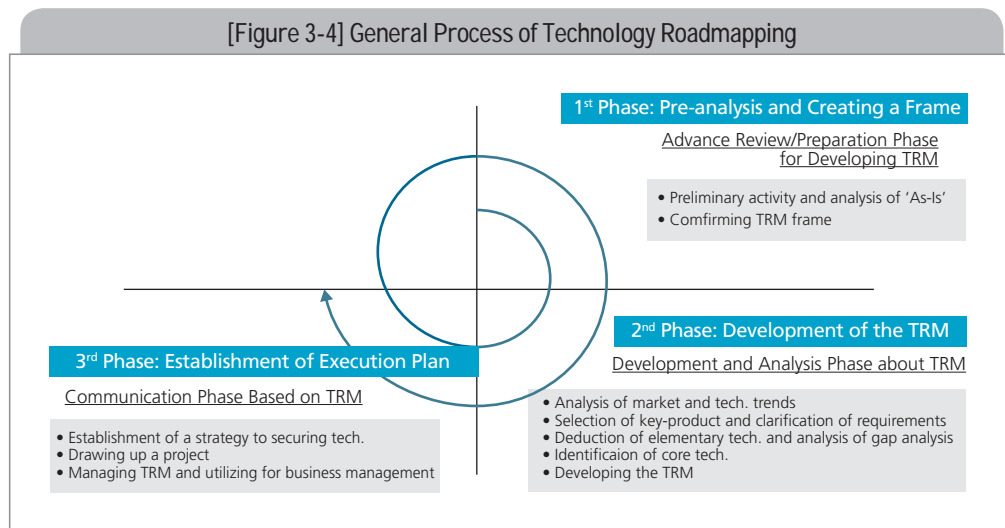
Although the process of technology roadmapping can be different according to the purpose and scope of use, the framework of market-products/services-technology R&D projects is used by default. In other words, TRM is a technology development plan that identifies the technologies needed to develop product/service that can meet the current or future market demands and provides a competitive edge over the competition.

Therefore, technology roadmapping begins with products and services that can meet the market's current or future demands and is developed in order of technologies and R&D projects to implement.



Source: TechnoValue (2012).

The technology roadmapping generally consists of 3 phases: preliminary activity, roadmapping and follow-up activity. Each phase have 3 to 5 steps with specific activities. Technology roadmapping process is represented as a spiral model indicating that TRM development process is not a temporary but a continuous process. In practice, the TRM development process should be constantly modified in accordance with changes in the market and technology environment.

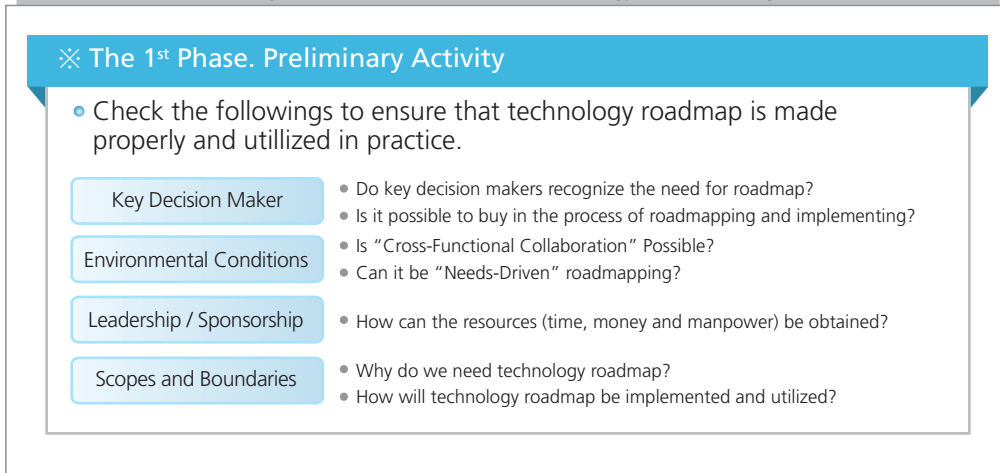


Source: TechnoValue (2012).

2.3.2. Process & Methodology of Technology Roadmapping

Preliminary activity, the first phase, is defined as a step of developing a promotion plan for successful roadmapping by visioning and organizing a working group. In the preliminary preparation phase, scope and duration of the technology roadmapping, composition of participating personnel and working team, and workshop are planned. Considering these decision makers, the scope of TRM establishment, environmental factors, etc. are an important factor that will determine goals and types of technology roadmapping. Leadership for deployment and utilization of TRM is of great importance. This is because participation and cooperation of various stakeholders should be guaranteed during the TRM establishment process.

[Figure 3-5] The 1st Phase of Technology Roadmapping

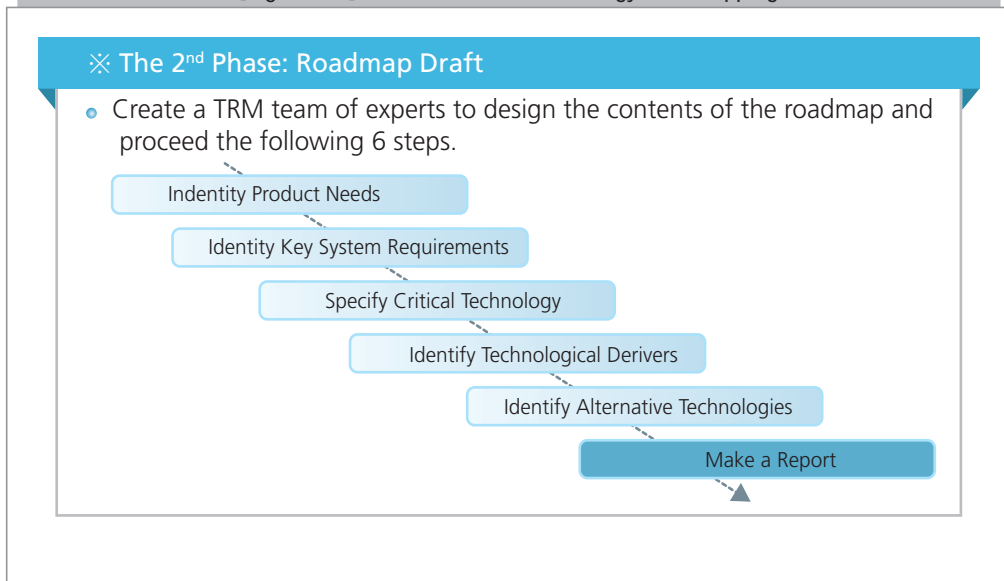


Source: KISTEP (2005).

In the 2nd stage, roadmapping is the phase of developing a TRM based on a systematic environmental analysis of the target market.

First, it is essential to grasp the current or future market needs of the target products/technologies and to analyze the competitive environment of the market and external environment including domestic and global technology development trends. In addition, the company (or the public research institute) will identify its superiority or weakness technology comparing to its competitors by analyzing the level of technology and R&D capabilities of its own. Based on this, future directions in technology development and strategies, including promising products and technologies, core/element technologies and technology development goals, are set. Also a Tech-tree is required to identify core technologies and element technologies in addition to materials, components, manufacturing processes and software. Next, a gap analysis is conducted to identify the level and capabilities of a company compared to competitors in terms of core/element technology. Using the result of the gap analysis, technology development goals to enhance strengths or complement weaknesses are set. Finally, TRM is finalized with measures of technology acquisition considering the importance of technology and the level of competency of the company.

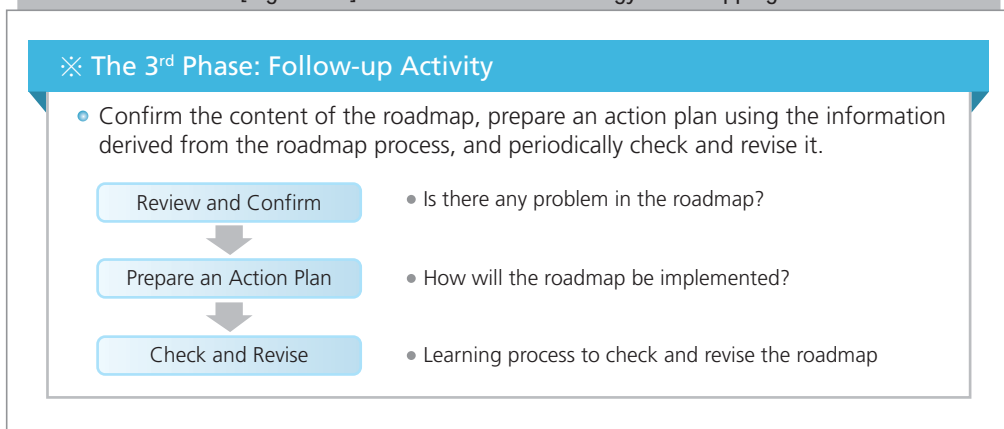
[Figure 3-6] The 2nd Phase of Technology Roadmapping



Source: KISTEP (2005).

The 3rd stage, follow-up activity (action plan), is a step to implement a technology development project according to TRM and produce an action plan including resource allocation, risk-management, etc. Also measures of managing internal organization such as performance evaluation management system should also be established to enhance performance of the TRM. In particular, the TRM at the national level shows a shift in direction of governmental R&D investment so that researchers and related companies get a chance to expand their R&D investment.

[Figure 3-7] The 3rd Phase of Technology Roadmapping



Source: KISTEP (2005).

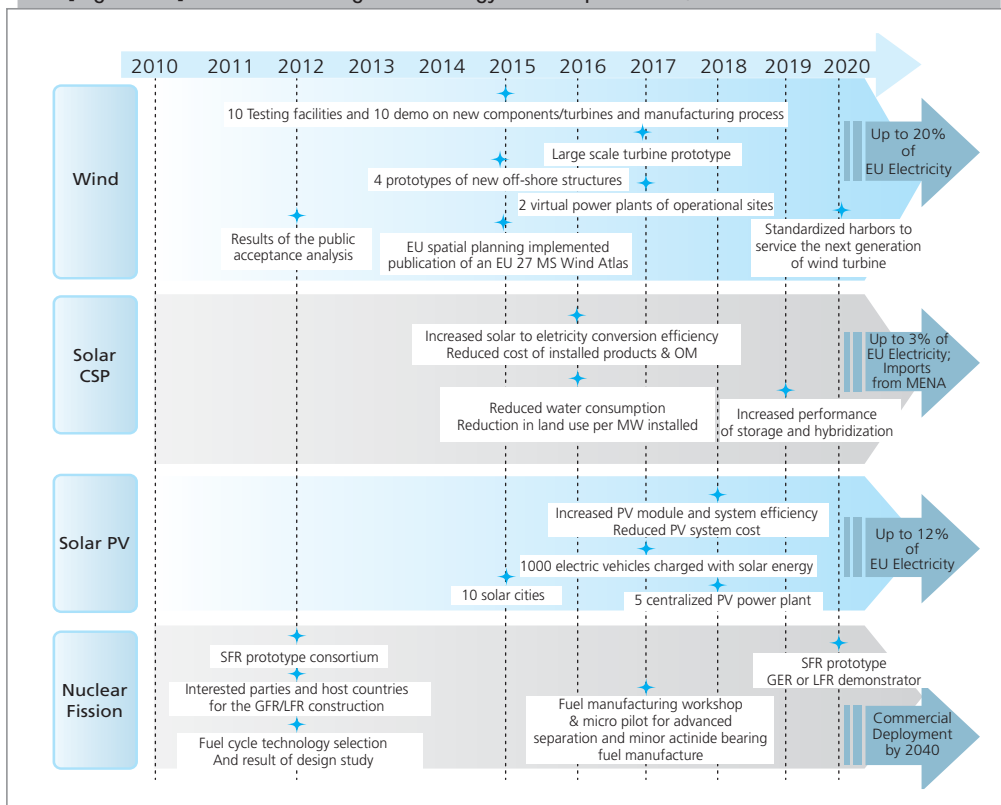
In addition, TRM is the only R&D guideline for SMEs which lack R&D planning capacity. Therefore, it offers open access to link them with public research institutions.

2.4. Global Cases of Technology Roadmapping

2.4.1. EU Energy Technology Roadmap

The European Committee established the Strategic Energy Technology Plan (SET) in 2007. In December 2010, the EU established the Energy Technology Roadmap including 7 industrial infrastructure fields, including solar energy, bioenergy, wind energy, carbon capture and storage, smart grids, smart cities, and sustainable nuclear fission. Specifically, roadmaps for these 7 energy sectors have been constructed and managed separately by the governmental bodies of major countries as well as research institutions and energy companies in the EU. After establishing overall energy industry TRM in 2010, it made updates in 2014 and 2016, focusing on changes in technologies, market environment and energy policy of the EU among others.

[Figure 3-8] Industrial Strategic Technology Roadmap for Wind, Solar and Nuclear Fission



Source: European Commission (2009).

Through sharing TRM with companies and researchers, EU aimed at solving energy problems and raising competitive energy industries with member countries in the context of the EU. It shows the main targets of energy policy and strategic R&D items so it provides the guidelines for R&D investment to researchers and companies in the EU.

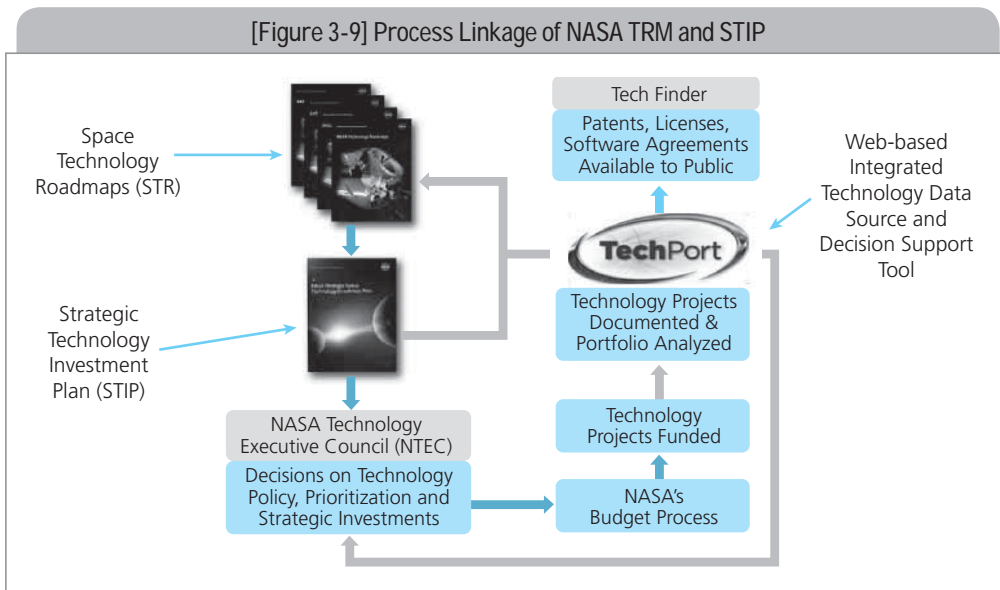
2.4.2. NASA Technology Roadmap

NASA announced an integrated technology roadmap on aviation/space, energy, robots, and automation systems in 2015, which is an updated version of the 2012 technology roadmap. As such, NASA regularly updates the technology roadmap and announces it.

The Technology Roadmap is established under the initiative of NASA's OCT (Office of the Chief Technologist). The OCT provides the strategy and leadership that integrates NASA's technology development and open innovation activities. The office plays a technology coordinator at the agency-level. Through cooperation with other government agencies, external organizations and experts, the OCT continuously develops and extends the following 3 technical planning activities.

- NASA Space Technology Roadmaps
- NASA Strategic Space Technology Investment Plan (STIP)
- TechPort Database

NASA established "NASA Space Technology Roadmaps" while operating TechPort, which is the internal/external technology DB. Based on this, it plays the role of linking with the R&D investment plan, the "Strategic Technology Investment Plans (STIP)".



Source: NASA Website.

The 2015 NASA Technology Roadmaps include 15 distinctive Technology Area (TA) roadmaps and it was made by the OCT. The following table shows the Technology Area.

<Table 3-1> Technology Areas of NASA Technology Roadmap

Technology Area	Contents
TA1	Launch Propulsion Systems
TA2	In-space Propulsion Technologies
TA3	Space Power and Energy Storage
TA4	Robotics and Autonomous Systems
TA5	Communications, Navigation, Orbital Debris Tracking and Characterization Systems
TA6	Human Health, Life Support and Habitation Systems
TA7	Human Exploration Destination Systems
TA8	Science Instruments, Observatories and Sensor Systems
TA9	Entry, Descent and Landing Systems
TA10	Nanotechnology
TA11	Modeling, Simulation, Information Technology and Processing
TA12	Materials, Structures, Mechanical Systems and Manufacturing
TA13	Ground and Launch Systems
TA14	Thermal Management Systems
TA15	Aeronautics

Source: NASA Website.

2.4.3. Core Technology Platform of 3M

3M developed a variety of innovative products which used various combinations of 45 core technologies called Core Technology Platform (CTP). The CTP is composed of the 45 core technologies, including materials, processes, software as well as application technologies, and 3M is boosting its global competitiveness through its combination of these key technologies in developing new products. For example, the Post-it by 3M was developed by combining adhesive technology and thin-film coating technology. 3M has invested continuously on R&D for the 45 core technologies using TRM. However, the process and output are not opened to the public, and therefore, it is impossible to know the details. However, the 3M case gives us lessons not only for Mexico but also for various government R&D. It follows a value chain path of public R&D focusing on accountability. Because emerging/edge technologies are hard to develop independently by an individual private company so these technologies are developed from government R&D and the technologies are seldom distributed to the private sector.

[Figure 3-10] Core Technology Platform of 3M

Type	Material		Processing			Software, Analysis and Control		Application		BIO	
Core Tech.	<u>Ad</u> Adhesives	<u>Ab</u> Abrasives	[3M] 45 Core Technology Platforms						<u>Ac</u> Acoustics	<u>Im</u> Imaging	<u>Bi</u> Biotech
	<u>Am</u> Advanced Materials	<u>Ce</u> Ceramics							<u>Di</u> Display	<u>Lm</u> Light Mgmt	<u>Dd</u> Drug Delivery
	<u>Fi</u> Films	<u>Do</u> Dental & Orthodontic Materials							<u>Ec</u> Energy Components	<u>Mf</u> Mechanical Fasteners	<u>Md</u> Medical Data Mgmt
	<u>Fl</u> Fluoro-Materials	<u>Em</u> Electronic Materials	<u>Mr</u> Micro-Replication	<u>Pd</u> Particle & Dispersion Processing	<u>Rp</u> Radiation Processing	<u>We</u> Accelerated Weathering	<u>In</u> Inspection & Measurement	<u>Fs</u> Filtration, Separation, Purification	<u>Op</u> Opto-electronics	<u>Mi</u> Microbial Detection & Control	
	<u>Nw</u> Nonwoven Materials	<u>Me</u> Metal Matrix Composites	<u>Mo</u> Molding	<u>Pm</u> Polymer Melt Processing	<u>Su</u> Surface Modification	<u>An</u> Analytical	<u>Is</u> Integrated System & Design	<u>Fc</u> Flexible Converting & Packaging	<u>Po</u> Porous Materials & Membranes	<u>Se</u> Sensors	
	<u>Sm</u> Specialty Materials	<u>Nt</u> Nano-Technology	<u>Pe</u> Predictive Engineering & Modeling	<u>Pp</u> Precision Processing	<u>Vp</u> Vapor Processing	<u>As</u> Application Software	<u>Pr</u> Process Design & Control	<u>Fe</u> Flexible Electronics	<u>Tt</u> Track and Trace	<u>Wo</u> Wound Mgmt	

Source: 3M US Website.

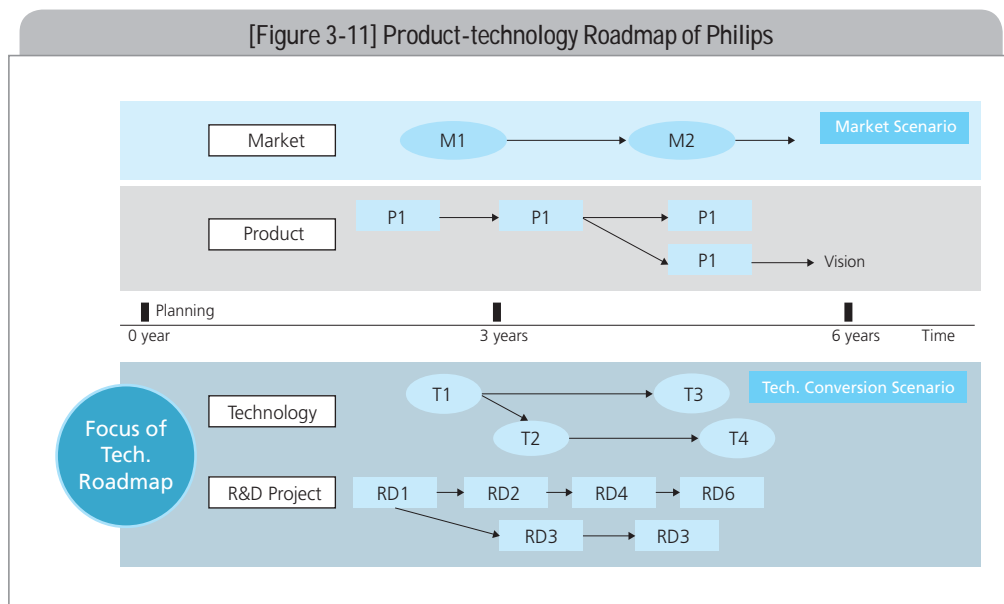
2.4.4. Product-Technology Roadmap of Philips

Philips was required establish a strategic development system from a mid- to long-term perspective to respond to changes in the business environment, such as an increase in consumer demand, shorter product lifecycle and rapidly changing technology.

Accordingly, as a tool for developing new businesses from a long-term perspective based on close cooperation by all departments, the company has developed and operated the Product-Technology Roadmap.

The Philips' Product-Technology Roadmap is aimed at systematically linking business strategies with technology strategies and integrating them, as well as improving the early stages of product development (the idea stage), and presenting the product and its production focus over the next 5 years.

A key characteristic of the Philips roadmap process is its focus on teamwork, integrated engagement and smooth communication. This process enables Philips to share product strategy and technology strategy, and to participate in the products-technology planning and Vision Setup process. The roadmap creation process utilizes a variety of techniques, such as maturity charts, quality function deployments, and technology innovation metrics, to help build an objective and strategic roadmap.



Source: Compiled by author.

These Philips' product-technology roadmaps provide a clearer understanding of how to enter a critical market with the right product in time. In addition, it is used to improve the process of integrating pan-volume books needed to create new products.

3. Current State of R&D Planning and Tech. Roadmapping in Mexico & IPN¹⁾

3.1. General Overview about R&D Planning in Mexico

3.1.1. Science and Technology Law (LCyT)

The goals of the Science and Technology Law aims to regulate the support that the Federal Government is obliged to grant in order to promote, strengthen, develop and consolidate scientific research, technological development and innovation in general in the country; to determine the instruments through which the federal government will comply with the obligation to support scientific research, technological development and innovation; and to establish mechanisms for coordination of actions between the agencies and entities of the Federal Public Administration and other institutions involved in the definition of policies and programs in the field of scientific, technological and innovation development, or directly carrying out activities of this type.

Furthermore, the LCyT establishes the mechanisms and instances of coordination of entities under the federal government with the other public sector and social and private sectors as well. In addition, it promotes links and participation of the scientific and academic community of higher education institutions. By doing so, it aims to generate and formulate the policies of promoting, diffusing, developing and applying science, technology and innovation. And it attempts to train professionals in the area and link the education sector with productive and service sector in the field of scientific research, technological development and innovation.

In June 5, 2002 the LCyT was promulgated. As mentioned before, this Law created most of the main actors in the Innovation System of Mexico: the General Council for Scientific Research, Technological Development and Innovation and the Science and Technology Advisory Forum, as well as restructured CONACYT, established in 1970. PECITI was also established based on the guidelines of the National Development Plan (NDP). PECITI is the framework document and planning instrument for the Mexican Science Technology and Innovation policy (Rosanis *et al.* 2015).

1) The main contents of Session 3 were excerpted among the reports written by a local consultant.

In 2009, an amendment to the Law introduced changes in the governance with the creation of the Inter-sectoral Innovation Committee. The aim was to develop a more comprehensive approach to innovation by fostering greater coordination at the ministry level. A year later, the Committee Specialized in Science, Technology and Innovation was created to improve information in the field. **And the main coordinator of the innovation system is CONACYT.**

In this sense, it is important to highlight the amendments made to the Law in 2015, in relation to commercialization of technology as follows²⁾:

- Article 40 bis: “Educational institutions, public research centers and public administration entities that carry out scientific research, technological development and innovation activities **may create linking and knowledge transfer units wherein technological developments and innovations made in the same can be incorporated**, as well as the personnel of said educational institutions, centers and entities.”
- “These units may be constituted” by the legal figure that best suits their objectives, in the terms of the applicable provisions, as long as they are not constituted as parastatal entities and may hire project staff from academic institutions, centers and entities subject to disposed to articles 51 and 56 of this Law.”
- “The units referred to in this article, in no case may finance their operating expenses with public resources. The public resources that, in terms of this Law, the units will have to be used exclusively to generate and execute projects related to technological development and innovation and to promote their linkage with the sectors of economic activity.”
- Article 50: “Educational institutions, public research centers and public administration entities that carry out scientific research, technological development and innovation activities will jointly **promote the creation of strategic partnerships, technological alliances, consortia, linking units with the public and private sectors and knowledge transfer, new technology-based private companies** and regional innovation networks in which technological developments and innovations will be incorporated in these educational institutions, centers and entities, as well as researchers, academics and specialized personnel assigned to the institution, center or entity, participating in the substantive part of the project.”

As described above, the LCyT is now identifying the necessity to provide regulation for creating technology-based companies by technology development, mostly, in the public research centers and universities. However, this is a late recognition compared to other reforms to public laws like Technology Transfer Commercialization Act in the U.S. (2000).

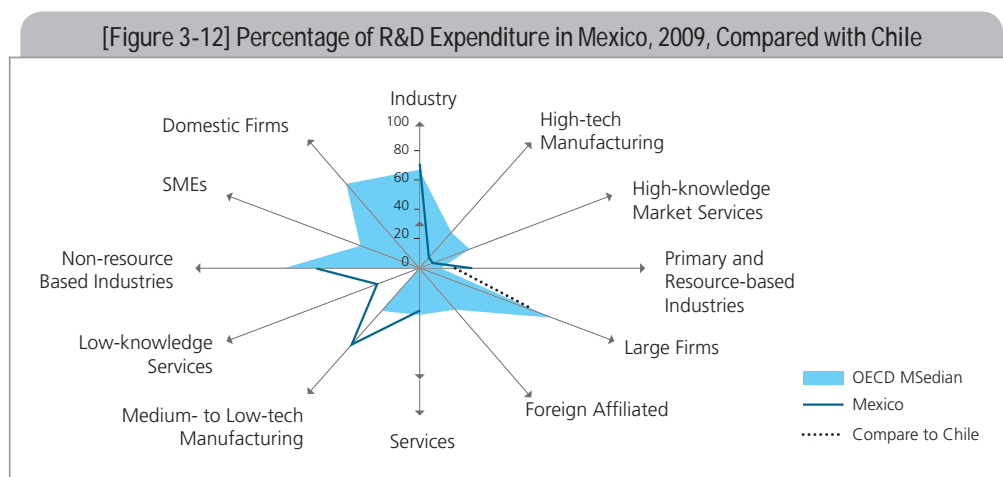
2) Science and Technology Law in the Mexico (2015).

3.1.2. The Special Program for Science, Technology and Innovation 2014-2018 (PECITI)

The PECITI, which was also established based on the guidelines of the National Development Plan, is the framework document and planning **instrument for the Mexican science technology and innovation policy**.

In first place, the PECITI has the purpose of guiding the country's transition to a knowledge-based economy. First of all, the need to achieve a national investment in scientific research and experimental development that represents **at least 1% of GDP**, considered as the turning point for sustainable development. The training of national, regional and local capabilities of human capital and infrastructure are also taken into account as well as institutional strengthening in the local context with the purpose of achieving balanced regional development. Besides, it is also explicit the need to take advantage of the knowledge created through the linkage of the various actors, which is particularly lagging behind in Mexico.

Bearing in mind the above, the OECD (2012) establishes that the share of the business sector in total R&D performance rose significantly from 2000 to 2006 but then declined from 0.49% to 0.42% in 2010. Despite various support measures to boost business R&D investment, the overall results have proved disappointing in terms of increased expenditure and innovative outputs as measured by patent applications. **OECD highlighted an innovation policy mix unbalanced in favour of indirect support and a multiplicity of poorly endowed programs**. This has recently changed: the tax incentive was eliminated in 2009, and public funding to the business sector is now direct and competitive (see Figure 3-12).



Source: OECD (2016).

A new R&D and innovation stimulus package was introduced in 2009 with a strong emphasis on SMEs and links with research institutes. New innovation programs financed by the Ministry of Economy have been introduced.

According to Article 21 of the LCyT, the formulation of the Special Program is the responsibility of the CONACYT, which must be based on the proposals presented by the agencies and entities of the Federal Public Administration that supports or carries out scientific research, technological development, and innovation. In the elaboration of the PECITI, proposals from the scientific, academic, technological, and productive sector communities, convened by the Scientific and Technological Advisory Forum (FCCyT, 2016) were also taken into account. By law, it corresponds to the General Council of Scientific Research, Technological Development and Innovation, the governing body of the national policy on the matter of its approval and subsequent follow-up. It is the responsibility of CONACYT to coordinate instrument allocation.

Vision and Mission of PECITI

- Vision to 2038
 - *“Mexico is a global and prominent player in the knowledge economy, which has reached sustainable levels of competitiveness and productivity.”*
- Vision to 2018
 - *“Mexico stands out for having achieved a significant increase in its levels of productivity and competitiveness to be on a clear path to a knowledge-based economy. The fulfillment of the NDP, through the sum of the efforts of all National Science, Technology and Innovation System (SNCTI) actors, laid the foundations for the generation of capabilities that have led it to move to the knowledge economy.”*
- Mission (2014-2018)
 - *“Making knowledge and innovation a fundamental lever for the sustainable economic growth of Mexico, which favors human development, enables greater social justice, consolidates democracy and peace, and strengthens national sovereignty.”*

To achieve the vision in the medium and long terms, Mexico requires going through 4 stages, whose progress will be measured with the indicator that is used internationally: the Research and Development expenditure (GIDE) as a percentage of GDP (see Table 3-2). Making the Science, Technology and Innovation (CTI) focus on solving the problems of the present, and in particular the future of Mexico.

The 4 stages are:

- **Strengthening and Coordination of CTI Capabilities:** To promote and consolidate CTI capabilities, transform the institutional environment and

consolidate a significant segment of innovative companies (2013-2018).

- **Takeoff:** Enhance CTI capabilities oriented towards strategic sectors and social needs, and accelerate innovation (2019-2024).
- **Competitive Consolidation:** Strengthen the financing of the business sector (2025-2030).
- **Maturity:** The private sector performs the largest financing in R&D (2031-2038).

(Table 3-2) Federal Expenditure in STI in 2012

Activity	Millions of MXN	Millions of USD ¹⁾	Percentage by Activity
Scientific Research and Experimental Development	39,474	2,610	63
Postgraduate Education	13,894	919	22.2
Scientific Services	7,075	468	11.3
Innovation	2,228	147	3.5
Total	62,671	4,144	100

Note: 1) Conversion based on an Exchange rate of \$15.12 MXN per 1 USD.

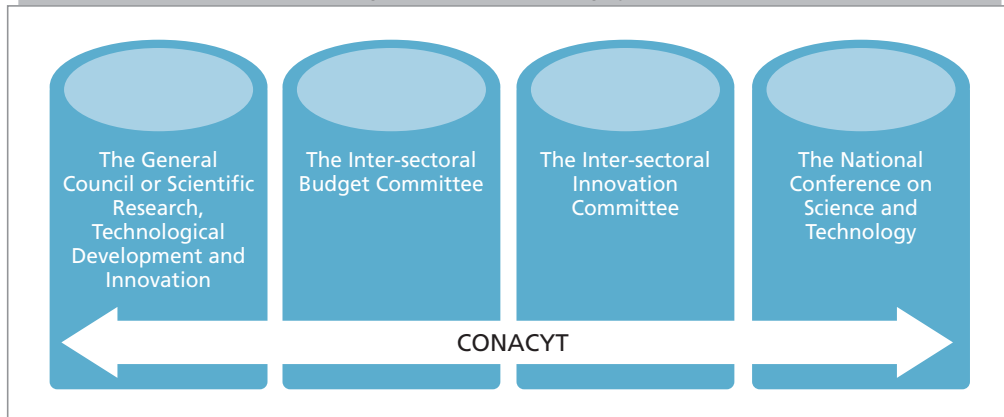
Source: CONACYT (2013).

3.2. Governance of R&D Planning in the Mexican Government and IPN

3.2.1. R&D Planning Governance at National Level

Based on the 2002 Science and Technology Law, the main actors in charge of the orientation of the innovation system in Mexico are as follows.

[Figure 3-13] STI Planning System



Source: Rosanis & Casanova (2015).

As previously stated, The CONACYT is responsible for articulating the Mexican government's public policies concerning scientific research, technological development and innovation. CONACYT was restructured in 2002, before it was part of the Ministry of Education and it is now an autonomous body within the Executive branch.

The General Council is a high-level scientific advisory body that was created in 2002 to help set the national science and innovation policy. The President of Mexico presides this Council, the CONACYT is the Executive Secretary and among the members are the Foreign Affairs, Energy, Economy, Rural Development, Education and Health Ministers, the Director of CONACYT, the coordinator of the Science and Technology Advisory Forum, the President of the Mexican Academy of Sciences, a representative of the National Conference on Science and Technology, 3 representatives of the productive sector that have coverage and national representation, a representative of the Public Research System and the Executive General Secretary of the National Association of Universities and Higher Education Institutions.

The Inter-sectoral Budget Committee is coordinated by the Ministry of Finance and Public Credit (SHCP by its Spanish acronym) and the Director of CONACYT, and reviews the correspondence of the programs with the budget.

The Inter-Sectoral Innovation Committee is presided by the Minister of Economy, the Director of CONACYT as the Vice-President and the Minister of Education are responsible for approving the innovation program of the General Council. The National Conference on Science and Technology is entrusted with the coordination of federal and state STI policies and is formed by CONACYT and the representatives of the State governments in science, technology and innovation. With the changes occurred in CONACYT, policy is now directed to new programs/funds not only for basic science but technological development (see Table 3-3).

〈Table 3-3〉 Scope of the Main Programs for R&D

Program / Fund	Fundamental Research	Applied Research	Technological Development	Technology Transfer	Commercialization	Linking Agent
Sectorial Funds						
Minister of Education -CONACYT fund						
Mixed Funds (State and Federal Government)						
Innovation Fund						
Thematic Networks						
International Cooperation Funds						

Source: CONACYT (2017).

In the case of thematic networks, Mexico has placed emphasis on nanotechnologies and biotechnologies, areas in which it currently has no Revealed Technology Advantage (RTA), through the development of 2 thematic networks (the Network for Agriculture and Food Biotechnology and a network dedicated to nanosciences and nanotechnologies). CONACYT has also signed bilateral agreements with Argentina and Brazil for the establishment of virtual centers in both fields.

On the other hand, development of industry-science linkages has been included as a secondary objective for project selection in a number of innovation support programs. Public-private partnerships are being encouraged by Strategic Alliances and Innovation Networks for Competitiveness (AERIs by its Spanish acronym). Furthermore, support for the development of Technology Transfer Offices (TTOs) aims to accelerate the commercialization of research outcomes and facilitate the creation of spin-offs.

Historically in Mexico, as in most Latin American countries, there are strong ties between education and research institutions but limited ties to the industry. While CONACYT has increased the number of researchers in higher education and research institutions, it has been weak at connecting research to the needs of the domestic productive sector (Rosanis & Casanova, 2015).

CONACYT has established a National Registry of Scientific and Technological Institutions and Businesses (RENIECYT by its Spanish acronym) to identify the institutions, centers, and businesses, among others, that participate in scientific and technological activities. In 2014, there were 6,889 registered individuals and corporations.

In this sense, the business accounts for 72.9% of RENICYT and it consists of micro-sized (38.7%), small-sized (32.4%), medium-sized (16%) and large-sized (12.7%) while 0.03% is not classified. In 2009, an innovation stimulus package was introduced to stimulate private investment in R&D and innovation via subsidies that partially cover the costs of technological innovation projects focused on SME's and projects that link businesses with academia. In 2012 a seed fund for investment in high-tech startups was established by National Financial (NAFIN by its Spanish acronym).³⁾

Moreover, with regards to the private sector, although there are incipient innovations processes, the data indicates the extremely low expenditure on R&D. Thus, **the private sector is not a relevant actor and its interaction with the universities is weak.** More incentives should be introduced to reverse this situation and increase the role of the private sector in the innovation system of Mexico as well as the linkages with the research centers and educational institutions (Rosanis & Casanova 2015). However, the resilience of Mexican entrepreneurs is evident. In adverse conditions and against all odds, they began to innovate.

3.2.2. R&D Planning System & Departments in IPN⁴⁾

The planning in the Institute is the one that identifies the needs of the organization, its reason to be and its objectives to later orient resources and activities towards the achievement of the vision through strategies and tactics of long-, mid- and short-terms.

The planning and setting activities of IPN are done through 3 principal programs.

- The Institutional Development Program (IDP) establishes the participation of IPN in the fulfillment of the national and sectoral objectives and goals. It has its basis in accordance with 3 principal instruments of the National Development Plan, the sectorial program and the PECITI. Through its structural correlation and functional alignment, it proposes action frameworks for the institutional task and the definition of commitments for a 6-year period (IPN 2017). IDP is a 3-year program and the most recent version is for period 2015-2018, which should be updated in the first quarter of 2018. Once the IDP is ready, the MTIP is developed.
- The Medium Term Institutional Program (MTIP) is derived from the IDP, as part of the strategic planning process. Its purpose is to focus the tasks of IPN in a concerted and comprehensive manner to conduct academic and administrative management during a 3-year period (IPN 2017). The MTIP, an operative program, gives the alignments, strategies and goals to different activities.

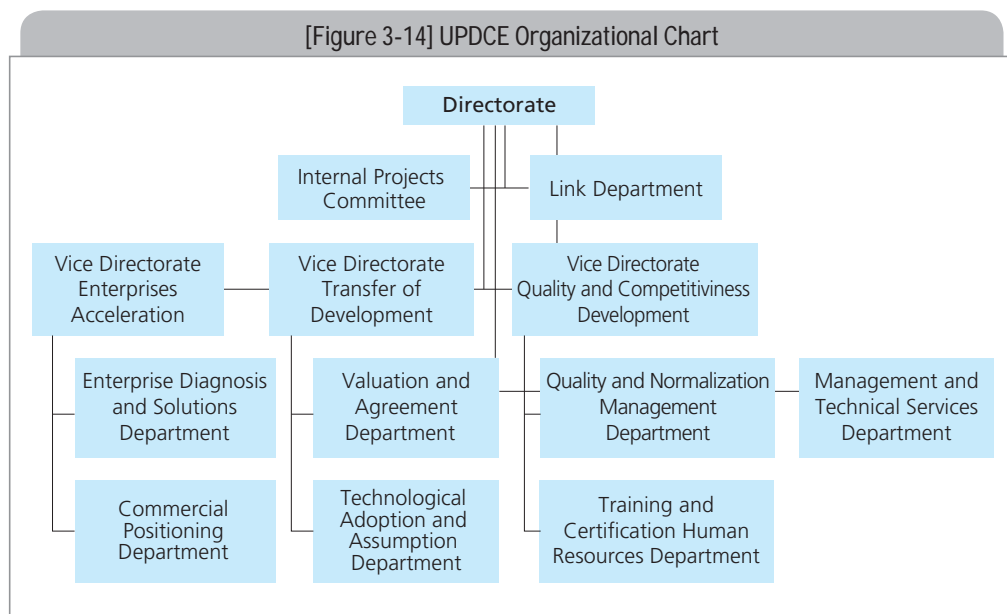
3) "The objectives of NAFIN are to promote the overall development and modernization of the industrial sector with a regional approach; stimulate the development of financial markets and act as financial agent of the Federal Government in the negotiation, contracting and management of credits from abroad."(<https://www.idfc.org>)

4) Permission was granted for reproduction of some sections by the original authors.

- The Medium Term Strategic Development Program (MTSDP) of each polytechnic unit considers the MTIP as a conceptual, methodological and operational reference. Every department or entity of IPN has its own MTSDP and it is aligned with the IDP.

3.2.2.1. Development and Competitiveness Enterprise Polytechnic Unit (UPDCE)

UPDCE objective is to coordinate linking support with environment and to collaborate and articulate institutional capacities to attendant projects which strengthen enterprise development and competitiveness. And it offers technology management, training, consultancy, technology transfer and commercialization and technological services to support progress of enterprise by applying knowledge from different learning environments of the institute.



Source: UPDCE Website.

Human resources who are in the medium and high positions (managers/deputy directors) in UPDCE have careers with a Master degree in business, but not relevant to technology foresight field. So some of them receive a technology management education training, specifically in technology surveillance and competitiveness intelligence which could be useful for employees to understand technology foresight.

On the other hand, to explain other kind of participation of the IPN human resources in technology services of UPDCE is through researchers specialized in innovative fields, so they support technological projects to solve specific problems of enterprises.

Furthermore, IPN has a Knowledge Transfer Office (OTC-IPN) recognized in the call 2017 of Innovation Economical Sectorial Funds of Economy Sector (SE) and CONACYT.

The OTC-IPN supports polytechnic community and the public with general themes of intellectual property, knowledge transfer, specialized consultancy and specialized training. The supports is detailed below.

IP Prosecution Services

- Prior-art search
- Trademarks
- Copyright
- Patent prosecution
- Intellectual property conferences

Courses and Training

- Enterprises acceleration strategies
- Competitive intelligence
- Regulations applying to business

3.2.2.2. TechnoPoli

TechnoPoli articulates with the academic and business sectors by supporting the integration of inter- and multi-disciplinary teams capable of generating innovative projects and technological and social development. And its mission and vision are as below.

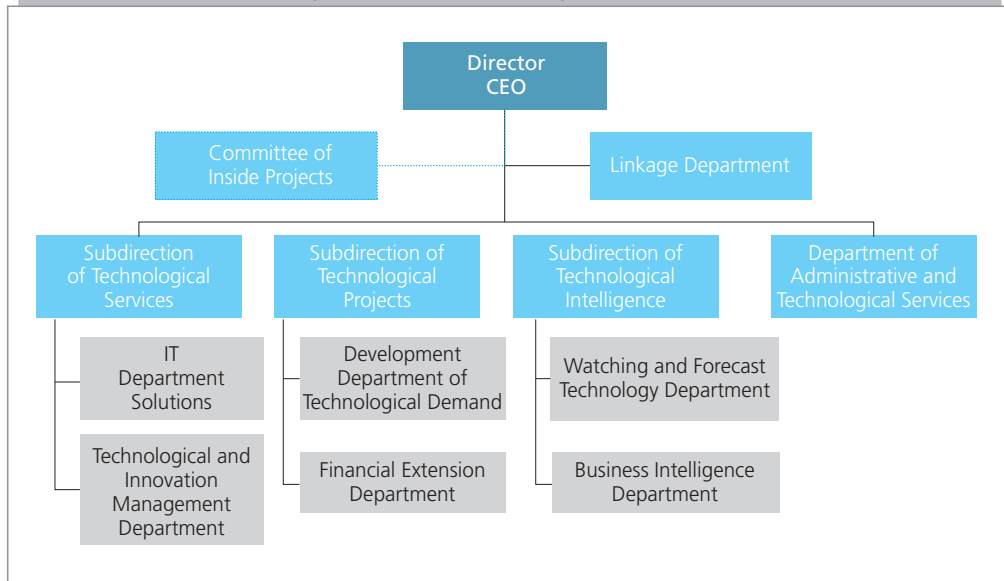
Mission Statement

“The Technological Development Unit, TechnoPoli, contributes to the generation, growth, and consolidation of high impact businesses, by managing the flow of knowledge and technology between the institute, companies, and markets.”

Vision Statement

“TechnoPoli aspires to be the strategic ally of choice for highly competitive companies, through the management of technological services and projects, knowledge transfer and innovation.”

[Figure 3-15] TechnoPoli Organizational Chart



Source: TechnoPoli (2015).

In this sense, as shown in [Figure 3-15], there is a distribution of functions aimed at providing indicators for companies or some units of the IPN and supporting them in carrying out an incipient technological planning. The followings are some core functions of the main departments in TechnoPoli:

Direction

- To make the proposal policy and action projects, goals and necessary instruments
- To contribute to technological and innovation development of the country, by managing the flow of technology between the institute, companies and markets for the creation of technology businesses.
- To articulate the institutional offer of generating applied research, technological development and innovation with the demands of the productive sector and society in order to create a closer relationship and synergy.

Linkage Department

- To participate in the coordination of the necessary actions to contribute to the technological and innovation development of the country by managing the flow of technology between the institute, companies and markets for the creation of technology businesses.
- To carry out the necessary procedures for linking to the inside of the IPN and with other educational institutions and the federal and local governments.
- To evaluate the achievement of the linkage programs.

Department of Administrative and Technical Services

- To participate in coordination of the necessary actions to contribute to the technological and innovation development of the country by managing the flow of technology between the institute, companies and markets for the creation of technology businesses.
- To coordinate the preparation of The MTSDP and the Annual Operating Program, in the same way, to evaluate and supervise the TechnoPoli unit.

IT Department Solutions

- To participate in the coordination of the necessary actions to contribute to the technological and innovation development of the country by managing the flow of technology between the institute, companies and markets for the creation of technology businesses.
- To form sustainable partnerships with the business sector, with the purpose of bringing to society the benefits of developments, research and innovations generated in IPN, particularly in the Software and Hardware Development Center and Digital Art.
- To draw the mechanisms so that the TechnoPoli operates a software development laboratory with the purpose to assist the institute in the adoption of best programming practices software.
- To provide printing service of 3D prototypes and CNC machining to support the polytechnic community and the companies in the design and development of technological prototypes.

Development Department of Technological Demand

- To participate in the coordination of the necessary actions to contribute to the technological and innovation development of the country by managing the flow of technology between the institute, companies and markets for the creation of technology businesses.
- To coordinate the institutional spin-off program with the purpose of supporting academics, researchers, and technologists of the Institute, as a viable outlet to the market for their developments and applied research.

Watching and Forecast Technology Department

- To participate in the coordination of the necessary actions to contribute to the technological and innovation development of the country by managing the flow of technology between the institute, companies and markets for the creation of technology businesses.
- To operate the technological observatory, a tool that serves to determine the international, national and regional trends in economic sectors and technologies of interest to the TechnoPoli unit, companies, IPN and its researchers and technologists.

- To systematize own databases with relevant information of diverse classifications of technologies of interest and with valuable information for the Institute, referring to its academics and technologists located in networks of research and other concentration mechanisms. And to identify the potential collaborators in the development of technological projects among companies and TechnoPoli Unit.

3.2.2.3. Technology-based Business Incubation Center (CIEBT)

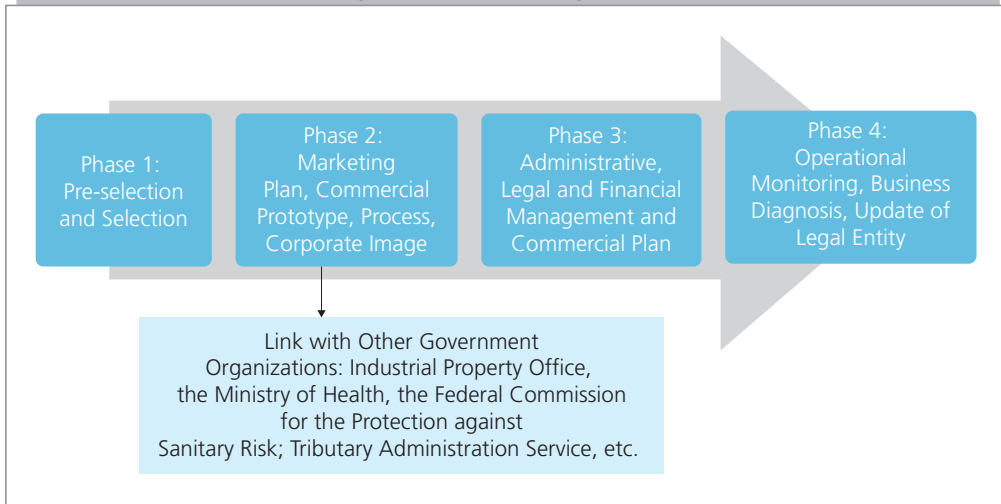
The CIEBT works with the nucleus of business development, where diverse specialists provide advice in various Fields. In addition, in case that technology requires modifications or some technical service, it uses the IPN infrastructure. A central element of the results of the CIEBT is related to the links it maintains with its environment with participation in forums to give feedback on experience and value the importance of the MIR.⁵⁾ At the same time the CIEBT has made it possible to connect financing alternatives (public support, prizes, donations, strategic alliances and the transfer itself of the MIR) to graduated companies, which makes it to play a leading role in the company incubation system in Mexico.

The CIEBT has a team (experts in different fields of business development) with a profile of the experts more in business than academic.

The MIR modifies the classic concept of being a physical space or a shelter for business projects and it became an integral system that contributes to the development of an innovative idea until it is specified in a product or service. These innovative features allow companies to offer greater performance and have a superior efficiency compared to the traditional conception of incubator (see Figure 3-16).

5) The Strong Incubation Model (MIR)

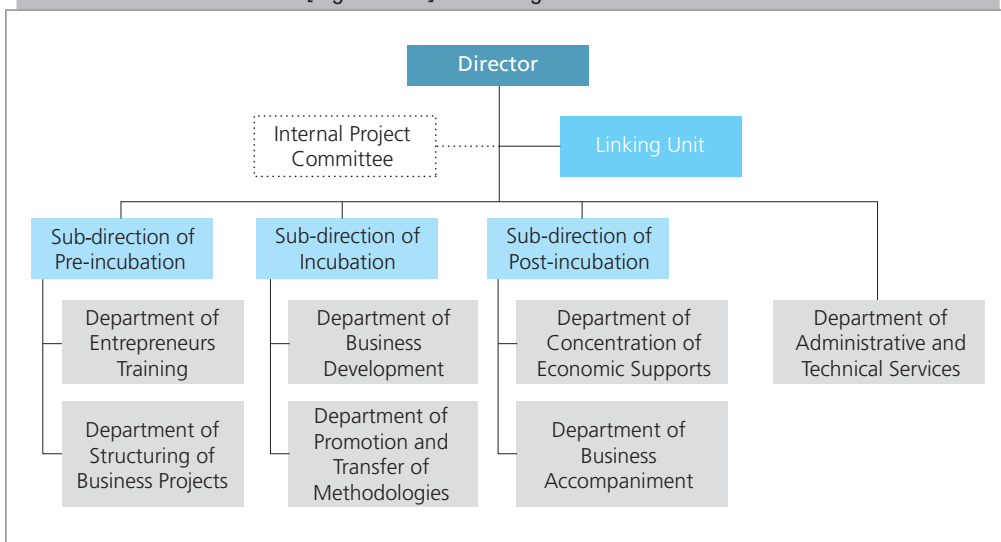
[Figure 3-16] Establishing a Process



Source: Author's elaboration based on Duque 2010.

An essential aspect of the MIR is its transfer to other incubators and together with the performance results of the model. This has contributed to that CIEBT consolidates not only its presence in IPN, but as leader of all incubators in Mexico (Among 220 existing incubators in Mexico, 62% is using MIR) in addition to strong national and foreign institutional links.

[Figure 3-17] CIEBT Organizational Chart



Source: CIEBT (2015).

While there are no human resources who have technology forecast/foresight experience, the profile of the CIEBT is more directed to the business implementation. Here, it is important to mention success stories of SME's which have been supported by the CIEBT.

Promoted by the Consulate of Mexico in Boston and the CIEBT of the IPN, the initiative began with orientation offered to the companies MAVA Technologies and Helten Acoustics. MAVA Technologies develops public safety solutions through the use of unmanned aerial systems or drones; while Helten Acoustics specializes in applied sound engineering to solve problems of noise pollution and the acoustic conditioning of enclosures.

- FIX YOU: Custom pediatric orthopedic helmet for the treatment of cranial, moderate or severe deformities or flattening.
- CHILD ALERT: Low cost portable device for the alert and supervision of minors. It works through a mobile application that receives information issued by the device.
- NAVOA: Organic fertilizer that corrects the acidity of the soil and generates conditions to increase the richness of agricultural soils in order to increase their productivity.
- RENOVART: Herbal oil that facilitates the regeneration of the cartilage of the joints and contributes to improve the quality of life of people suffering from rheumatoid arthritis.
- VOXEL: Design and development of device and software for 3D printing, whose raw material is a commercial resin. It is 3D equipment of national manufacture of high quality and economic prices.

3.3. Case Review in Mexico

There are different government agencies and federal ministries that have made recent efforts to try to establish an exclusive technology roadmap.

Some of these most relevant agencies are ProMexico and FUMEC, while in the public-sector research institutions like CIATEJ-IPN or the Ministry of Energy have also developed technology roadmap each including an analysis with the available information and at the same time proposing routes mostly for the private sector.

It is important to reiterate that the cases that were analyzed and that are apparently the only ones available for Mexico refer exclusively to a current state of emerging technologies and their opportunities for development within the national territory. Moreover, the results of the roadmap are referred to public policy opportunities taking into account social and economic aspects.

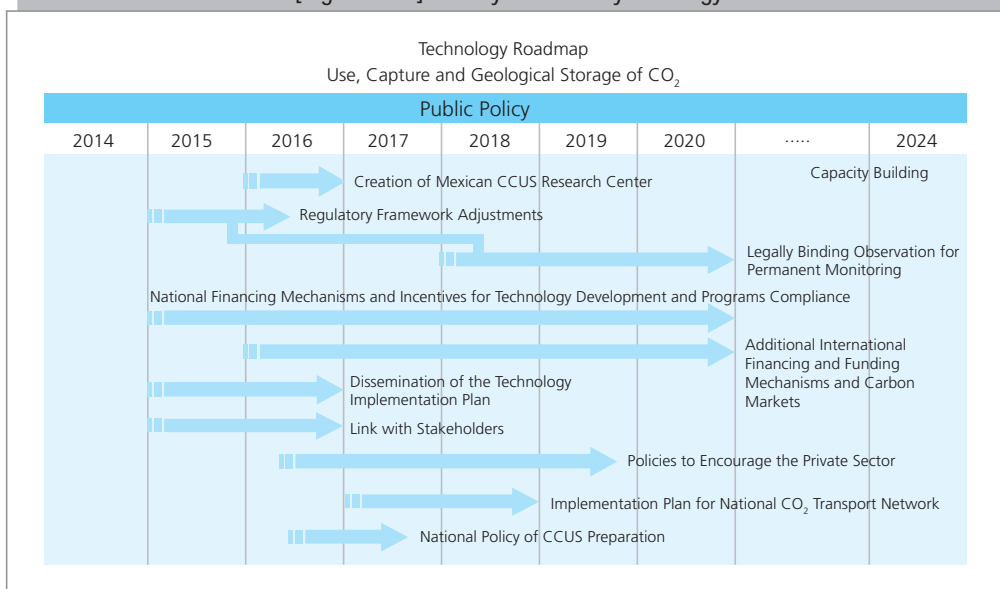
3.3.1. Technology Roadmap in Secretary of Energy

The Ministry of Energy of Mexico (SENER by its Spanish acronym) has initiated an orderly process through a Carbon Capture, Utilization and Storage (CCUS) Technology Roadmap. To achieve the goal, SENER had formed a working group headed by SENER and the Ministry of Environment and Natural Resources (SEMARNAT by its Spanish acronym). Other participants include Mexican Petroleum (PEMX its by Spanish acronym), Federal Electricity Commission (CFE by its Spanish acronym), the National Autonomous University of Mexico (UNAM by its Spanish acronym), IPN and Mario Molina Center.

The TRM was established for the following objectives:

- To design the official roadmap for CCUS from incubation to commercial scale.
- To promote emissions and carbon markets in which Mexico can participate, as well as to facilitate international support.
- To establish a systemic and orderly basis for CCUS resources management and assimilation of technological knowledge.
- To coordinate research activities on CO₂ regulation, capture, transport, use and storage.
- To promote economic and regulatory incentives for technology implementation.

[Figure 3-18] TRM by the Ministry of Energy

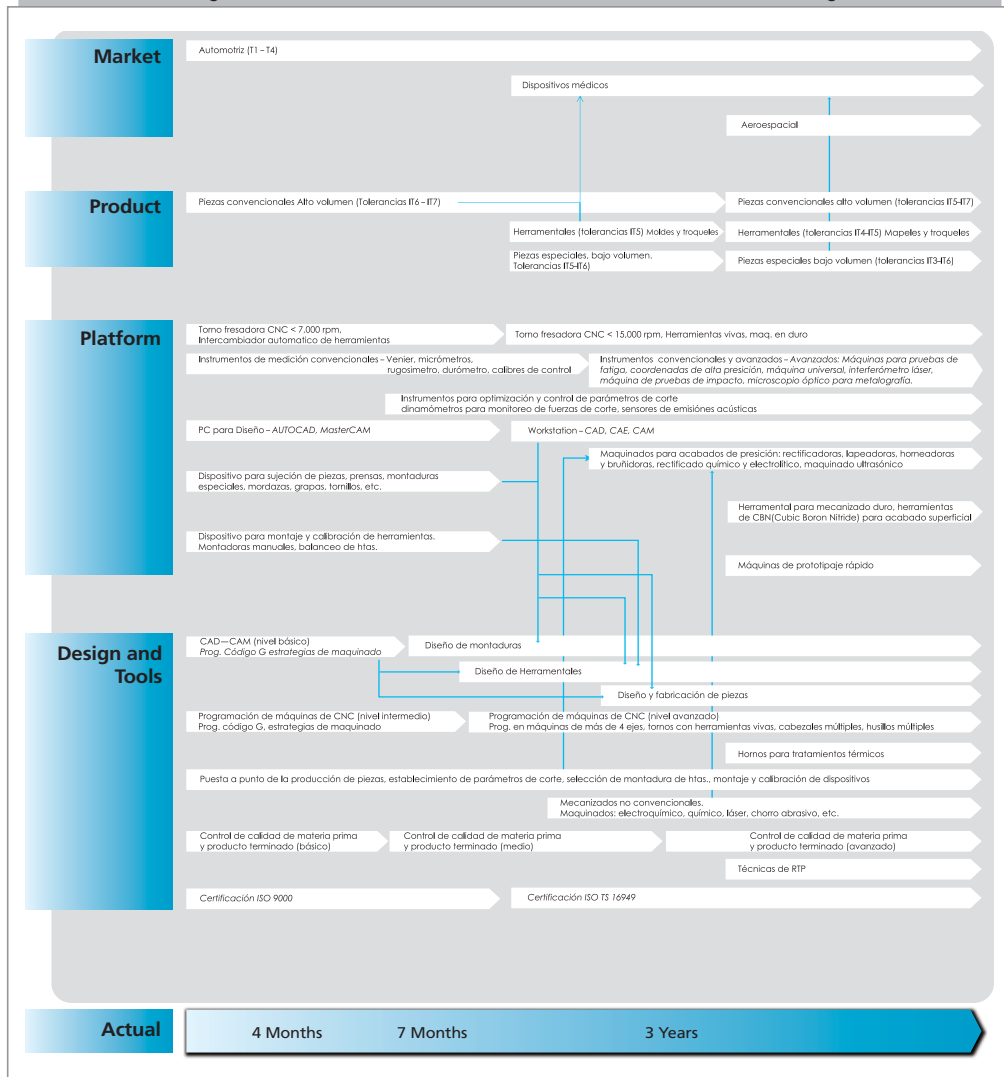


Source: Ministry of Energy (2014).

3.3.2. FUMEC's Automotive Industry Strategy Roadmap

Together with the Mexico-Sate Council of Science and Technology (COMECYT by its Spanish acronym), FUMEC has established a strategic roadmap to strengthen the competitiveness of the automobile industry, one of Mexico's strategic industries. The aim of this work was to analyze the characteristics of existing cars aimed at creating a strategic plan to facilitate auto exports from Mexico. In the course of establishing such a strategic roadmap, major sector-specific technology roadmap, including precision processing, plastic materials, and embedded SW, was developed (FUMEC-COMECYT, 2008).

[Figure 3-19] TRM of FUMEC Related to Precision Heat-Processing



Source: Compiled by author.

4. Korean Experience of Technology Roadmapping

4.1. Overview

In Korea, the R&D planning using technology roadmap has been spreading since the 1990s. It is widely used in public R&D policy establishment, R&D project planning, private companies, and so on. The government is examining the technology roadmapping process and the systematic nature of the results through a preliminary feasibility study for new R&D projects of above KRW 50 billion, which has become an opportunity to expand the base of TRM for relevant researchers and research institutes.

TRM can be divided into public (government and public institute) TRM and private (enterprise) TRM depending on the subject of creation. It can also be classified into product/service technology roadmap and emerging technology roadmap.

Public Sector TRM usually focuses on establishing technology development plans such as establishing investment plans for public research, development projects, technology development plans for each industry sector, and others. TRM in the private sector, on the other hand, commonly focuses on establishing product/service development plans such as identifying the core/element technology for research planning and developing tasks.

4.2. Major Cases of Technology Roadmap in Public Sector

The ministries that conduct R&D projects in Korea establishes and operates technology roadmap as technology development strategies for the specific areas of each ministry. 'The Industrial Technology R&BD Strategy Roadmap' and 'the Energy Technology Roadmap' of the Ministry of Trade, Industry and Energy, 'the SME Technology Roadmap' of the Ministry of the SMEs and Startups, 'the ICT Convergence Technology Roadmap' of the Ministry of Science and ICT would be great examples. Other ministries also establish and operate a technology roadmap periodically every 1 or 2 years in each field like environment, weather, agriculture, land transportation, space/aviation, marine/fishery, culture/contents and so on.

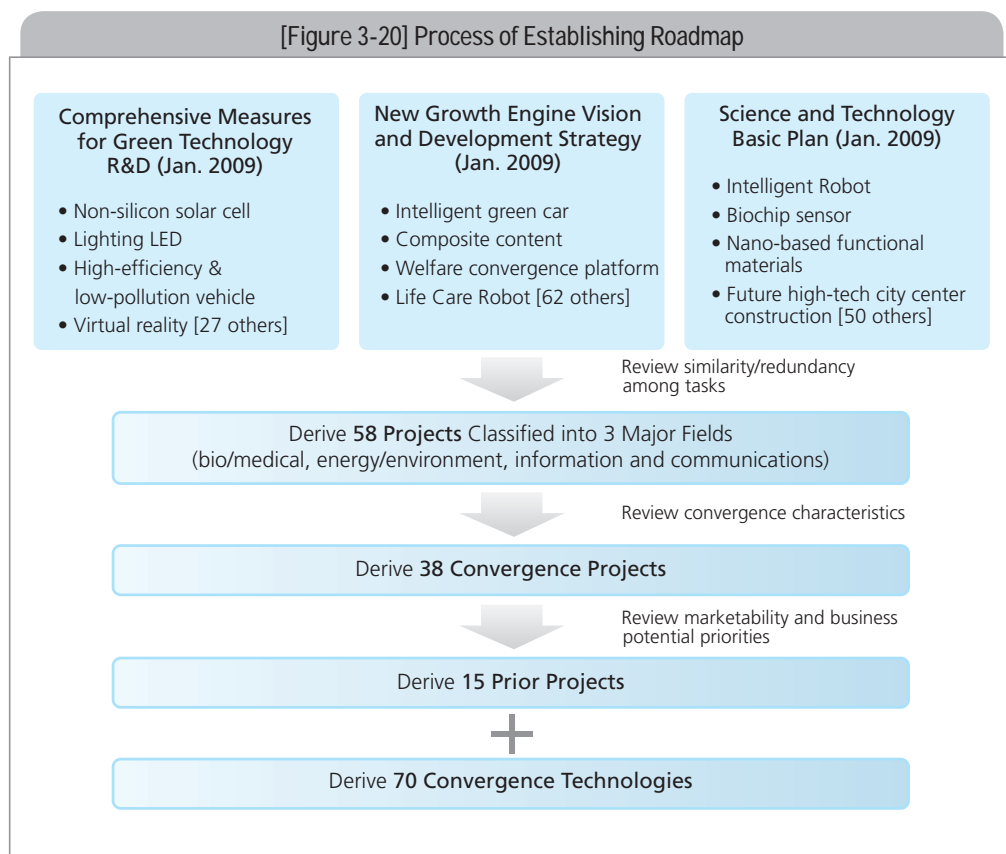
In addition, public organizations and government-funded R&D Institutes such as the Basic Science Research Institute and the Korea Hydro & Nuclear Power Corporation also establish and operate a technology roadmap at the institutional level. Thus, we can assume that the most government institutions and research

institutes that utilize government R&D budgets above a certain level are pursuing R&D investment and activities based on developed technology roadmaps.

In this regard, this study aims to share knowledge from the current practice of technology roadmap in the Korean government/public sector by presenting the NBIC Convergence Technology Roadmap and the industrial technology R&BD strategy roadmap as main examples of Korean government/public sector TRM establishment and operation.

4.2.1. National NBIC Convergence Technology Roadmap

The National NBIC Convergence Technology Roadmap was developed in accordance with the National Convergence Technology Innovation Initiative, and was established and operated in order to assure a nationwide integrated fusion technology acquisition strategy for 5 years from 2009 till 2013 (Ministry of Education and S&T, 2008).



Source: National NBIC Convergence Tech. Map (2008).

It aimed to prevent sporadic investment where R&D investments can be pursued across the ministry's technology/industry sectors due to the characteristic of the convergence technology, and even promote R&D investment efficiency and competitiveness in convergence technology at the national level.

This roadmap was established through the following procedures:

[Step I] Derive 38 Main Convergence Tasks

- Select tasks to be converged through linkage and integration of detailed tasks in major national planning such as the science and technology basic plan.
- Classify the target tasks into 3 major fields (medical, bio/energy, environment/ICT) and derive 38 convergence tasks through analysis of convergence.

[Step II] Select 15 Prior Projects by Prioritizing Each Conversion Tasks

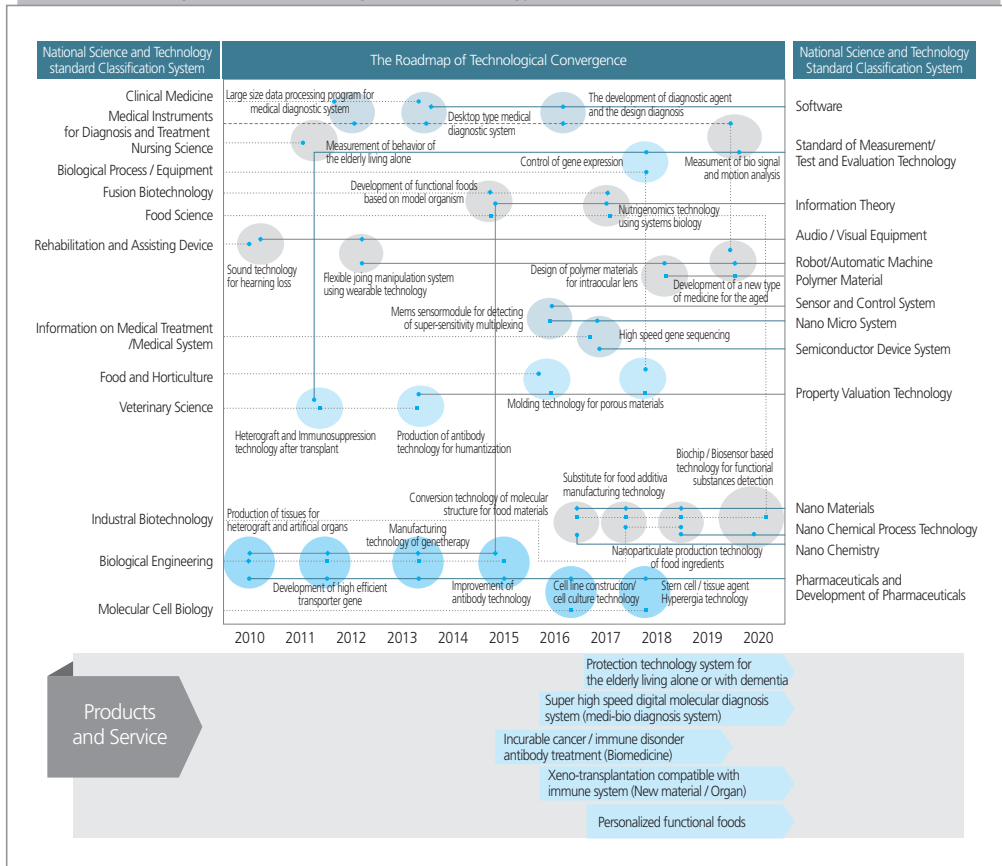
- Comprehensively evaluate the market attractiveness (market size and growth rate) of the 38 main convergence tasks and the possibility of technological success (IP, existing investment performance, etc.).
- Select 15 prior projects based on the evaluation results.

[Step III] Derive Source Conversion Technology and Strategic Products/Services

- Analyze the environment and prospects of the 15 prior projects to derive core technology, and in order to implement the core technology, derive and structure the component technology such as Nano Technology (NT), Information Technology (IT), Bio Technology (BT), Environmental Technology (ET) and Cultural Technology (CT).
- Establish a convergence technology roadmap that includes the structure and development plan between core technology and component technology.
- Provide the strategic product/service and period of implementation expected through the development of source conversion technology and the map the core technology.

Through this process, the following key technologies were developed to establish a roadmap for national convergence technology R&D and to establish the direction of investment as well.

[Figure 3-21] Convergence Technology Roadmap for Medical/Healthcare



Source: National NBIC Convergence Tech. Map (2008).

4.2.2. SMEs Technology Roadmap

The SMEs technology roadmap is a customized technology roadmap for small and medium enterprises, which is established annually and updated by the Ministry of SMEs and Startups. The TRM finds and presents future promising technologies for the major industries suitable for SMEs. Based on the TRM, the government establishes the direction of R&D support projects for SMEs and utilizes it as an investment guideline.

The SMEs technology roadmap aims to develop the future industry of SMEs and presents R&D guidelines by presenting the promising business items and technologies to promote SMEs with weaker R&D capability compared to that of large companies. Based on this, it presents the direction and guidelines of the government investment in SME R&D projects and contributes greatly to strengthen the cooperation between government and SMEs on R&D projects.

The Korean Technology and Information Promotion Agency for SMEs (TIPA), affiliated with the Ministry of SMEs and Startups, is in charge of establishing the SMEs TRM, which is composed of 40 new industries and main industrial fields. Each industry sector planning committee and WGs (Working Groups) are included to establish a technology roadmap.

〈Table 3-4〉 SMEs Technology Roadmap Sector

Data Intelligence	Contents	Mechanical System	Smart Media Device
Knowledge Information Service	Smart Home / Business	Next-generation Car Technology	Aerospace Engineering
Safe Living	Information Security	Robot	Smart Factory
Bio	Smart Health Care	Medical Device	Advanced High Tech Machine Component
New Energy Industry	High-value Products	Cosmetics	Design
Automobile / Railway	Shipbuilding	Plants Engineering	Semiconductor
LED / Light	Display	Home Appliances	Embedded Software
Computing Infrastructure	Next-generation Broadcasting and Communications	Microelectromechanical System	Energy / Environmental System
Ceramic Materials	Chemical and Materials Process Engineering	Textile Industry	Metal Materials
Foundation of Production	Energy Supply	Energy Demand Management	Energy Storage

Source: The SME Technology Roadmap (2016).

The SMEs TRM includes 6 to 7 promising business items by industry sector. Each item consists of domestic and global market trends, analysis of global industrial environment, patents/level of technology, competitiveness analysis of SMEs compared to global leading companies, analysis of industrial ecosystems, etc. Based on these comprehensive analysis, Technology roadmap is presented with short-term (within 3 years) promising technology and element technologies.

〈Table 3-5〉 TRM of the I/O Device Technology for Virtual Reality

Time Span		2017	2018	2019	Final Goal	
Annual Goal		Development of Data I/O Technology	Accuracy Improvement of Input, Processing and Output Efficiency	I/O Device Convergence	Representation Realities of Virtual Reality	
I/O Device Core Technology for Virtual Reality	Location Tracking	Accuracy Improvement of Location Information		User Intention Inference	User Motion and Gesture Recognition Device Development	
	Motion Awareness Module	Gesture Recognition Improvement	Collaborative Device			
	Input Device	Wearable Computer Development	Haptic Technology Development		Wearable Input Device (voice, text) Development	
	Smart Voice Recognition	Smart Voice Recognition Technology	Collaborative Device			
	I/O Data Integration and Processing	Cognitive Data Integration	Data Processing Efficiency Increase	Visual/Auditory/Tactual Feedback	Data Integration Processing Capable of High-level Display	
	HMD	Implementation of High Resolution Display		Various Contents Development		Development of a More Realistic Visual Expression Technology
		Wide Field of View Display	Collaborative Device			
Haptic Interface	Wearable Actuator Development			Realization of Various Tactile Expression	Development of Tactile Expression Technique	
	Collaborative Device					
Technology / Market Needs		User Intention/ Gesture Recognition and Feedback	Virtual Reality like Reality	Tactile Expression Technology	Stability and Immersiveness	

Source: The SME Technology Roadmap (2016).

4.3. Major Cases of Technology Roadmap in Private Sector

Among Korean private companies, Samsung Advanced Institute of Technology first introduced a technology roadmap in 1999 by creating a technology roadmap for semiconductor, display and optical communications. Samsung Advanced Institute of Technology is holding its position as a top-tier company in the fast-changing market and is utilizing its strategic planning capabilities to discover new growth engine. Its main contents are to define the necessary technologies and core technologies for the mid- and long-term (upcoming 5 to 6 years), to provide development strategy and schedule, and to examine uncertainties and risks.

Since then, in the 2000s, use of TRM has spread not only in other affiliates of Samsung, but also in large companies like LG and Hanhwa. It is now spreading to technology-innovative SMEs.

Although application fields, processes and methodologies are different for each company, TRM is developed and operated for innovative products/services for future business development as private companies seek profit. Moreover, compared to the public TRM, it is a common among private companies to utilize TRM in order to establish core technology and technology development plans so that they can develop product/service based on market demands.

In this regard, this study aims to share knowledge on the use of the technology roadmap in the Korean private sector by presenting a case study of the establishment and operation of L Corp's technology roadmap.

- **Case of Establishment of a Technology Roadmap by L Corp.'s Industrial Material Business Division**

L Corp.'s industrial materials business area includes functional films, automobile parts, and interior/exterior construction materials such as windows and flooring. In 2005, L Corp established a technology roadmap for new future business and product development.

L Corp's TRM schematizes element technology and core technology based on the new product roadmap of the industrial materials division. Then, to realize the diagram, it analyzes the gap with competitors using PTH Matrix which helps identify the status of researchers of each core technology. As presented below, L Corp demonstrates an implementation process.

L Corp's industrial materials business TRM has been established for over 10 product groups such as window frame, covering, future housing material, functional films, artificial marble, automobile parts, BIPV, and etc. Each project manager and R&D strategy planning expert formed TF and established TRM. The establishment TRM process has the following 5 steps.

[Step 1] Analysis of Industrial Environment by Product Line

- Establish the direction of product development based on technology trends by product line, market trends, competitive analysis, and its own capability analysis, etc.

[Step 2] Mid-term Product Development Plan

- Based on the previous step, it presents the annual direction of product development by mid-term (within 5 years), and the Product Roadmap (PRM) that defines the characteristics/functions of each future product.

[Step 3] Tech-tree Building

- List up element technologies to implement key functions and performances based on the PRM, and build tech-tree based on that relationship.

[Step 4] Define Core Technologies Through Technical Evaluation and Competitor Gap Analysis

- Define core technologies through technical evaluation and competitor gap analysis for R&D investment.

[Step 5] Establish the Core Technology Platform (CTP)

- Establish CTP for industrial materials business area by clustering of core technologies in each product line.

[Step 6] Establish Technical Improvement Plan and TRM

- After defining target level by key technology, establish the TRM including technology development point, human resources input plan, etc. by using the definition of the target level.

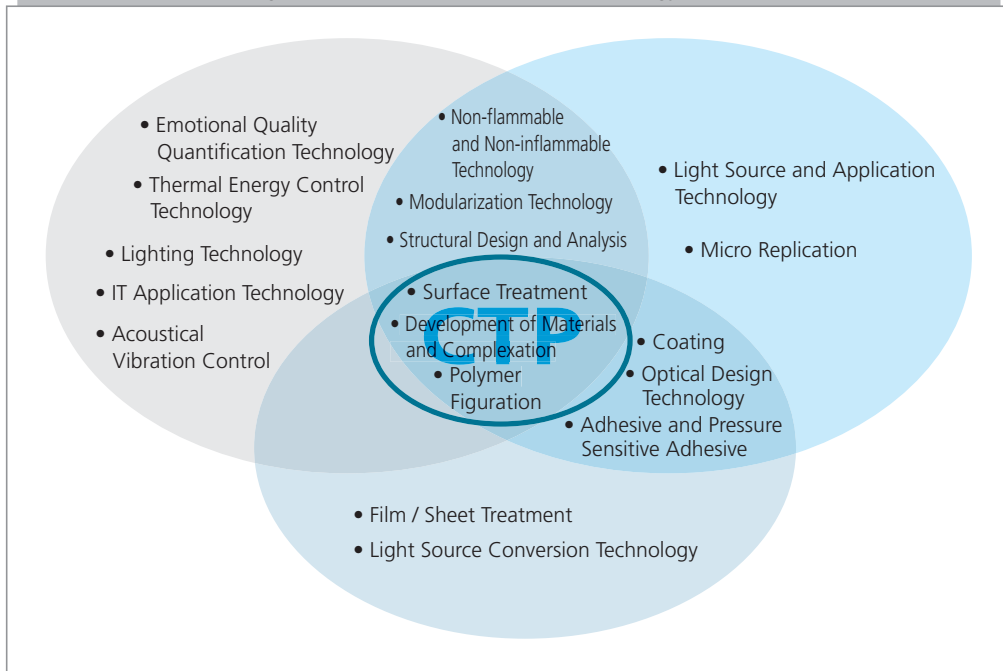
[Figure 3-22] L Corp's TRM

Content of Technology	Acquisition Method	Roadmap				
		2005	2006	2007	2008	2010
Ultrasonic Waves Application Technology	<ul style="list-style-type: none"> • Launching Projects Officially • Industry-university Collaboration Project (Seo-gang Univ.) • Co-work with Installation Company 	Installing Lab Equipment	React of Pressing-out, and Speed Improvement	Finishing Solid Extrusion Pilot	Scale-up and Mass Production	
Polymer Orientation	<ul style="list-style-type: none"> • In-house R&D • Partial Outsourcing • Co-work with Installation Company 	Installing Lab Equipment	Finishing 1 st Pilot (solid type) (draw ratio 3)	Finishing 2 nd Pilot (hollow type) (draw ratio 3)	Product Application and Enlargement of Application Area	
Molding Die Design Technology	<ul style="list-style-type: none"> • Outsourcing • In-house Projects • Industry-university Collaboration Project • Co-work with Techcenter 	Die Concept Derivation	Industry-university Collaboration Project for Outsourcing	Prediction System Construction (equipment+SW+human resource)	In-house Die Design Making / Improvement / Application	
Solution Casting	<ul style="list-style-type: none"> • In-house Projects • Developing Technology by Pilot-test 	<ul style="list-style-type: none"> • A-film: Elongation > 400% • B-film: Controlling Phase Difference (Rth, Rin, <2nm) 		<ul style="list-style-type: none"> • Achieving Degree of Uniformity of 100% (thickness, side, optics) 		
Melting Casting	<ul style="list-style-type: none"> • In-house Projects • Developing Technology by Collaborative Research Projects 	Formulation	Temperature/ Dimensional Stability < 0.2%	Cooling and Heat Treatment / Hard Coating		
High Embo Retention Technology	<ul style="list-style-type: none"> • Developing Technology by In-house Research Projects 	Retentivity of Embo of 70%	Retentivity of Embo of 80%			

Source: Compiled by author.

Additionally, L Corp has its own unique process called CTP. It consists of a common core technology that is highly utilized in several product lines, such as thin film coatings technology, adhesive technology, optics technology, etc. These CTP technologies are developed and managed at the institutional level, not by the product R&D team. This can help prevent overlapping investment by research teams and increase the competitiveness of core technologies.

[Figure 3-23] L Corp's CTP (Core Technology Platform)



Source: Compiled by author.

5. Suggestion of Technology Roadmapping Process Customized to IPN & TechnoPoli

This session presents the process and methodology of technology roadmapping, available for IPN and TechnoPoli, taking into consideration the current level of technology planning capabilities in Mexico. As mentioned above, there are various types of forms and approaches to establish a technology roadmap. But this study proposes a technology roadmapping process and methodology for technological planning at the research institute considering IPN's capability.

A process suitable for IPN is presented with a general template in addition to summary of major activities at each stage so that it can be used immediately to develop TRM.

The process is focused on the future technology development strategy planning of IPN level aiming at development and commercialization of future promising technologies selected through technology foresight and priority setting for future technologies. Therefore, an appropriate process is proposed to device TRM for technology strategy planning at the institutional level. A technology roadmapping

process which minimizes as many unnecessary or complicated steps as possible, and makes it easier to focus on the core process is suggested. The result of each phase is presented as an example with output image from other institutions and companies to help the practitioners perform the technology roadmapping in the future.

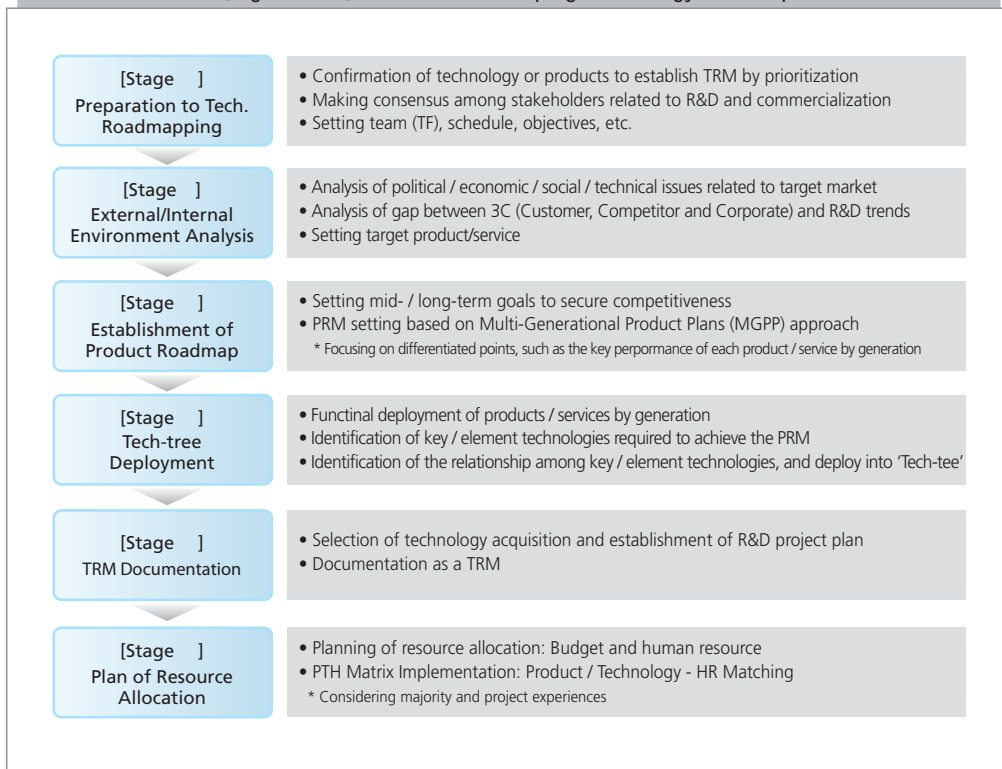
Prior to describing the process, organization of TF team leading this process can be of paramount importance. In order to establish technology roadmap, it is necessary to ensure that the team has a sufficient number of experts who are familiar with the roadmapping process. It is most desirable for these experts to have expertise in the product and technology areas and to have knowledge in the roadmapping process as well. However, when it is difficult to have these experts, it is important to form a team with a roadmapping experts and technology experts so that they can participate at the same time. One thing to note is that it is very important that experts from a certain field or a few team members do not lead the entire process of roadmapping. If a so-called “Big Mouse” is overly involved in the process, it can be biased throughout the roadmapping process and can have a negative impact on TRM's key success factor, “reaching a stakeholder consensus.”

5.1. Overall Process of IPN's Technology Roadmap

As stated above, the establishment of the technology roadmap for IPN is aimed at establishing a technology strategy based on the strategic products and technologies selected through technology foresight and prioritization. Therefore, we suggest the IPN technology roadmapping process consisting of 6 stages, such as the preliminary preparation stage, environment analysis stage, the establishing PRM stage, the Tech-tree development stage, the establishing TRM stage and execution planning stage.

The environment analysis and market/technology trend analysis process are clearly different from the analysis process at the R&D priority setting. In this stage, a more detailed analysis is needed because the analysis targets are concentrated on specific products and technologies.

[Figure 3-24] Process of Developing Technology Roadmap



Source: Compiled by author.

5.2. Contents & Methodology by Stages of Tech. Roadmapping

5.2.1. [Stages I] Preparation for Technology Roadmapping

This stage defines the products or technologies for establishing TRM as preparation stage for TRM development. In this stage, scope and target period of TRM establishment are set, and schedule of the project team, development process and arranging the main meetings are prepared.

The most important activity at this stage is to ensure consensus among stakeholders involved in TRM development. To do this, it is important to have empathy with stakeholders by transparently and objectively explaining the process and importance of TRM technology selection through workshops and conferences. The reason why these stakeholders' consensus is important is that a large number of people and resources must be included during the TRM development period of 3 to 6 months for successful establishment and execution of TRM. And research team

and key stakeholders need to engage senior-level personnel with expertise and experience rather than junior-level personnel.

The second most important activity at this stage is to organize a working group for TRM development. The composition of the working group may vary depending on the purpose and use of the technology roadmap, but in principle, various teams such as research team, planning team, production, sales and marketing are involved. Since this process focuses on technology roadmapping specialized to IPN, it is desirable to organize external experts such as companies, research institutes, and IP specialists in addition to practitioners of IPN such as from TechnoPoli. It is common to form a TF and team members must have expertise and experience in their field. When organizing a TF, each team member should be assigned a clear role and mission, and the benefits for internal personnel and appropriate compensation for external personnel should be considered.

The TF team leader must have expertise in the process and methodology of technology roadmapping, and this role is suitable for those who are in a position to engage the entire team and can encourage stakeholders' involvement. The qualifications and roles of the TF Team leaders are defined as follows.

Qualification

- The knowledge of TRM methodology

Roles

- To understand main issues, goals, purpose, application plan.
- To motivate the group and attract active participation.
- To clarify the process and the deadline of the tasks.
- To coordinate team members' tasks and external requests.
- To monitor performance and create ideas using results.
- To have accountability for completion of the roadmap within the schedule through collaboration with business manager.

Once such technology roadmapping is ready, it is advisable to inform others that the technology roadmapping activity has started through a formal procedure, such as a kick-off meeting. Through a kick-off meeting with top decision makers, the importance of technology roadmapping can be highlighted so that encourage more stakeholders to join.

5.2.2. [Stage II] External/Internal Environment Analysis

This is the stage for conducting an analysis of market and technology trends for target products/technologies to identify the market demand and to select the core

products/technologies to meet the demands. At this stage, the technology levels and gaps in the major players are identified by analyzing the market size, market growth forecast, macro-environment (such as the status of domestic and international competition) and global R&D trends. In addition, investigation of the availability of technologies that can replace target products and technologies, and conducting maturity level surveys are done.

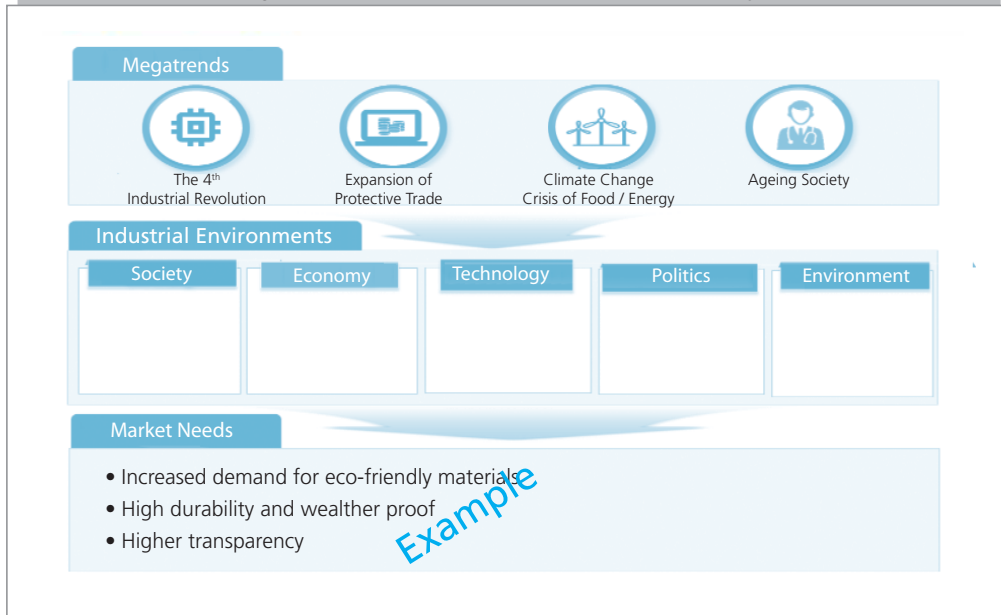
It is difficult to propose specific frames and examples because the frames of environmental analysis vary considerably depending on the contents and method of analysis. Presenting a specific frame in this study rather provides a bias and may limit the scope of environment analysis. However, the following contents must be reviewed and analyzed through environment analysis.

- Issues related to key industrial environments such as political, economic, social, technological, environmental, legal, and institutional issues for target market and technology and driving forces for current and future markets
- Analysis of target market size, growth rate, industrial ecosystem and major players
- Analysis of domestic and global technology development trends and patent trends
- Analysis of the technology level of major competitors and R&D trends

Although there are many different methods of implementing this stage, this study proposes to combine a macro analysis of global megatrends with a microscopic analysis based on the 3C analysis of target products and technologies. In detail, it is recommended to analyze in the order of "Megatrends Analysis→Macro-level Environment Analysis→Micro-level Environment Analysis."

First, we derive current and future issues of key industry environments such as economy, politics, society, technology, environment related to the target market through megatrends analysis, and then derive current or future demands of the market based on the analysis results. The [Figure 3-25] shows a sample of the output image of the megatrend analysis.

[Figure 3-25] Sample Template of Environment Analysis



Source: Compiled by author.

Next, through the macro-level environment analysis, it is possible to identify the size and growth rate of the target market, the demand of the current and future markets, and the trends of domestic and foreign technology development as well. In addition, market demands, driving forces, competitors' product/technology levels and capabilities are scrutinized through 3C analysis. Based on this, the direction of technology roadmap can be determine with gap analysis.

The results can be summarized through the 3C analysis frame, and each content should be presented based on objective evidence. [Figure 3-26] is an example of the results of environment analysis for ITO (Indium-Tin Oxide) Film products, which are commonly used for mobile device displays and touch panels.

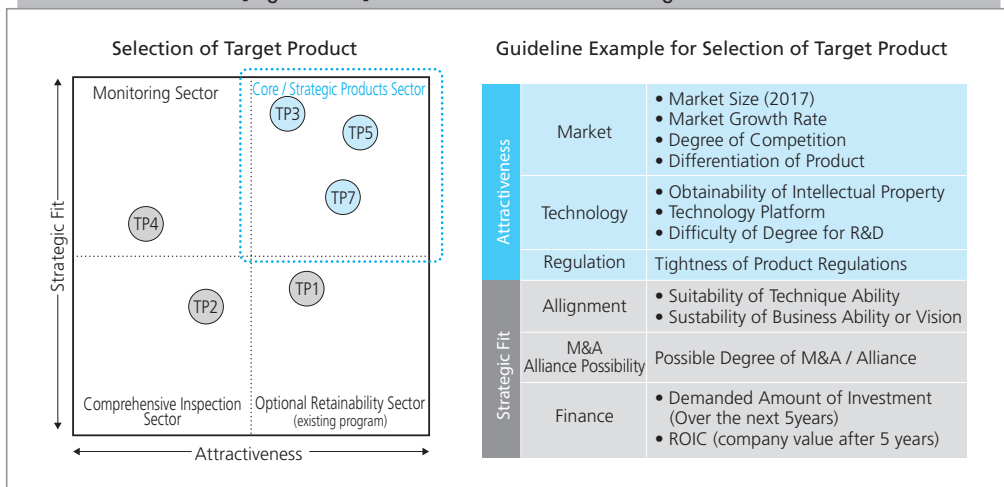
[Figure 3-26] 3C Analysis: TO Film (Example)



Source: Compiled by author.

Based on the results of this environment analysis, strategic product candidates are identified, which meet the current or future market demands and can strengthen the competitiveness. And market attractiveness and suitability of company's strategy are evaluated. Finally, core products/services are selected by matching the portfolio using the evaluation results.

[Figure 3-27] Guideline for Selection of Target Product



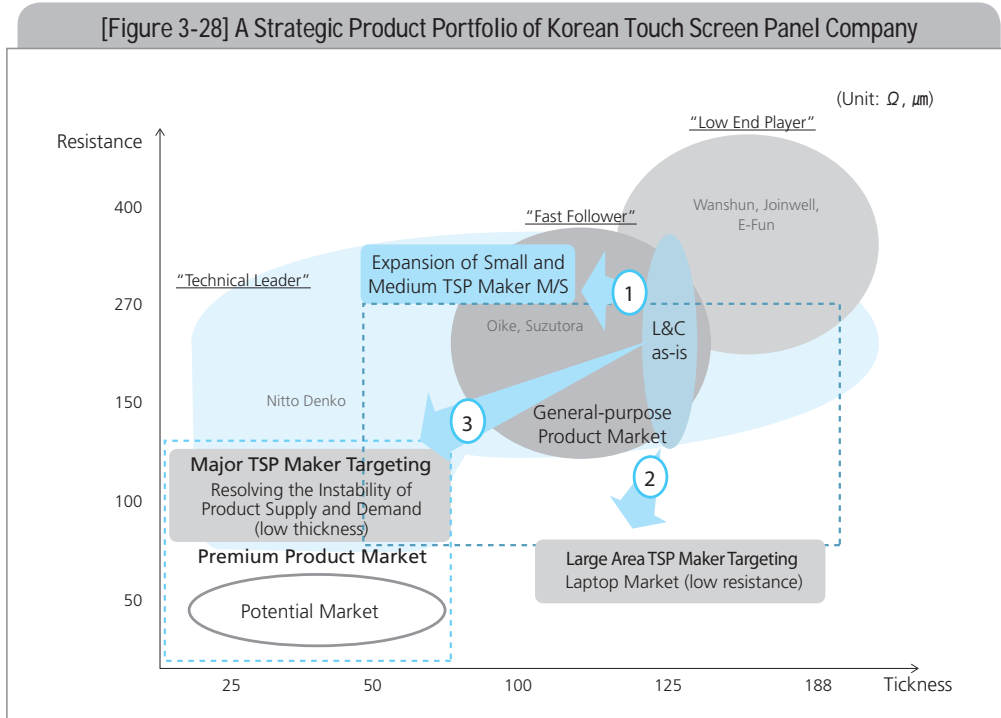
Source: Compiled by author.

5.2.3. [Stage III] Establishment of PRM (Product RoadMap)

Evaluation of market appeal and its strategic fit is conducted, mapping them to a portfolio to select key products and services among potential ones.

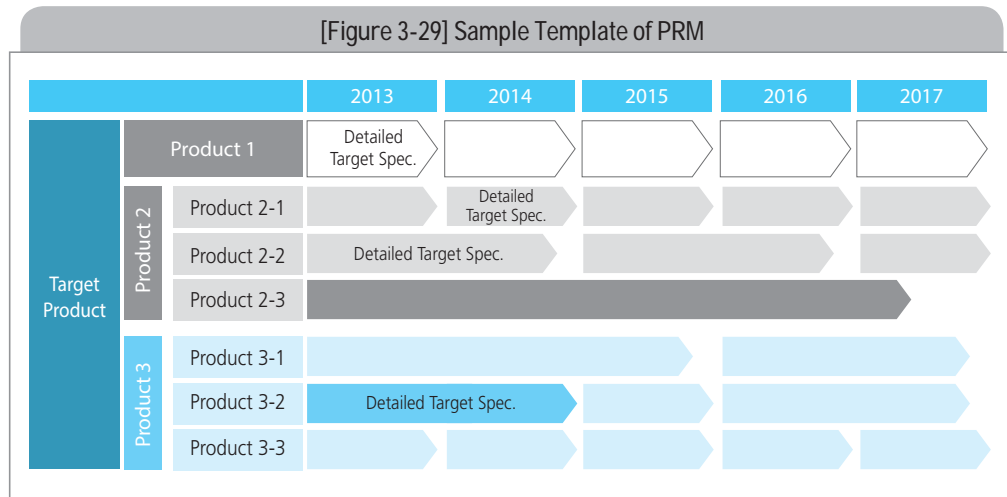
This is the stage of building the PRM as a mid- and long-term development plan for the target products and services. The PRM is a time series plan of product and service development plans with the target specifications to secure competitiveness in the market, taking into consideration current and future market demands and trends in domestic and international technology development.

Strategic products and services are generally set up based on business strategies that meet market demands and reinforce their strengths or complement weaknesses. They are selected according to various strategies, such as strengthening existing market power, exploring new markets, and strengthening brands. PRM is the result of establishing an annual and step-by-step plan for products and services. [Figure 3-28] is an example of a strategic product/service portfolio developed by Korean touch screen panel companies to strengthen their market competitiveness. Based on this, the company has developed a strategic product with 3 strategic goals.

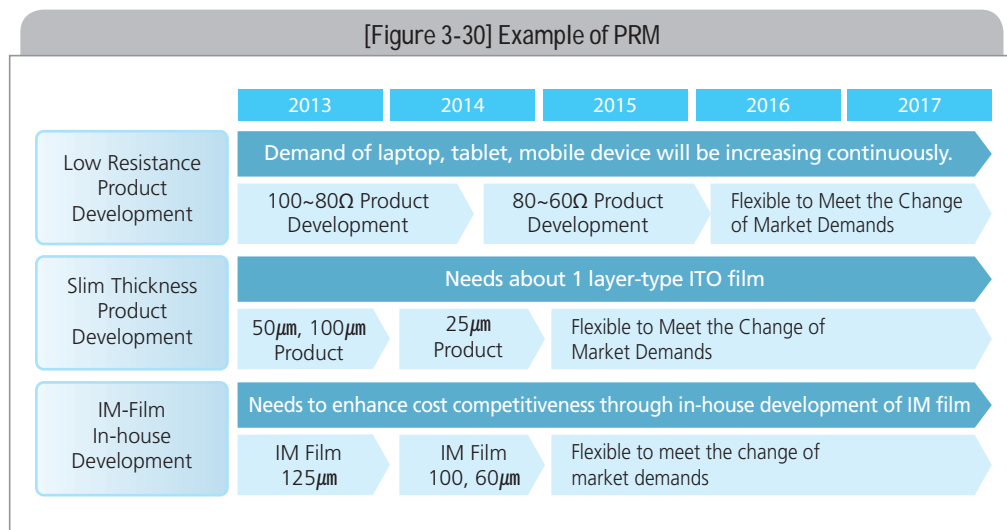


Source: Compiled by author.

First, the mid- to long-term goals, including core function & specifications, are set to enable the strategic products/services to be derived from the previous stage for competitiveness in the market. Based on this, a product launching plan for market over 5 to 10 years is established. The PRM is based on products with critical functions to ensure market competitiveness, including time-to-market that reflects market demand. [Figure 3-29] shows a template for creating a PRM and an example of company's PRM is presented in [Figure 30] for better understanding.



Source: Compiled by author.

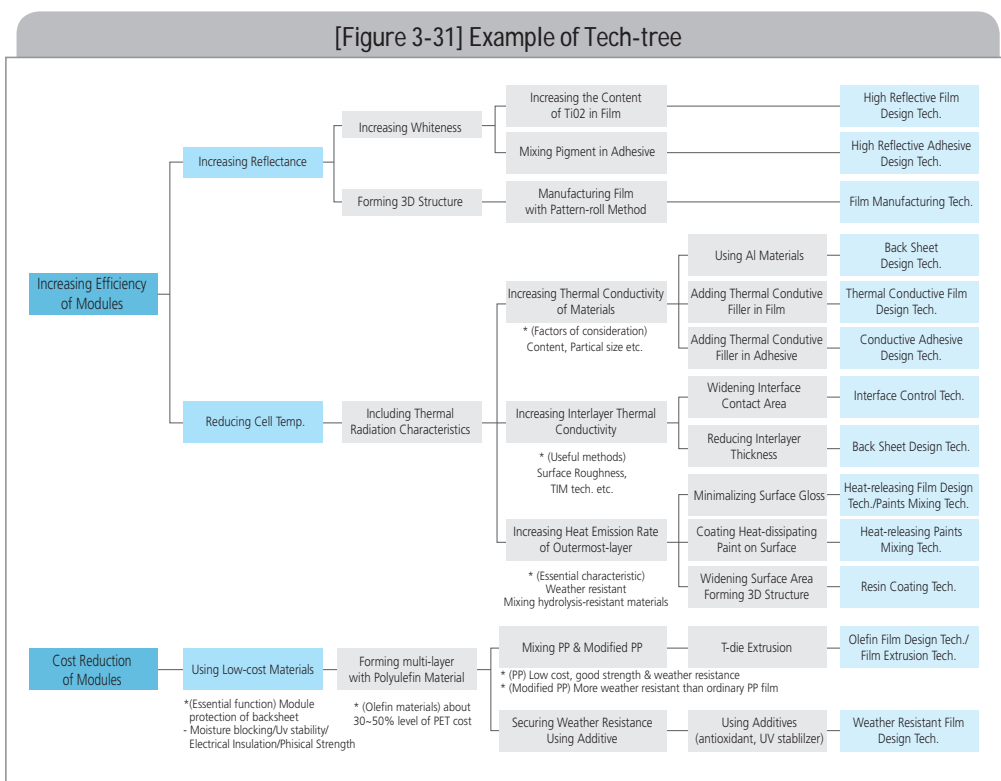


Source: Compiled by author.

5.2.4. [Stage IV] Tech-tree Deployment

This is the stage to derive the core technology necessary for the development of the strategic products/services presented by PRM, according to the review of the technical factors needed to produce the strategic products/services.

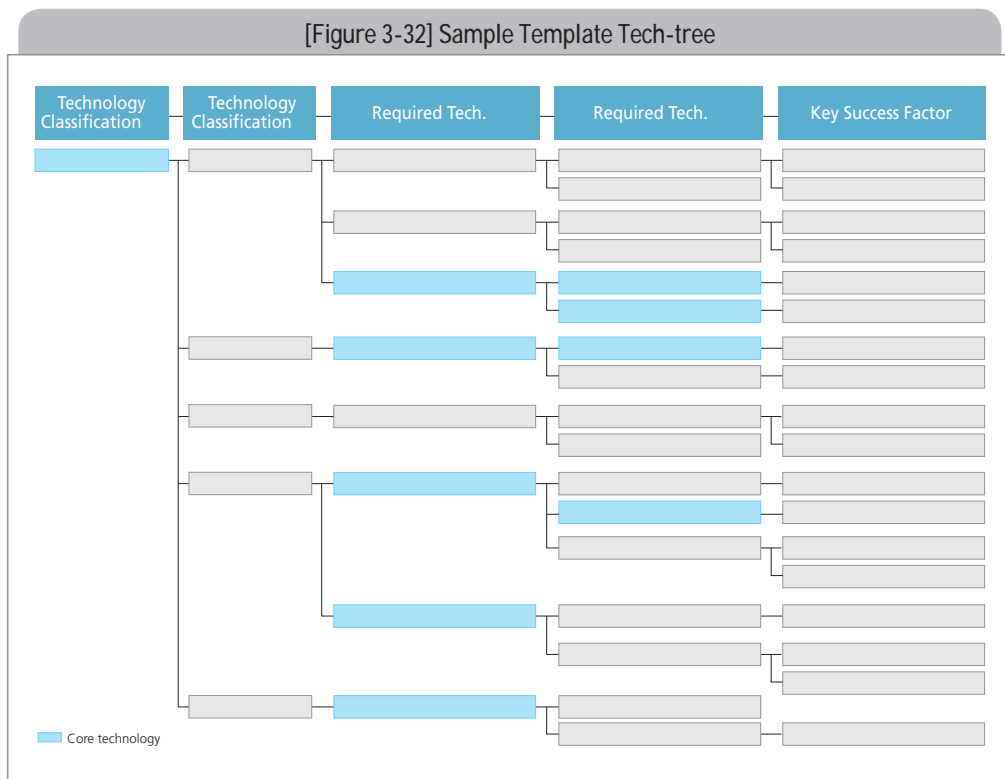
The process of classifying the technologies required for the production of strategic products/ services into materials, components, processes, tests/inspections, and equipment should be preceded. Next, element technology is derived to implement the core functions of the strategic products selected by PRM. Among the element technologies, it is possible to select the core technologies that can meet market demands and are differentiated from competitors. Therefore, developing the Tech-tree can be defined as a process to identify core technologies needed to produce strategic products/services.



Source: Compiled by author.

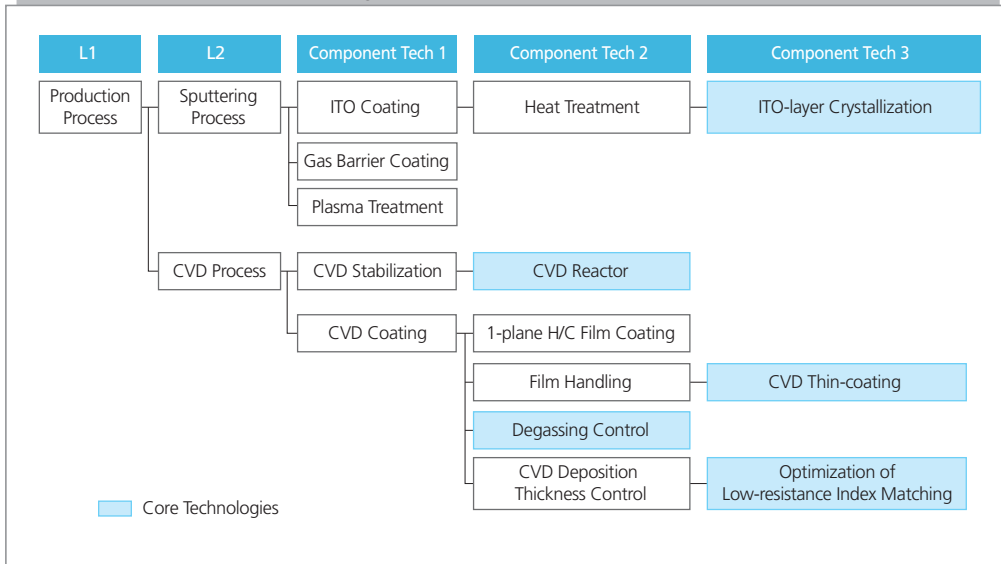
The Tech-tree deployment requires first deploying a core function. This is the process of converting the critical function of the strategic product into the working process/design element and exploring the related technical elements. Then, it is possible to derive the element technology necessary for implementation of the critical function. In the example above, the key function “increasing module efficiency” can be converted to process/design elements such as reflectance, cell temperature, and so on. Based on this, it is possible to derive element technologies such as high reflective film design technology, adhesive design technology, and film production process technology by deploying a Tech-tree.

The derived element technology is classified into material/part, process and system to organize a Tech-tree. In other words, it is desirable to classify core technologies derived from the deployment of core functions into material/part, process technology, and system technology, and deploy a Tech-tree for each category. [Figure 3-32] is a sample template for Tech-tree, and the results of deploying the Tech-tree for the ITO film process technology is as shown in [Figure 3-33].



Source: Compiled by author.

[Figure 3-33] Tech-tree of ITO Film



Source: Compiled by author.

The core technologies that are closely linked to competitiveness among the element technologies derived through the Tech-tree are selected considering the following items.

<Table 3-6> Requirements of Core Technology

Items	Core Technology Requirements
Connection of Strategy	Can the technology contribute to the achievement of the research institute's/company's mid-and long-term technology strategies and goals?
Business Value	Can the technology contribute to the business aspects such as competitiveness, and cost reduction?
Cost	Is the technology development and maintenance cost appropriate?
Internal Capability	Can the technology contribute to the development and maintenance of internal capabilities?
Risk	Technical risks such as difficulty in developing a technology, and competing technologies, and threats of alternative technologies

Source: Compiled by author.

Core technology sets development goals for each core technology by deriving key performance factors compared to the current levels. <Table 3-7> is a sample template charting the core technology development goals. The CTQ of <Table 3-8>

represents the core technology element for achieving the R&D goal, and parameter (X,Y) represents the measurable and manageable factor associated with the core technology.

〈Table 3-7〉 Sample Template of Developing Core Technology

No.	Core Technology	Level	Parameter		The Highest Level (targeting level / customer level)
			X	Y	
1					
2					
3					
4					
5					
6					
7					

Need to Secure First
 Need to Upgrade

Source: Compiled by author.

〈Table 3-8〉 Example of Developing Core Technology

No.	Core Tech	Current State (capability)	CRQ (Critical To Quality)		R&D Goals
			X	Y	
1	CVD Reactor	Pilot-Scale	Cost Competitiveness	Production Yield	Cost Reduction > 10%
2	Low-Thickness CVD Coating	Thickness: 125 μ m TD Uniformity: 5~6%	Film Control	Film Thickness	25 μ m IM Film Development
3	Degassing Control	Production Speed: 2m/min Degassing Hours: 24Hr	Degassing Hours	Production Speed	Production Speed: 8~10m/min Degassing Hours: 4Hr
4	Multi-layer Optical Thin-film Design Technology	AR Design Technology Index Matching Desing Technology	IM ITO Thickness	Low-resistance IM Film Design	60 Ω /sq IM Film Design
5	Non-resistance Process Control	295 $\mu\Omega$ *cm	ITO Thickness	ITO Resistance	150 $\mu\Omega$ *cm
6	ITO Crystallization	ITO: SnO2 5% Crystal (150)	Annealing Tech	SnO2 Proportion (150)	SnO2 8.5%
7	Low-resistance Index Matching Optimization	L*+ a*+ b*=-2~2.5 150 Ω /sq	IM Thin-film Thickness Control	L*+ a*+ b* IM Film Resistance	L*+ a*+ b*=<1.5 60 Ω /sq IM Film

Need to Secure first
Need to Upgrade

Source: Compiled by author.

5.2.5. [Stage V] TRM Documentation

This stage is to establish TRM by integrating the results of previous steps. TRM is developed to schematize core technology development plans and a final report is completed.

First, a maturity level (beginning, growing and maturing) and the internal capability of each research institute of the core technology are reviewed. After measurement, a way of technology acquisition is designed such as independent R&D, join R&D, commissioned research and technology introduction.

〈Table 3-9〉 Example of the Core Technology Development Planning

Required Tech./ Capabilities	Targeting Level	Development Cost	Availability (Internal)	Availability (External)	External Cost	Measures of Technology Development
A	80	Middle	High	High	Middle	Independent R&D
B	85	Low	High	Low	High	Independent R&D
C	95	High	Middle	Middle	Middle	Cooperation R&D
D	85	Low	High	High	Low	Technology Transfer
....

Source: Compiled by author.

Based on this, a time-series TRM is established including the development targets and the schedule for each core technology. [Figure 3-34] and [Figure 3-35] are examples of the TRM template.

[Figure 3-34] Sample Template of a TRM

Core Technology		Parameter	2014	2015	2016	2017
Core Technology 1	Parameter 1.1					
	Parameter 1.2					
	Parameter 1.3					
Core Technology 2	Parameter 2.1					
	Parameter 2.2					
	Parameter 2.3					
Core Technology 3	Parameter 3.1					
	Parameter 3.2					
	Parameter 3.3					
Core Technology 4	Parameter 4.1					
	Parameter 4.2					
	Parameter 4.3					

Source: Compiled by author.

[Figure 3-35] Example Template of a TRM

		2013	2014				2015	
		4Q	1Q	2Q	3Q	4Q	1Q	2Q
IM Film In-house Development	CVD Reactor	Facility Review & Order	CVD Facility & Process Set-up				Ready for Mass Production	
	Low-thickness CVD-Coating	125µm IM Film Development	50µm IM Film Development	25µm IM Film Development		Ready for Mass Production		
	Degassing Control	Film Pre-processing	Hard-Coated layer Removal & Barrier Coating Process Set-up					Ready for Mass Production
	Multi-layer Optical Thin-film Design	IM ITO 100Ω Design	IM ITO 80Ω Design	IM ITO 60Ω Design		Ready for Mass Production		
Low-resistance Film Development (Target Spec.: 60Ω/sq)	Non-resistance Process Control	SnO2 5~10% Target, LVS / UBM				SnO2 7.5~10%, LVS / UBM +RF Power		Ready for Mass Production
	ITO Crystallization	Polycold, Plasma Treatment & Gas Barrier Coating Process Set-up						
	Non-resistance Index Matching Optimization	100Ω IM Film Thickness Tuning	80Ω IM Film Thickness Tuning	60Ω IM Film Thickness Tuning				

Source: Compiled by author.

5.2.6. [Stage VI] Plan of Resource Allocation

This stage is to establish a plan of budget & human resource required to achieve the goal. Based on these resource allocation plans, the plan drives an activity to secure budgets from decision makers such as CONACYT.

Estimation of the budget and HR required to implement TRM are normally based primarily on the opinion of the research team. However, it is important to note that researchers tend to over-estimate the budget and the manpower needed in general. Given this, efforts should be made to ensure that the resource allocation plans are made to a reasonable level through comparisons with similar R&D tasks and reviewed by financial experts.

In preparing the HR plan, the necessary size of researchers as well as the degree, specialty area, and the quality level of researchers shall be simultaneously considered. For this, retention status of necessary research personnel should be reviewed using techniques such as PTH Matrix. It is important to consider recruitment plans if the manpower required to implement TRM is not available within the organization.

After establishing the resource allocation plan, the project team conducts activities to secure budget from decision makers based on the results of TRM establishment. When preparing the documents for securing resource, more emphasis is placed on the expected effects of success, such as national strategic importance, need for economic growth, and job creation than on technological superiority. Researchers and research institutions believe that good technologies create economic or social value added, but policy makers and investment decision makers generally pursue the need for employment and national competitiveness.

6. Suggestion of Technology Roadmapping for IPN

6.1. Implications for the Review of the Technology Planning System in Mexico

The Mexican technology planning system, viewed through analysis by local consultants and the results of field study to Mexico, can be summarized as “inexperience” and “Disconnection between policy – planning – R&D investment”.

While the Mexican science and technology system operates by CONACYT, CONACYT does not meet the needs of researchers and their own companies due to

1 year R&D investment mechanisms, non-systematic technology planning, and so on. R&D investment is more of a so-called “seeding formula” based on the needs of researchers than on a systematic future strategy, and performance assessment and management of R&D investment is insufficient. The low patent asset retention rate in Mexico and the low performance of major institutions’ technology transfers are the results of counteraction.

In the 4th Industrial Revolution era, R&D can be defined as an “Era of Hyper-Convergence” based on convergence among technologies from different fields. For example, intelligent robots can be created by combining various technologies such as robot hardware, Artificial Intelligence (AI), biomaterials, cognitive sciences and others. Therefore, the nation’s R&D strategy to create new industries in the future should focus on promoting cooperation among different actors. TRM-based technology planning provides guidelines to help diverse actors have one single goal and produce optimal R&D results in their respective fields.

In terms of policy and beyond incipient strategic technological planning, there are still some weaknesses:

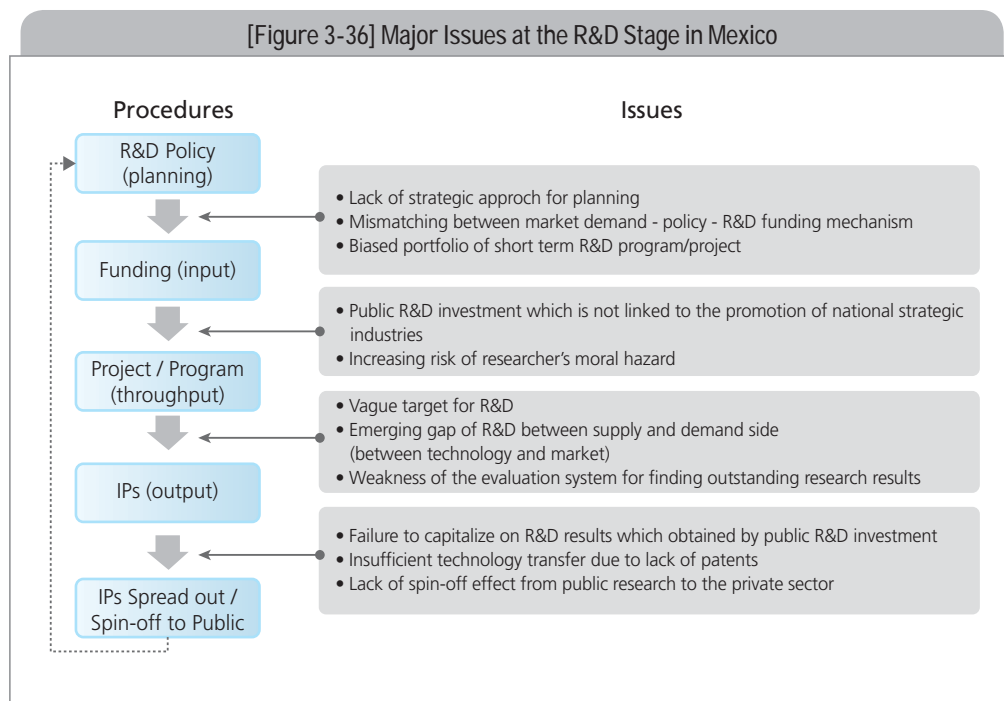
- A long-term approach based on the consensus and commitment of the key players is insufficient, which counteracts the cumulative effects and the expected change in the behaviors of the agents.
- Certain changes in the government programs give rise to confusion among the players, which does not contribute to altering their behaviors.
- A systematic and sustained Innovation system approach is absent. Scientific and technology policy has been more geared to solving market failures than to solving those of the system as a whole.
- Different conceptions on the innovation model persist, and many policy makers seem to assume the old idea of the linear model.
- Beyond decentralization efforts, an up-down approach persists which is imposed on the down-up proposals that emerge from the regions.
- Combining demand and supply innovation policies has not been in place. The measures continue to be basically direct on the supply side. Various novel instruments have begun to be implemented or have been designed but not implemented, which weakens science and technology policy as a whole.
- Policy instruments in Mexico tend to be changed every 6 years by the incoming government, which hinders cumulative effects to change the behavior of the agents. It is likely that this practice will be maintained.
- Lastly, the lack of technology planning in Mexico is due to the fact of weak relationship between all the main actors. In the country, traditionally there has been a maquila-oriented industry, but in recent years the Mexican private sector has developed the capacities to advance manufacture that cater to

specific market niches.

In general, the task related to technology planning and TRM is allocated to a technical planning organization. But for systematic technology planning, it is necessary for the planning organization to co-work with researchers and planners including the head of the organization and external expert. In these processes, systematic efforts to maintain objectivity through analytical work are important to eliminate the intuition of researchers and planners as much as possible.

As a result, it is necessary to establish objective and consensus-ensured TRM through full investigation and analysis for market and technology, brainstorming and workshop involving all stakeholders.

Establishment of R&D culture based on systematic technology planning, such as technology roadmap, should precede the preparation of government-level institutional arrangements. In addition, programs should be prepared to enable universities, public research institutes and businesses to collaborate for R&D to achieve the government's future goals of creating new industries and investment strategies.



Source: Compiled by author.

6.2. Recommendations for IPN

(Recommendation 1) To Move to Top-down R&D Systems for the Convergence of Technology/Industry in the 4th Industrial Revolution Era

In 4th Industrial Revolution Era, hyper-convergence is needed so that innovative products and services are created through boundless convergence between technologies such as nano, Biotechnologies and AI. Thus, national competitiveness in the future depends on maturity of the innovation platforms to create value by connecting their own innovation resource each other and facilitating collaboration.

In contrast, Mexico's R&D system has been led primarily by the bottom-up method, which relies on creativity of researchers. The bottom-up type R&D systems are not suitable for creating new industries for the nation's future. In particular, during the 4th Industrial Revolution in which hyper-convergence between various technologies is required. Mexico's R&D funding structure based on the bottom-up method may bring up concerns on uselessness of systematic R&D planning or on emerging researcher's moral hazard. Additionally, there is a chance for someone who has a lack of understanding on the market to drive R&D planning and technology development, so it may have negative effect on R&D output and cause disconnection to the market or fail to enhance productivity.

In the era of the 4th Industrial Revolution, it is important to establish a top-down national strategy and plan to achieve global market competitiveness. A bottom-up approach is needed to utilize the creative ideas of researchers from a viewpoint of implementation.

TRM can be used as a bridge between the national strategy & goal established with the top-down approach and the researchers' creative ideas collected with the bottom-up approach.

(Recommendation 2) To Prepare Institutional Devices to Spread Technology Roadmap

In Korea, presentation of TRM is practically mandatory for R&D projects larger than a certain size. Such a legal system helped the technology planning using TRM to spread in Korea. TRM is utilized at various levels of government ministries, public agencies and R&D projects, not to mention the private sector.

In Mexico, where R&D investment is relatively low, enhancing productivity based on systematic R&D planning is a very important national agenda. First, it is important to establish a national strategic technology roadmap, which is necessary for development of new industries, to inform various universities, research institutes and businesses of the direction of investment for the nation. Then, it is important to

link the national strategies of new industries to the R&D of researchers by creating legal framework that requires the establishment of a technology roadmap.

(Recommendation 3) To Strengthen the Creation of Intellectual Property Rights for Public R&D Performance

Public R&D alone cannot create economic and social value-added. Public R&D performance can only create economic and social value-added when it is transferred to businesses and converted into innovative products or services.

Mexico has a very poor track record of intellectual property rights and technology transfers compared to the size of its public R&D investment. Even the IPN with 80-year history has had less than 10 cases of technology transfer. This is a clear example of how Mexico's public R&D is disconnected from corporate R&D. This means that investment of governmental R&D is not considered to be a national asset, additionally, it was difficult to differentiate public R&D compared to private R&D because of absent definite mission and accountability. There are structural limitations for non-assetized public R&D output for technology transfer and commercialization to private companies so that the filing/expansion IPs are necessary condition on governmental R&D investment.

In the public sector, TRM is both a technology development plan and an intellectual property acquisition strategy. Performance of public R&D investment by TRM should be converted into national intellectual property, such as patent rights, and transferred to private households so that it can be converted into economic or social value added.

Accordingly, the IPN should enhance the creation of intellectual property rights for research tasks that are supported by public R&D and facilitate the transfer of private technologies via TTO and others.

(Recommendation 4) To Expand Investment to Foster Technical Planning Experts

The specialized manpower required for TRM establishment is not trained through simple education. Technical planning staff are required to have long on-site experience, along with theoretical knowledge.

In Mexico, major institutions, including IPN, are considered to have sufficient staff with the necessary skills to become technical planning specialists. However, Investment is insufficient to foster them and track for accumulation of field experiences.

In conclusion, it is necessary to have a track in place to support the planning staff at institutions such as TechnoPoli to accumulate experience. It is also a good idea to support their collaboration with Korean experts to obtain experiences of directly

implementing the TRM establishment process through KSP.

In addition, it is also necessary to develop a system for fostering strategic planning expertise to meet the needs of public and private technology planners.

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