

Major Determinants for the Successful Implementation of Technology Roadmap in the Technology Intensive Organization: A Case of Smart Grid Roadmap in Korea

Won Il Lee

Department of Business Administration, Hanbat National University, Daejeon, South Korea

E-mail: tech201@hanbat.ac.kr

Abstract—This study is about the major determinants for the successful implementation of technology roadmap in the technology intensive organization. For this study, I defined the concept of the Strategic Technology Roadmap and its characteristics. I also studied the key processes of the Strategic Technology Roadmap and the major success factors for the implementation of it. The study was performed based on the theoretical study and related qualitative case study approaches. In this study, the Smart Grid Technology Roadmap implementation process was deeply analyzed. From the initial adoption stage of the roadmap development to the actual utilization of it was scrutinized. Through the case study the major determinants for the adoption of the smart grid technology roadmap can be summarized as follows; the top management support for the implementation of the Strategic Technology Roadmap, the relevance - the goodness of the fit - of the Roadmap, the organizational capability among the functional teams such as strategy planning team, marketing team, R&D Project teams. This study regarding the adoption of the Strategic Technology Roadmap can be the good reference for the Technology organization which is willing to adopt and utilize the Strategic Technology Roadmap in the future.

Index Terms—strategic technology roadmap, implementation, smart grid.

I. INTRODUCTION

With hypercompetition, assumptions of market stability are replaced by notions of inherent instability and change [1]. In this global hyper-competitive business environment, many technology-savvy organization which regards the R&D as the future growth engine is trying to adopt the Strategic Technology Roadmap (STRM) for the integration of the strategy and R&D system. Strategic Technology Roadmap can be the powerful technology strategy tool for the future technology development and align the business strategy with the R&D projects [2]-[4], also eventually can be the infrastructure for technological innovation in the long-term perspective [5]. In the strategic technology roadmap, the strategic core

technologies can be selected among many key technologies considering the organizational external environments and internal capability in the future. This strategic core technologies can be broken down into the various element technologies and grouped into some categories and can be developed in the future. R&D organization can actively utilize the strategic technology roadmap as an innovation execution for innovative R&D project launching and implementation. In this competitive business environment, strategic technology roadmap can be the infrastructure for technological innovation and directs the R&D system toward the more strategic R&D system [5]. Eventually, strategic technology roadmap can align the business strategy, technology strategy with the R&D system [2]-[4]. Because of these innovative aspect of the strategic technology roadmap, many technology firms are trying to adopt and utilize it in the whole organization. However, there has been emphasis only on the 'technological evolution' of the roadmap and systematic adoption process has been relatively neglected.

It is only after the successful adoption process that technology roadmap can be actually utilized in the organization and can be the infrastructure for technological innovation in the long term perspective. This study, firstly, examines the concept of the strategic Technology Roadmap and its key processes. Secondly, examines its function in the R&D organization. And finally, this study scrutinize the major determinants for the successful adoption of it and its relevant case. This study regarding the major determinants for the successful adoption of it can be the good reference for the technology savvy organization which will adopt and use the roadmap as a future technology guidance.

II. STRATEGIC TECHNOLOGY ROADMAP DEFINITION AND PROCESS

A. Strategic Technology Roadmap Definition

In this hyper-competitive business environment, many technology organizations are trying to adopt the strategic technology roadmap for the integration of the strategy and R&D system. Strategic Technology Roadmap can be

Manuscript received November 15, 2012; revised December 30, 2012.

the infrastructure for technological innovation and direct the R&D system in a more strategic and systematic way [5]. Particularly, Strategic Technology Roadmap is the technology roadmap developed in the organizational level. Strategic Technology roadmap can be developed, shared, and updated in the R&D organization and can be used as a powerful technology strategy tool for technological innovation and also for the technological exploration and exploitation in the organization. It is the time to use the technology roadmap when there is an inconsistency in R&D system, there is no clear technology vision in the organization and don't know what is the strategic core technology. Through the strategic technology roadmap, R&D organization can align the business strategy, technology strategy with R&D system [6].

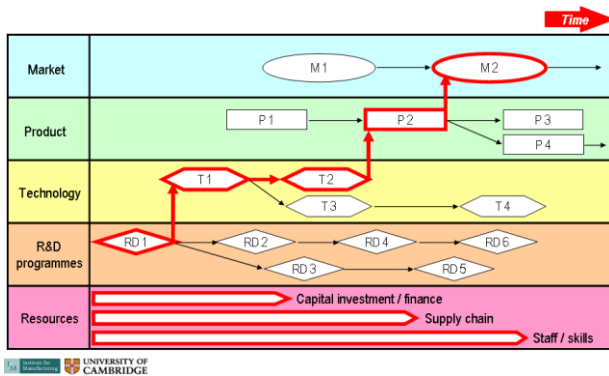


Figure 1. Technology roadmap simple frame, university of Cambridge (2001)

B. Strategic Technology Roadmapping Process

Technology roadmapping process can be categorized as follows; first is the strategic core technology selection in the R&D organization and the second is the deployment of the technologies in the time-frame in the technology roadmap in the macro and micro level. This study analyzes the whole process of the adopting of the strategic technology roadmap in the R&D organization.

TABLE I. STRATEGIC TECHNOLOGY ROADMAPPING PROCESS

Stages	Process
Stage 1	Select and prioritize the Strategic Core Technology in the R&D organization considering the organizational external environment, internal capability and strategy(organizational position).
Stage 2	Deploy the element technologies and sub-element technologies in the technology roadmap timeframe (Technology nodes are connected by technology links, and technological evolution can be easily detected)

Strategic Technology Roadmap can be developed in stages. To be a successful adoption of the roadmap in the organization, in addition to the top management support, voluntary participation of the whole member is needed. Particularly, reaching a consensus of the R&D members regarding the organizational strategic core technology and the deployment of the key technologies in the timeframe of the technology roadmap. All these procedure of making the strategic technology roadmap should be transparent also have the 'procedural justice' in the organization.

III. STRATEGIC FUNCTION OF THE TECHNOLOGY ROADMAP IN THE TECHNOLOGY INTENSIVE ORGANIZATION

A. Balancing between the Exploration and Exploitation

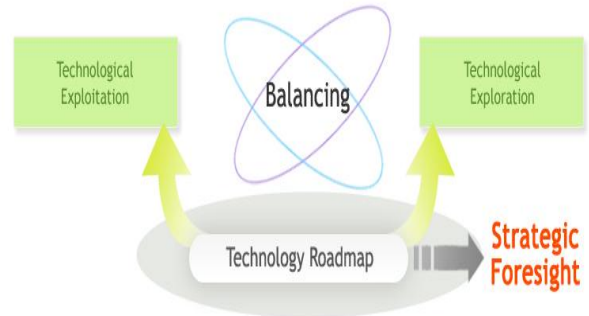


Figure 2. Technology roadmap balancing between the exploration and exploitation

The difficulty in balancing the exploration and exploitation cause many firms to unable to adapt efficiently to continually changing business environments [7]. There is a basic tension between exploration and exploitation and these two different objectives cannot be coordinated easily [7]. In this hyper-competitive business environments, Management of Technology (MOT) can be the best solution for the balancing the exploration and exploitation by practicing the management of technology activities such as the technology foresight, planning, management, and evaluation and commercialization. At present, the concept of management of technology (MOT) embraces the R&D management and eventually includes the concept regarding the strategic decision making for the acquisition of the technology outside the organization [8]. That is, management of technology (MOT) is the overall management activities from the efficient acquisition, management and utilization of the hard and soft technology for organizational competitiveness and technology commercialization [8].

The organization can adopt this management of technology (MOT) framework, and successfully can search for new technological information and resources; that is technological exploration, also can use for the existing organizational resources; that is technological exploitation. So the management of technology (MOT) can overcome this trade-off between exploration and exploitation and balancing it strategically. This means the paradigm shift from the functional approach such as marketing, organization, operation to the technology-centered management approach centered on technology. In this perspective the most important issues of the management of technology (MOT) is the adoption and utilization of technology roadmap in the organization because technology roadmap provides the frameworks for the technological exploration by deploying technology nodes in the time-frame towards multiple technology visions and future scenarios, and also supplies the frameworks for the technological exploitation by technology prioritization and technology selection process. So the conclusion is that the technology roadmap

in the organization can be the powerful balancing tool for technological exploration and exploitation.

B. R&D System Innovation through the Strategic Technology Roadmap

R&D system evolves from 1 generation to 4th generation. Generation 1 R&D system is the lab level R&D management, and the Generation 2 is the R&D project management level [9] and [10]. The integration of the Strategy and R&D system starts from the 3th Generation R&D system and in the 4th Generation R&D system R&D system dynamics occurs spontaneously for the blue oceans [9] and [10]. From the 3th Generation R&D system, Technology roadmap can be used for strategy-R&D integration for goal-oriented R&D project management [9] and [10]. The general level of the Korea R&D system can be refer to as the 2.6 generation R&D system and the system level difference between the chaebol and small-medium sized firm R&D system is huge. For a more productive R&D system, Firstly, Strategy, R&D portfolio management and R&D project management should be aligned with each other. Only after these integration, 4th Generation R&D system can be achieved.

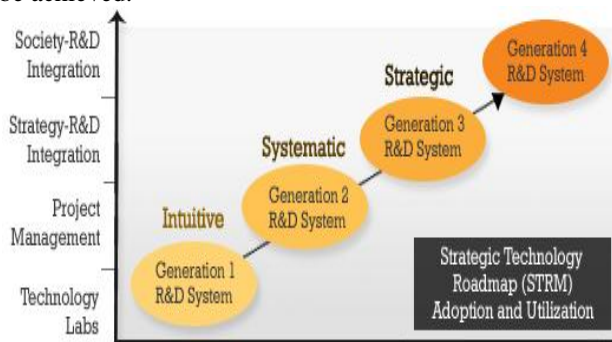


Figure 3. R&D System innovation through the strategic technology roadmap

So there has been an emphasis on the strategic technology roadmap as a powerful tool for integration of the strategy and R&D system for efficiency and optimization of the technology resources. As mentioned earlier, strategic technology roadmap has the capability of the R&D optimization and R&D resource integration if it is properly utilized. In addition to that technology roadmap contains information regarding the disruptive technology. By the utilization of the technology roadmap, R&D system evolves from 3th generation to 4th generation.

C. Strategic Technology Roadmap as an Infrastructure for Technological Innovation

Strategic Technology roadmap systematically links the market, product, technology and external environment [11] and [12]. Also Strategic Technology roadmap provides the R&D organization with the technology intelligence capability and guides the technology development timing in a strategic way [11] and [12]. According to the agent model in technology roadmap, 'technology nodes' and 'links' in the technology roadmap

spontaneously makes innovation virtually and technologically evolves and revolves systematically [5]. Technology Roadmap can accelerate technological innovation by the path exploration in the technology roadmap and the merge of the Macro and Micro technology roadmap [5] and [13]. In this innovation perspective technology roadmap can be the 'living organism' which is self-organizing mechanism and evolves spontaneously for innovation. So the more the organization has the technology capability and technology resource, the more the technology roadmap made in that organization can have the innovation capability. This means technology roadmap has the innate characteristics for technological innovation and innovation dynamics.

So, when the organization adopt the technology roadmap and utilize the roadmap in the R&D project, the characteristics of the technology roadmap can be realized and technology roadmap begin to align the strategy and R&D system and can be the catalyst for the technological innovation. When technology nodes and links in the technology roadmap converted into technology cluster and implemented in the R&D project, technology roadmap can be action-oriented living document. So Technology roadmap in the organization can be the infrastructure for innovation in the long term [5].

IV. CASE STUDY FRAMEWORK : MAJOR DETERMINANTS FOR THE SUCCESSFUL IMPLEMENTATION OF TECHNOLOGY ROADMAP

In this study, the Smart Grid Technology Roadmap adoption process was deeply analyzed. From the initial adoption stage of the roadmap development to the actual follow-up stage of it was scrutinized. Case analysis are done as follows; Consensus regarding the strategic core technologies at Initial Stages, The Goodness of the Fit of the Roadmap at Adoption Stage, Top Management Support (CTO), Marketing-R&D Synergy and Active Utilization of TRM in R&D Project Teams at Follow-Up Stage.

A. Initial and Adoption Stage(Technology Roadmapping Process)

1) Consensus regarding the strategic core technologies at initial stage

In stage 1 strategic technology roadmapping Process, firstly, strategic core technology should be selected considering the organizational external environment, internal capability, strategy and organizational position in the market [14]. After selecting the strategic core technology, prioritization among the key technologies should be done. As mentioned earlier, the most important thing in this stage is the reaching a 'consensus' regarding the strategic core technology lists. That is "what is the strategic core technology in the organization in the future", and "what should be done to carry that technologies". There should be the whole member's participation in the organization for selecting and prioritizing the strategic core technologies including the top management and R&D personnel.

2) *The goodness of the fit of the roadmap at adoption stage*

In stage 2 'strategic technology roadmapping Process', the detailed roadmap should be drawn in stages [2] and [3]. Firstly, core technology's technological requirement should be defined, technological analysis should be done. Secondly, 'the technology tree' of the core technology should be drawn. Key technologies in the technology tree can be clustered and can be grouped in 'technology nodes' in the technology roadmap, so this process of making the technology tree is very important stage. Final stage is deployment of the element technologies and sub-element technologies in the technology roadmap timeframe. Technology nodes are connected by the technology links, and technological evolution can be easily detected visually. According to this technology roadmapping process stage 2, technology development strategy can be made and R&D project action plan can be finally drawn [2] and [3].

When developing the strategic technology roadmap, the relevance of the technology-tree of the core technology is very important. Technology nodes in the technology roadmap is the representation and standardization form of the R&D activity, technology nodes can be clustered and R&D project can be executed as per this grouped technology nodes. So technology level and technology digit of the technology tree is important factor for the successful R&D action plan. Also the technology nodes can be deployed in the Macro and Micro technology roadmap and transformed into the R&D project. In this respect, the goodness of the fit of the Strategic Technology Roadmap can be the most important factor for the successful utilization of the roadmap. The goodness of the fit of the Strategic Technology Roadmap is as follows; the relevance of the key technology and technology digit level and its links each other in the technology roadmap, the relevance of the realization period of the technology nodes. This relevance of the roadmap should be emphasized from the beginning, continually updated for the goodness of the fit between the technology evolution and R&D project activity in the organization.

B. *Follow-Up Stage*

1) *Top management support (CTO)*

For the successful adoption of the strategic technology roadmap in the R&D organization Top management support is needed. Top management can be the CEO, CTO and direct the organization toward the strategy-focused organization. From the initial stage of the technology roadmapping process, Top management should emphasize the participation of the whole member of the organization, committed themselves to successful adoption of the technology roadmap and communicate with other stakeholders of the organization. Through the top management support regarding the whole process of roadmapping, the strategy and R&D system starts to align with each other and innovation characteristics of the technology roadmap can begin to move from roadmap to R&D project. Top management support is as follows; furnishing the personnel and material support related to

roadmapping, giving the authority to utilize the roadmap, providing the information regarding the technology roadmap, emphasizing the utilization of technology roadmap in the organization and supply the rewards and incentive for it.

2) *Marketing-R&D synergy*

Strategic Technology Roadmap is the technology communication tool for integrating Market, Product, Technology and external environment [2] and [3]. As a market-driven technology planning tool, technology roadmap can be the linkage pin of the market and technology. In this respect, technology roadmap T-plan developed from the market, product, and technology, workshop has been done through this stages [2] and [3]. So Strategic Technology Roadmap should be the integration tool for market and technology, technology information should be exchanged in the roadmap strategically. In this process technology roadmap and organization can be coupled and the innovation characteristics of the roadmap can realized in R&D activity. So relational capability of the marketing, product planning and R&D project team should be enhanced for the strategic utilization of roadmap.

3) *Active utilization of TRM in R&D project teams*

The essence of the R&D project is the exploration and development of the technology alternatives. Basically, the R&D project is composed of the continuous series of the uncertainties focusing on the solving the technological and managerial problems. The relational and structural characteristics of the R&D project teams can be stated as the 'loose coupling'. The essence of the relation of the project teams is the technology knowledge transfer and sharing [15]. The new technology information and knowledge can be transferred from the other R&D project teams and can be the competitiveness advantage of the R&D project team. The more the new and diverse technology information the R&D project teams has, the more needs the systematic and strategic decision making in doing the R&D project. The technology roadmap provides the systematic framework for integrating the technology information. So the R&D Project teams should actively utilize the technology Roadmap for performing the R&D activities.

V. CASE STUDY : A CASE OF KOREA SMART GRID TECHNOLOGY ROADMAP

A. *Initial Stage*

"Smart grid" refers to an electric power grid that incorporates information & communication technologies to maximize efficiency for greater eco-friendliness [16]. Korea was named a leader in the smart grid area at the Major Economies Forum on Energy and Climate in July 2009[16]. At a national level, ground was broken for a smart grid test-bed on Jeju Island in August 2009, and a national roadmap for smart grids was announced in January 2010[16].

Korea Electric Power Corporation (KEPCO) has participated in all five areas of the Jeju smart grid test-bed project (2009.12~2013.5) [16].

TABLE II. CASE STUDY FRAMEWORK

Stages	The major determinants for the successful implementation of TRM in technology intensive organization	Detailed factor for supporting the major determinants for the successful implementation of technology roadmap
Initial stage	<u>Consensus regarding the strategic core technologies</u> (in core technology selection process)	<ul style="list-style-type: none"> - the whole member's participation in the organization for selecting and prioritizing the strategic core technology - the procedural justice regarding selecting and prioritizing the strategic core technology
Adoption Stage (Roadmapping Stage)	<u>The goodness of the fit of the roadmap</u> (in roadmapping process)	<ul style="list-style-type: none"> - the relevance of the key technology, technology digit level and its links in the technology roadmap, - the relevance of the realization period of the technology nodes. - the continual updating the goodness of the fit between the technology evolution and R&D project activity in the organization
Follow-up Stage	<u>Top management support</u> (CTO)	<ul style="list-style-type: none"> - furnishing the personnel and material support related to initial roadmapping, - providing the information regarding the technology roadmap, - emphasizing the utilization of technology roadmap in the organization - supply the rewards and incentives. - giving the authority to utilize the roadmap,
	<u>Marketing-R&D Synergy</u>	<ul style="list-style-type: none"> - strategic technology roadmap should be the integration tool for market and technology, technology information should be exchanged in the roadmap strategically. - relational capability of the marketing, product planning and R&D project team should be enhanced for the strategic utilization of roadmap.
	<u>Active utilization of TRM in R&D Division</u>	<ul style="list-style-type: none"> - the R&D Planning division should actively utilize the technology Roadmap for the real R&D planning and its execution(RFP launching) - the relational capability building among the R&D Project team in loose coupling state for technical information exchange

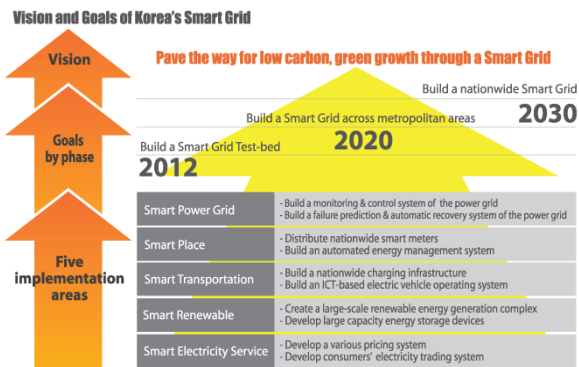


Figure 4. Vision and goals of KEPCO smart grid

KEPCO is focused on smart grid projects to reduce greenhouse gas (GHG) emissions, improve energy efficiency and promote the use of new & renewable energy [16]. KEPCO's smart grid business has five central pillars: reduction in peak demand and load leveling, smart power grid, CO₂- reducing renewable energies, standardization of a smart grid and establishment of an information protection system and future growth engines [16]. KEPCO has outstanding technologies in the smart grid such as transmission/distribution automation technology [16]. Coupled with technical prowess, KEPCO develops customized business models per regions and countries to promote exports. Its smart grid business targets are to secure a foothold based on its smart grid test-bed study by 2013, establish the broad smart grid by 2020 and build the world's first nation-level smart grid by 2030[16]. From the initial stage of the smart grid technology roadmapping process hosted by Korea Smart grid Institute, CTO emphasized the participation of the whole

technical member of the organization and communicated with the R&D personnel and engineers and technology roadmap specialists.

B. Adoption Stage

For this Smart grid technology roadmap, the organizational environment, technology level, technology capability, patent and competitors' technology capability was thoroughly analyzed. Firstly, emerging technology, strategic technology was selected and prioritization among the key technologies was done, finally, strategic core technology was selected. After that, the key technologies was deployed in the time-frame, and final detailed roadmap was drawn in the macro and micro level. In this stages the goodness of the fit of technology roadmap - the relevance of the key technology and technology digit level and its links with technology nodes was examined carefully.

C. Follow-Up Stage

After the adoption of the technology roadmap in the whole organization, to make the R&D project team utilize the roadmap more effectively, various support by the management support team has been done. Firstly, KEPCO CTO encouraged the R&D researchers and technician to take part in the smart grid roadmap workshops and special education program. After participating these workshops the R&D project team member was able to know the importance and meaning of technology roadmap also the relationship between the technology roadmap and the organizational strategy and the smart grid technological vision. Also the R&D Project team leader has the responsibility for evaluating the technology information in the project team and mold it to manageable technology unit. By way of technology

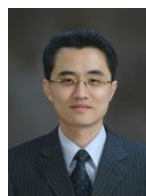
standardization activity, the R&D project team can develop the technology and manage it systematically and was able to actively use the technology roadmap in the R&D project. After the successful adoption of the roadmap, the technological and formal cooperation meeting and mini-conferences regarding the smart grid has been made among the R&D project teams to build the strong relational capability of the R&D project teams. After the these meeting and discussion to solve the technological problems and build the relation capability, each project teams could understand the other technology areas, and search the new ways of technical cooperation and also was able to find the new innovation patterns. Consequently, each R&D project team actively use the technology roadmap as a technical guidance tool. After these technology roadmapping process, KEPCO was able to launch the more innovative service in the market.

VI. CONCLUSION

In this global hyper-competition business environment, many R&D organization which regards the R&D as the future competitiveness engine is trying to adopt the Strategic Technology Roadmap (STRM) for the integration of Strategy and R&D system. Also the R&D organization can utilize the strategic technology roadmap for the innovative R&D project launching and implementation. Strategic Technology Roadmap can be the infrastructure for technological innovation and directs the R&D toward the strategic R&D and eventually align the business strategy with the R&D system. Because of these innovative characteristics of the Strategic Technology Roadmap, many organization trying to adopt it in the whole organization. However, there has been emphasis on only the technological evolution of STRM and technological aspect of it. So strategic and systematic STRM adoption process including the top management support, considering the relevance of the roadmap and organizational capability building regarding STRM has been neglected. It is the only after the successful adoption process that Strategic Technology Roadmap can be the infrastructure for technological innovation and 'coupled' in the organization. Nowadays, many organization are trying to adopt the technology roadmap, however, there was not enough study for Strategic Technology Roadmap. This study regarding the major success factors for the adoption of the TRM in the R&D organization can be the good reference for the organization which is willing to use the STRM in the future as a technological innovation infrastructure.

REFERENCES

- [1] R. A. D'Aveni, "Coping with hypercompetition: utilizing the new 7S's framework," *Academy of Management Executive*, vol. 9, pp. 45-57, 1995.
- [2] R. Phaal, C. J. P. Farrukh, and D. R. Probert, "Fast-start technology roadmapping," presented at the 9th International Conference on Management of Technology, 21-25th February, Miami, 2000.
- [3] R. Phaal, C. J. P. Farrukh, and D.R. Probert, "Technology roadmapping - a planning framework for evolution and revolution," *Technological Forecasting & Social Change*, vol. 71, pp. 5-26, 2004.
- [4] R. Phaal, C. J. P. Farrukh, and D. R. Probert, "Technology management tools: Concept, development and application," *Technovation*, vol. 26, pp. 336-334, 2006.
- [5] R. Martin, "Technology roadmaps: Infrastructure for innovation," *Technological Forecasting and Social Change*, vol. 71, pp. 67-80, 2004.
- [6] J. P. Irene and E. Ann, "Technology roadmapping in review: A tool for making sustaining new product development decisions," 2004 *Technological Forecasting and Social Change*, vol. 71, pp. 81-100., 2004.
- [7] J. G. March, "Exploration and exploitation in organizational learning," *Organizational Science*, vol. 2, pp. 71-87, February, 1991.
- [8] P. Alan, "Management of technology: Themes, concepts and relationships," *Technovation*, vol. 26, pp. 288-299, 2006.
- [9] D. Nobelius, "Towards the sixth generation of R&D management," vol. 22, pp. 369-375, July, 2004.
- [10] L. M. William, *Langdon, 4th Generation R&D, Managing Knowledge, Technology and Innovation*, 1999. Ch. 1. pp. 1- 25.
- [11] J. P. Irene, "Roadmapping as a mitigator of uncertainty in strategic technology choice," *Int. J. Technology Intelligence and Planning*, vol. 1, pp. 171-184, 2005.
- [12] T. W. Steve, "Roadmapping a disruptive technology: A case study The emerging microsystems and top-down nanosystems industry," *Technological Forecasting and Social Change*, vol. 71, pp. 161-185, 2004.
- [13] R. S. Robert, "Technological innovation in the semiconductor industries: A case study of the international technology roadmap for semiconductors", Ph.D. Dissertation, George Mason University, 2004.
- [14] S. Noordijn and P. I. Robert, "From theory to practice: Challenges in operationalizing a technology selection framework," *Technovation*, vol. 26, pp. 324-335, 2006.
- [15] L. Argote and P. Ingram, "Knowledge transfer: A basis for competitive advantage in firms," *Organizational Behavior and Human Decision Processes*, vol. 82, pp. 150-169. 2000.
- [16] Smart grid. [Online]. Available: http://www.kepco.co.kr/smartgrid_eng/



Won Il, Lee. Professor, He is the Professor at the department of business administration at Hanbat National University in Daejeon, South Korea. He received Ph.D. in business administration at Yonsei University, Seoul, South Korea. Before joining the faculty of Hanbat National University, he has worked for the KISTEP (Korea Institute of Science and Technology Evaluation and Planning) as a national science and technology planning researcher for years. His main research interests include technology strategy, R&D management and innovation clusters.