Standardization Roadmapping: Cases of ICT Systems Standards †

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Abstract

Despite a commonly held belief that standards obstruct innovation, recent research shows that they can actually play critical roles in supporting various activities of technological innovation. Thus, providing an innovation-friendly environment through standardization has been gaining much attention in recent years; however, there is as yet limited understanding, due to complex dynamics and high uncertainties associated with innovation, as well as a variety of different types and functions of standards with various stakeholders involved. The problem becomes even more challenging for standardization in highly complex systems, such as Information and Communication Technology (ICT) systems, where a large number of domains and components are involved, along with various types of stakeholders. In order to deal with such complexity and variations, a systematic approach of standardization roadmapping has been used in many technology-leading countries as a strategic policy tool for supporting effective management of standardization. Despite its wide adoption, the current understanding of standardization roadmapping is somewhat limited, leaving significant challenges for policymakers and standards organizations in terms of how to structure and manage roadmapping exercises, and how the government should get involved.

In this regard, the current research explores existing standardization roadmaps in various contexts related to ICT systems (ICT in Korea, Smart Grid in the US, and electromobility in Germany), as there is a particular need for systematic development of strategies for such complex systems of ICT. Focusing on various aspects of standardization roadmapping exercises such as their structures, processes, and participants, their common features and key characteristics are identified. Comparing these roadmaps also reveal distinct differences between standardization roadmapping approaches adopted by different countries in different contexts. Based on lessons learnt from existing practices, the study finally provides insight for the Korean ICT standards community on the ways in which their standardization roadmapping approach can be improved to support anticipatory management of standardization activities more effectively. It is expected that the current research

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can not only provide increased understanding of standardization roadmaps, but also help policymakers and standards organizations to develop more effective strategies for supporting innovation through the systematic management of standardization.

Keywords
innovation, standards, standardization roadmap, ICT systems

1. INTRODUCTION

1.1. Background & Motivation

There have been a prevailing perception that standards obstruct innovation by imposing certain constraints (Hanseth, Monteiro, & Hatling, 1996; Huh, 1998; Swann, 2010). However, there appears to be progressive understanding that standards, more generally, play critical roles in supporting innovation, including: defining and establishing common foundations upon which innovative technology may be developed; codifying and diffusing state-of-the-art technology and best practice; and allowing interoperability between and across products and systems, stimulating both innovation and diffusion of new technologies (Allen & Sriram, 2000; Blind & Gauch, 2009; Swann, 2010; Tassey, 2000). Therefore, there is an increasing realization that carefully constructed and implemented standards are crucial in transferring innovative ideas, hence facilitating innovation.

Such importance of standards and their effective management for innovation is being acknowledged in the real policy world as well. Korea and Japan have recently formulated international standardization strategies to improve their systems of standardization activities, as part of their national strategies promoting innovation and industrial competitiveness (CSTP, 2010; MCIE, 2011). The US also expanded research activities in their National Institute of Standards and Technology (NIST), promoting effective development and implementation of standards in order to secure national competitiveness in emerging technologies (White House, 2011). In addition, recognizing standards as effective policy tools supporting the Europe 2020 Strategy for smart, sustainable, and inclusive growth, the European Commission (2011) recently proposed various actions to improve the efficiency of their standardization processes.

With such policy initiatives, standardization roadmaps are used as one of the most adopted policy tools for supporting effective management of standardization, providing a systematic way of planning strategies for standards activities in an appropriate and timely manner. Standards developing organizations (SDOs) in many countries have developed standardization roadmaps in various areas where effective management of standards is of strategic national importance. Despite its wide adoption, the current understanding of standardization roadmapping is somewhat limited, leaving significant challenges for policymakers and SDOs when deciding structures and processes of the roadmapping exercise and how the government should get involved in the process.

In this regard, the current research proposes to explore existing standardization roadmaps in various contexts. By characterizing various aspects of standardization roadmaps in terms of their structures and processes, this study attempts to provide greater insight into the ways in which standardization roadmaps can support the effective management of standardization activities. With such new insight and understanding, the research aims to help standards organizations and policymakers develop more effective strategies, ensuring an anticipatory and timely management of standardization, supporting the overall innovation system.

1.2. Research Questions

This paper addresses the following research question and two interrelated sub-questions:
How can standardization roadmaps be used to support innovation of technology?
1) How are standardization roadmaps structured and developed in various innovation contexts?
2) What are the policy implications for effective management of standardization activities for supporting technological innovation?

2. LITERATURE REVIEW

2.1. Roles and Functions of Standards in Innovation

As "a voluntary process for the development of technical specifications based on consensus amongst the interested parties (Blind, 2009, p. 14)," standardization is noted by many academic scholars and policymakers as a powerful institutional mechanism that shapes innovation (Allen & Sriram, 2000; Bergek, Jacobsson, Carlsson, Lindmark, & Rickne, 2008; Ehrnberg & Jacobsson, 1997; Lundvall, 1992; Smith, 1997; Swann, 2010; Tassey, 2000). Recognizing its significance, various innovation literature have strongly emphasized important functions of various types of standards in innovation systems, with particular focus on the functions of legitimation, influence on the direction of search, development of positive externalities, and knowledge development and diffusion.

2.1.1. Legitimation

As a matter of social acceptance, legitimacy provides the new innovation system with appropriateness and desirability so that resources are mobilized and demand is formed; hence, it is a prerequisite for the advent of new innovation systems (Bergek et al., 2008). Standards provide this legitimacy by providing and communicating necessary information, therefore reducing uncertainty and stimulating interactive learning activities (Edquist & Johnson, 1997; Lundvall, 1992; Van de Ven, 1993). More specifically, they increase the acceptance of, and confidence in, new products and services through various types of standards, such as health, safety, and quality standards (Blind et al., 2004). In addition, as an industry consensus process, standards-setting also provides legitimacy and increases social acceptance by mitigating conflicts that may arise between different innovations (Carlsson & Stankiewicz, 1991).

2.1.2. Influence on the Direction of Search

Setting standards pertaining to specifications and performance criteria – that new products are expected to meet – has significant influence on guiding directions of search and learning activities in innovation systems (Edquist & Johnson, 1997; Smith, 1997). Standards are also powerful mechanisms for selecting dominant designs or specific technologies from among competing possibilities, thus providing important guidance in a technical sense (Lundvall, 1992; Van de Ven, 1993). Therefore, by channeling entrepreneurial resources and other innovation activities towards certain technological changes or specific technical designs, standards have great influence on guiding innovation systems toward particular directions.

2.1.3. Development of Positive Externalities

Establishing a coordinated acceptance of technical norms, standards also generate positive network externalities, i.e. benefits to users of a system rise with the increasing number of users (Smith, 1997). Hence, standardization may increase attractiveness for customers, leading to rapid diffusion of new innovation systems (Ehrnberg & Jacobsson, 1997). On the other hand, an absence of similarity standards may lead to a fragmented market lacking economies of scale, hence blocking market formation (Swann, 2010).

2.1.4. Knowledge Development and Diffusion

Standards foster the process of knowledge diffusion by not only allowing efficient dissemination of critical information and accumulated technological experience, but also forming a baseline from which new technologies and innovations emerge (Allen & Sriram, 2000; Blind et al., 2004; Sherif, 2001; Tassey, 2000). In addition, compatibility and interface standards help establish successful linkages between various components, contributing to knowledge development and entrepreneurial experiment (Bergek et al., 2008). It is also noted by Swann (2010) that quality and performance standards support knowledge development processes by enhancing competence building among competitors.

As discussed above, standards play many critical roles in the overall functioning of innovation systems. Recognizing such importance, policymakers and SDOs have introduced a number of policy initiatives and government programs for the effective management of standardization activities, with standardization roadmapping being one of the most common policy instruments among them. The following section reviews existing literature on roadmapping and standardization roadmapping approaches used for strategic planning and innovation.

2.2. Roadmapping for Strategy and Innovation

As a pioneer of the roadmapping approach, Galvin (1998) defines "roadmap" as "an extended look at the future of a chosen field of inquiry composed from the collective knowledge and imagination of the brightest drivers of change in that field (p. 803)." Although there are many different types of roadmaps, they all seek to answer three simple questions: (i) where do we want to go, (ii) where are we now, and (iii) how can we get there (Phaal, Farrukh, & Probert, 2010). The roadmapping approach has become one of the most extensively used techniques for supporting strategic planning and innovation; it has also been widely used in public domains, in order to influence policy, research funding, and standards (Phaal & Muller, 2009). This is due to its ability to provide a coherent, holistic, and high-level integrated view of complex systems, while displaying the interactions between various innovation activities over time (Groenveld, 2007; Kostoff & Schaller, 2001; Popper, 2008). Such a systems-based approach of strategic roadmapping is also potentially useful in managing and developing strategies for standardization activities in support of innovation, as a practical and operational tool for observing how standardization and other innovation activities influence each other with a more careful level of analysis.

2.2.1. Strategy as Process

As roadmapping is a technique used in strategy development, it is appropriate to first explore the process of developing strategies more generally. Comparing published process models for business and technology strategy, Phaal et al. (2010) developed a generalized strategy process model comprising of the following steps:

1. Vision and goals: to establish a sense of direction, in terms of a future vision and goals.
2. Appraisal of current position: to collate and assess information currently available, together with a review of current and historical strategies, activities, and performance.

3a. Assessment of external environments: to collect and assess information relating to external factors, issues, and drivers to identify opportunities and threats.

3b. Assessment of internal environments: to collect and assess information relating to internal resources, capabilities, and constraints, to identify strengths and weaknesses.

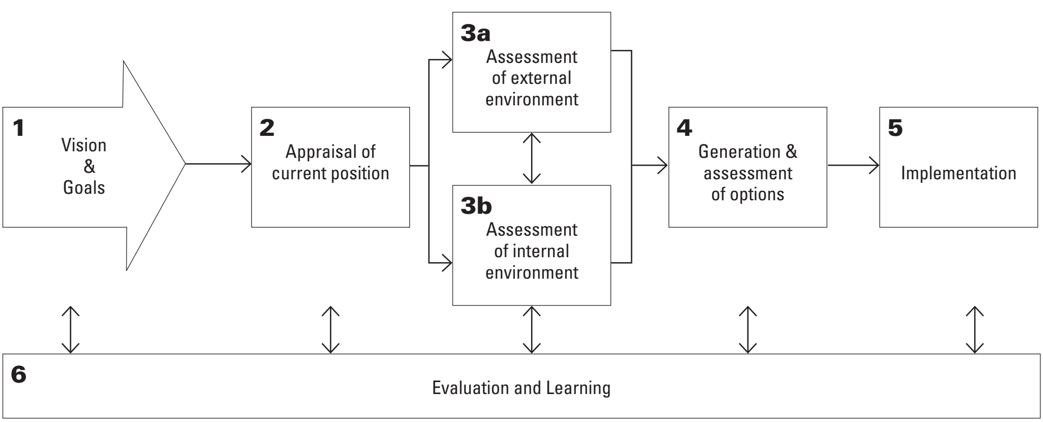
4.Generation and assessment of strategic options: to generate strategic options, identify gaps, and assess and select the options to derive strategic plans.

5.Implementation: to put the strategic plan into action.

6.Evaluation and learning: to review outcomes and disseminate results.

The overall process is represented in Figure 1.

FIGURE 1. Generalized Strategy Process Model



Source: Phaal et al. (2010)

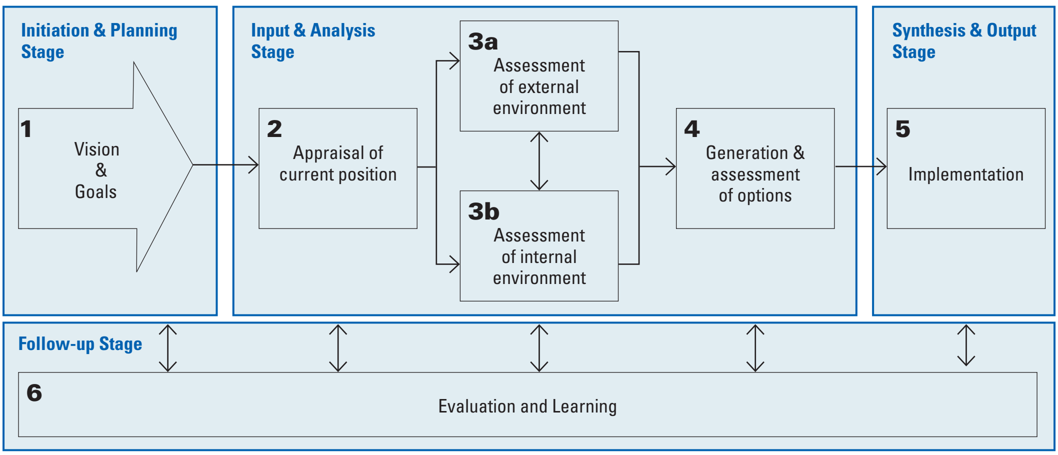
2.2.2. Roadmapping Process

There are no hard and fast rules on how to perform strategic roadmapping, and the process will differ depending on various factors such as the purpose and type of roadmap. Having said that, the following steps are presented in various literatures as a general guideline for roadmapping processes (European Industrial Research Management Association, 1997; Groenveld, 2007; Phaal & Muller, 2009):

- Initiation and planning: to define scope, objectives, and boundaries of the roadmap, and identify participants, structure, and process of developing the roadmap.
- Input and analysis: to capture, structure and share relevant knowledge.
- Synthesis and output: to create the roadmap through convergence and synthesis, and implement to fulfill the objectives.
- Follow-up: to review and update the roadmap; this is very important, as roadmapping is an ongoing learning process, rather than a single, one-off activity

These steps can be mapped onto the generalized strategy process model, emphasizing the strategic purpose of roadmap development (see Figure 2).

FIGURE 2. Process of Developing a Roadmap through a Generalized Strategy Process Model



Source: the author, based on Phaal et al. (2010)

2.2.3. Roles & Purposes of Roadmap

In practice, strategic roadmaps are developed for various purposes. They can be used not only to survey what are the various possible futures, based on what is known today (exploratory roadmapping), but also to examine how a particular scenario could be reached or avoided, based on clearly defined future targets or expectations (normative roadmapping) (Beeton, Phaal, & Probert, 2008). As both a learning experience and a communication tool for roadmapping participants, strategic roadmapping have important roles including:

- Bringing a consensus and creating a common vision among various stakeholders
- Providing guidelines for decision makers
- Analyzing current status and identifying possible opportunities and barriers
- Planning and formulating strategies and actions
- Improving cross-functional communication and coordination for innovation systems

(Amer & Daim, 2010; Garcia & Bray, 1997; Groenveld, 2007; Phaal et al., 2010; Rinne, 2004) These roles of strategic roadmapping are also relevant to certain functions of standards in innovation systems: bringing consensus among various actors, they increase social acceptance, providing legitimation; as a communication tool, they facilitate knowledge diffusion, by allowing dissemination of critical information; and roadmapping also influences the direction of search, by guiding innovation activities towards certain directions.

2.2.4. Existing Standardization Roadmaps

As an early outcome of roadmapping is often the identification of key gaps in knowledge and their context, the approach is also used in various countries as a practical way of identifying standard gaps (Phaal et al. 2010). Focusing more on standards perspectives, standardization roadmaps not only help identify key standard needs, but also generate plans to align necessary standardization activities in support of technological innovation. The approach is particularly useful in areas related to ICT systems, where interoperability and interface standards are essential for different components and systems to function properly. In addition, anticipating standard needs and developing them in an appropriate and timely manner are becoming increasingly important, as modern ICT systems are becoming more complex, fast-paced, and interdisciplinary in nature. Therefore, a number of standardization roadmaps have been developed in various contexts of ICT systems, where strategic management of standardization activities is critical for interoperability of highly complex, multidisciplinary systems with different types of stakeholders involved (JISC 2010; NIST, 2012; NPE, 2012a; TTA, 2013).

These standardization roadmaps take a variety of forms and processes, and are adopted at various levels to suit different strategic and innovation contexts. This demands careful planning and design of the roadmapping exercise, including how to structure roadmapping processes and select participants. However, studies exploring and comparing standardization roadmaps published in various contexts are limited, despite the fact that different approaches seem to be adopted by different countries with different contexts (Miao et al., 2012; Min, Cho, & Hahm, 2012). This leaves significant challenges for policymakers and SDOs in designing standardization roadmapping exercises. Therefore, in order to fill this research gap, the current study proposes to investigate how existing standardization roadmaps are structured and managed to support innovation in various ICT systems areas.

3. RESEARCH METHODOLOGY

3.1. Case Study Design

In order to explore existing standardization roadmaps in various contexts, multiple case studies were carried out. First, a preliminary study was performed to explore the ICT Standardization Strategy Map in Korea (Case A, hereafter referred to as “ICT standardization roadmap”), due to its long history of development since 2003, thus plentiful data available.

As Korea rapidly gained in technology capacity in recent decades, it also adopted a number of policy initiatives toward increasing its competitiveness in the international standards community, in order to gain technology leadership and secure global market access. Focusing on niche target areas with high potential, various initiatives were introduced to integrate technology and standards development. One policy tool was to develop the ICT standardization roadmap, which played an important role in Korea's catch-up in ICT standards activities; Korea used to adopt and implement existing standards developed by other countries up to the 1990s, whereas now it is an active participant, proposing and developing many standards with their own technologies. (Choung, Hameed, & Ji, 2012)

In this exploratory case study, many interviewees agreed that such roadmapping exercises supported the Korean ICT innovation system by guiding standardization activities in a more anticipatory and harmonized way. However, a number of limitations were also identified by various interviewees. Focusing on specific targeted technologies, the roadmap lacks a holistic and integrated view of various factors and disciplines that are important in overall innovation systems. This results in significant challenges as Korea is moving towards becoming a technology leader in emerging sectors of ICT systems, where systems are becoming more interdisciplinary and complex in nature, integrating various disciplines and involving a variety of stakeholders. In addition, unlike mature technologies, it is less obvious to identify standard gaps in areas that are not yet fully understood, hence the difficulty in proactively driving standardization activities. Therefore, in order for Korea to transform from a follower to a leader of technology and standards, a more systematic and holistic approach is needed for effective management of standardization in ICT systems, according to various interviewees.

Subsequent preliminary studies were then carried out, in order to explore other standardization roadmaps that might suggest how the ICT standardization roadmap in Korea can be improved to overcome such limitations. The following is a list of selected existing standardization roadmaps developed in emerging areas of ICT systems at earlier stages of their industrial development, where a more systematic approach of strategic management is needed to navigate complexities and uncertainties associated with the system:

- NIST Framework and Roadmap for Smart Grid Interoperability Standards in US
- NIST Cloud Computing Standards Roadmap in US
- German Standardization Roadmap for E-Energy / Smart Grid
- German Standardization Roadmap for Electromobility
- German Ambient Assisted Living (AAL) Standardization Roadmap
- Japan's Roadmap to International Smart Grid Standards

The NIST Framework and Roadmap for Smart Grid Interoperability Standards in the US (Case B1, hereafter referred to as "Smart Grid standardization roadmap") and the German Standardization Roadmap for Electromobility (Case B2, hereafter referred to as "electromobility standardization roadmap") were selected for further case studies, to compare with the ICT standardization roadmap in Korea. They not only provide diversity of contexts in limited time and resources, but also deal with greater challenges of alignment and coordination issues in standardization activities, as they are multidisciplinary areas with various different stakeholders involved. In addition, Germany and the US are the two most competent countries in the international standards community, measured in terms of criteria such as number of editors and contributions (Choi, 2013a). Hence, the two cases represent good examples of standardization roadmaps adopted by leaders of technology and standardization, as policy tools for supporting systematic and anticipatory standardization activities of emerging, complex ICT systems. Therefore, with the ICT standardization roadmap in Korea as the main case study, a comparative analysis of these three cases can not only reveal the nature of standardization roadmaps, but also suggest how they support effective management of standardization and innovation of ICT systems.

3.2. Research Methods

For this case study, mostly qualitative data were collected through archival documents and expert interviews. Documents such as standardization roadmaps, official reports published by governments and SDOs, and industry trade magazines provided reliable and detailed information on standardization roadmapping exercises. Expert interviews were also carried out to help understand the background of major activities, which may be difficult to access through document sources alone. Interviewees were selected from various organizations – such as government agencies, companies, research organizations, and academia – involved in standardization roadmapping. For the main case study, thirty interviewees from various areas of ICT participated in the research; many of these interviews were conducted in areas of "convergence service", in order to explore the challenges associated with more complex and interdisciplinary areas. For the other two shorter studies, main data came from documentary sources, supplemented with information provided by two interviewees from the US and one interviewee from Germany, helping the researcher validate the desk research and gather further insight relevant to the comparative analysis.

Collected information was analyzed mainly through two parts: within-case analysis and cross-case comparisons. Typically involving detailed case study write-ups for each of the cases, within-case analyses allowed the unique patterns of each case to emerge, helping the investigator with the generation of insight. Then, through the use of structured and diverse lenses on data, cross-case comparisons searched for patterns across different cases, allowing the researcher to capture novel findings with a close fit with the data. (Eisenhardt, 1989)

4. CASE STUDIES

4.1. Case A – ICT Standardization Strategy Map in Korea

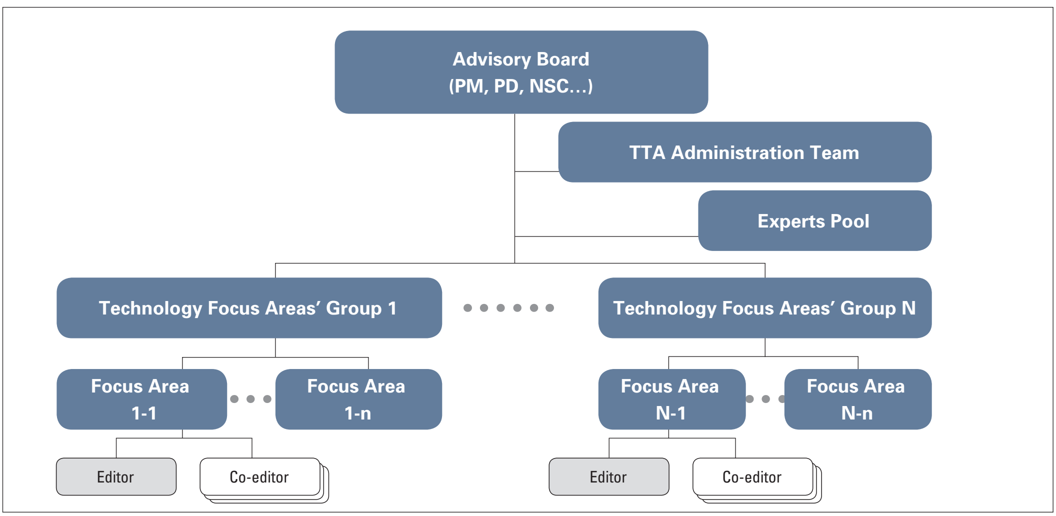
4.1.1. Empirical Context

According to many government officials and standards experts in Korea, standards have long been understood as significant a national resource to secure international market access, as 90% of Korea's Gross Domestic Product (GDP) relies on exports. Standards became even more important with the development of the ICT industry, where compatibility and interoperability are essential for systems to function properly. Recognizing such importance, Korea has been developing the ICT Standardization Roadmap since 2003 – which later changed its name to ICT Standardization Strategy Map in 2010, with more focus on strategies –, as a way of supporting targeted technology areas in line with government policies (Choung, Ji, & Hameed, 2011). Funded by the government, the Telecommunications Technology Association (TTA), an industry association for developing voluntary industry standards for wide areas of ICT, leads the development of ICT standardization roadmap every year, providing a detailed time plan of what standards to be developed by which organizations with what strategies.

4.1.2. Governance Structure

Figure 3 represents the governance structure of developing the ICT standardization roadmap. Consisting of high-profile standards experts including Project Managers (PMs), Program Directors (PDs), National Standardization Coordinators (NSCs), and other government officials, the Advisory Board advises the management of the roadmapping process, while a group of researchers at the TTA Administration Team coordinates and provides support for the overall development of the roadmap. The actual contents of the roadmap are developed by participants selected from the Experts Pool, divided into groups according to technology focus areas. Each focus area team consists of a chief editor and multiple co-editors.

FIGURE 3. Governance Structure of the ICT Standardization Roadmap in Korea



Source: the author, based on TTA (2013)

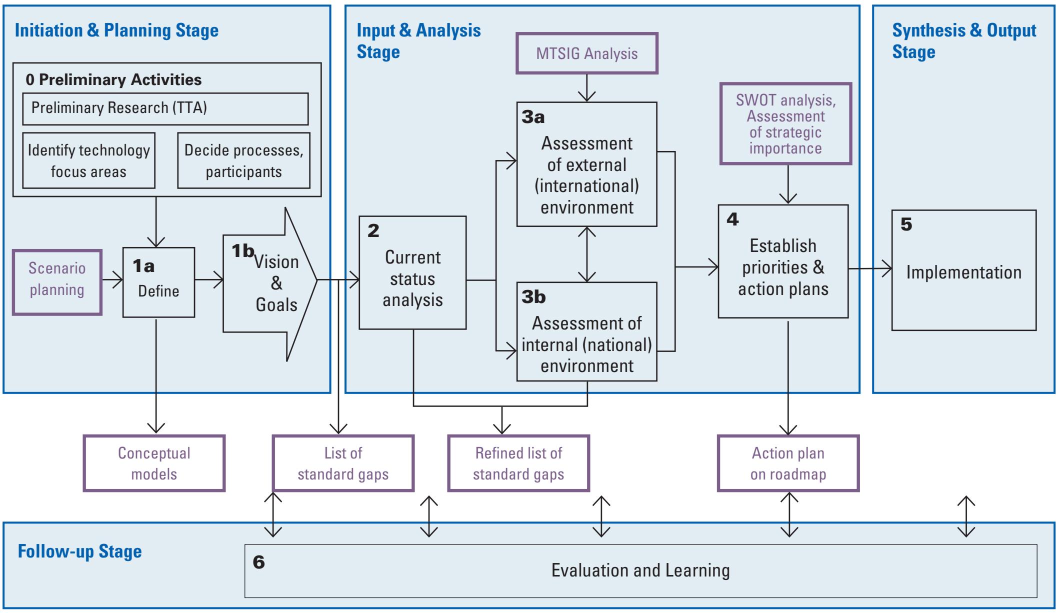
4.1.3. Participants

According to multiple interviewees, participants in developing the roadmap were selected from a pool of experts within the national and international standards community. They were invited by recommendations from the TTA administration team or the participants of the previous year; however, as technology focus areas remain more or less the same every year, there is subsequently little change among the participants as well.

4.1.4. Roadmapping Process

The following figure represents the overall process of developing the ICT standardization roadmap, based on Ver. 2013. Although it was developed more iteratively rather than being structured, and detailed processes varied depending on technology focus area, the general process followed four stages identified earlier: planning, analysis, synthesis, and follow-up.

FIGURE 4. Roadmapping Process of ICT Standardization Roadmap in Korea



Source: the author, based on Phaal et al. (2010), TTA (2013)

Step 0: Preliminary Activities

A number of preliminary activities were carried out, before the actual roadmapping process was started. First, the administration team at TTA conducted preliminary research; they identified potential areas of standard needs through keyword research on current standardization activities of major international SDOs, technological trends, government policies, and standards proposals by researchers. The Advisory Board then confirmed the list of focus areas; in 2013, thirty-one focus areas were selected and categorized into five groups (convergence service, contents/platform, communication, TV/broadcast, and information security). For each focus area identified, participants of roadmapping were determined from the experts' pool, along with the process and structure of developing the roadmap. (TTA, 2013)

Step 1: Definitions, Vision and Goals

The first step of developing the roadmap was to define each technology focus area and identify its vision and goals. Defining the technology not only helped reduce confusion and ambiguity, but also gave an overall view of the system they were dealing with. Planning service scenarios and developing conceptual models sometimes facilitated this process. According to an interviewee, scenario planning could be used to observe how systems needed to be developed in order to provide intended services to customers; while drawing conceptual models allowed a better understanding of overall technological systems and structures from a more holistic view, by identifying all domains and actors, their functions and characteristics, and their relations to each other. They usually existed as drafts in the beginning, and were often revised and updated at later stages as they reflected various input and analyses during the roadmapping process. Then visions, objectives, and expected outcomes of standardization were defined in order to guide the direction of roadmap; according to interviewees, these works were either collaboratively conducted by co-editors, or reviewed by them once done by a chief editor. Once the vision and goals were identified, participants listed detailed areas of technology with potential standard needs. Most interviewees said that it is obvious which standard gaps needed to be addressed, not only because participants were standards experts in their areas of expertise, but also because key trends and issues in technology and standards had already been analyzed in the previous year. According to an interviewee, since many participants were also involved in TTA project groups or forums that actually work on standards development, general consensus on which area need more attention to develop standards could be easily reached, and those are identified as standard gaps. (TTA, 2013)

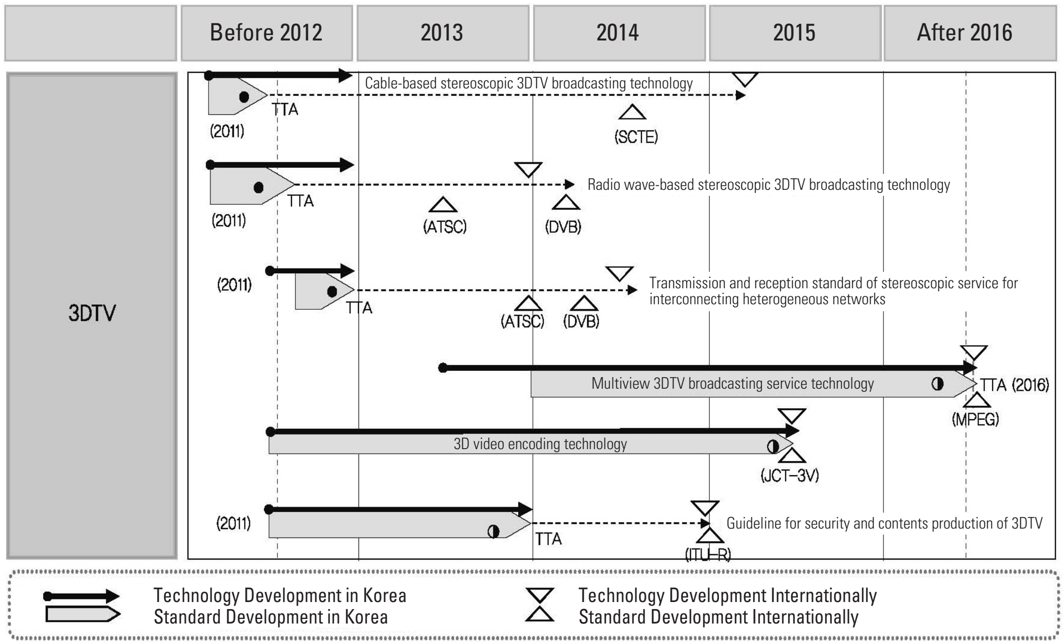
Steps 2 and 3: Analysis of Current Status and Assessment of Environments

For each standard gap identified, an analysis of current status and assessment of (inter) national environments were carried out in terms of market, technology, standards, intellectual property (IP), and government policies and key industry environments (MTSIG analysis). According to interviewees, work was usually distributed to participants according to their detailed areas of expertise; however, participants from research organizations – mainly from the Electronics and Telecommunications Research Institute (ETRI) – tended to take the main responsibility for analysis, while the others participated by giving feedback on the content developed by them. As a result, analyses and assessment generally focused on technology and standards perspectives, based on the knowledge and insight of researchers and information from publications of SDOs. Throughout these steps, the list of standard gaps was sometimes modified, as analyses of current trends and issues revealed new information. (TTA, 2013)

Step 4: Establish Priorities and Action Plans

According to interviewees, the next step involved analyses of strategic importance and the urgency of each standard gap in order to prioritize and develop action plans for standards developments. Participants conducted SWOT analyses, along with assessment on the strategic importance of each standard gap, based on criteria such as national competence in technology and standardization, contributions in international SDOs, the potential to secure IP, impact on industry, and alignment with government policies. Based on these evaluations, strategic positions – such as shaper, co-shaper, reserver, or adopter – for each standard gap were determined, with time plans for which SDO to develop a corresponding standard. Once strategies were individually developed by participants, they were reviewed by other co-editors in a meeting, in order to ensure objective and consistent assessment, especially between areas that were closely related to each other. They were then collated to form a medium-term roadmap (see Figure 5 for an example of 3DTV, a 2013 focus area), which was later reviewed by chief editors and reviewers from other focus areas as well. (TTA, 2013)

FIGURE 5. Medium-Term Standardization Roadmap for 3DTV



Source: the author, based on TTA (2013)

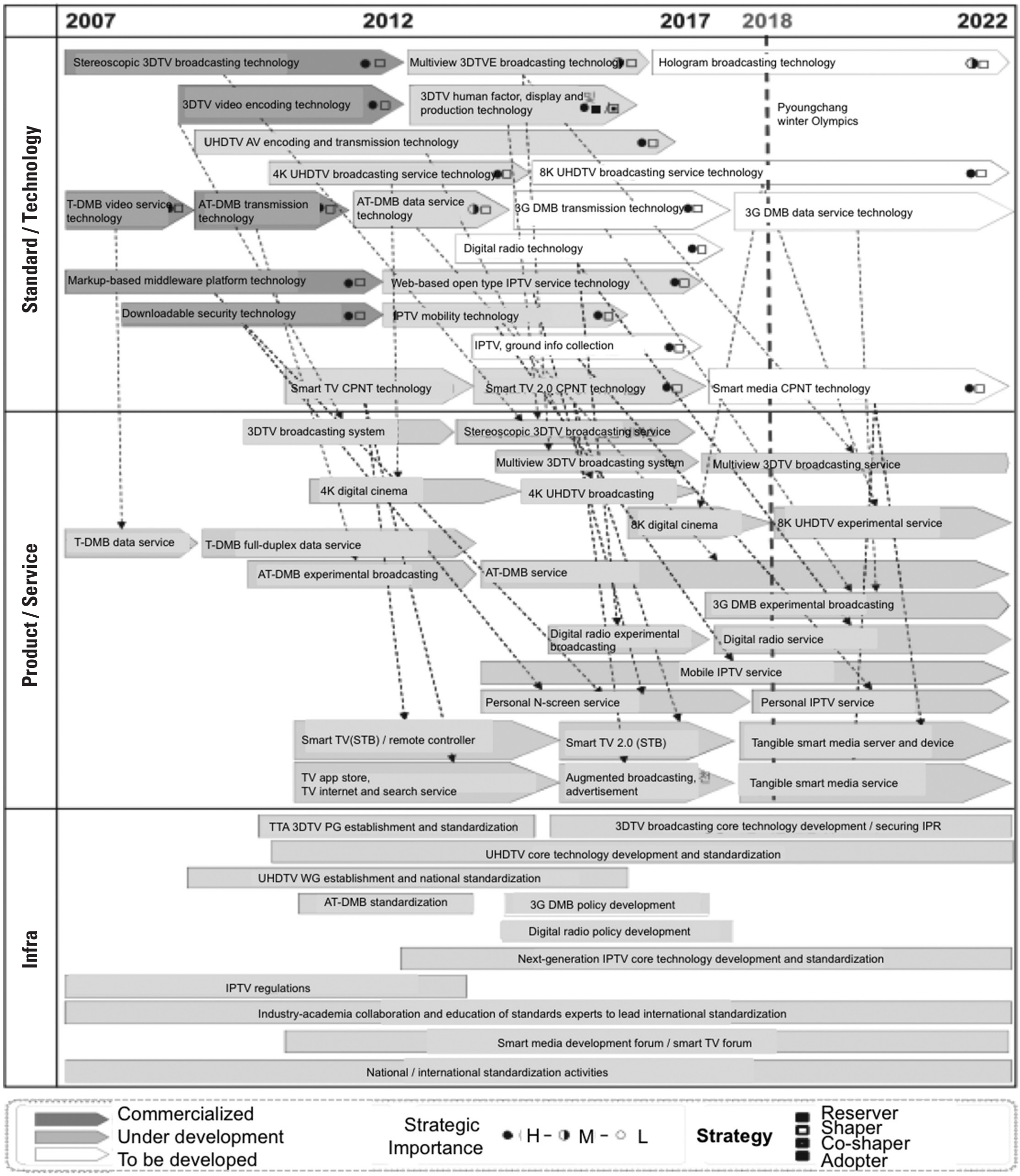
Step 5: Implementation

The final long-term roadmap was developed by consolidating medium-term roadmaps of each focus areas' group, and adding layers of relevant products and services, and infrastructure (see Figure 6 for an example in TV/broadcast). It was published after review in an open workshop, where standards experts and members of the public who did not participate in roadmapping were invited to comment on the final output. According to an interviewee, the published roadmap was used as important guidelines for the government and industry when developing strategies for standardization and R&D activities; it sometimes provided evidence base for the government in deciding which standards activities to fund, while developed strategies were applied in TTA's standards development. Companies could also obtain information on current trends of technology and standards, as well as directions of government policies. (TTA, 2013)

Step 6: Evaluation and Learning

According to interviewees, the TTA conducted a survey asking participants' opinions on the overall process of roadmap development, and used this information to revise and improve the structure, process, and management system of developing the roadmap next year.

FIGURE 6. Long-Term Standardization Roadmap for TV/Broadcast



Source: the author, based on TTA (2013)

4.2. Case B1 – NIST Framework and Roadmap for Smart Grid Interoperability Standards

4.2.1. Empirical Context

Although definitions and terminology vary sometimes, the Smart Grid generally refers to an advanced power grid for the next generation, integrating many varieties of ICT and services with the existing power-delivery infrastructure. Bidirectional flows of energy and two-way communication and control capabilities will allow electricity from a diverse range of power plants (including renewable energy) to be delivered to consumers, not only improving power reliability, but also reducing carbon emissions and reliance on oil consumption. The Smart Grid has a number of characteristics that have huge impact on its standardization activities:

- Highly complex system of devices and infrastructure
- Large number of actors involved in its development and operation
- Potential added value of interoperability across regional and national boundaries
- Increased vulnerability to cyber-attacks due to greater ICT-enabled critical national infrastructure (O'Sullivan & Brévignon-Dodin, 2012)

Due to such characteristics, the development of appropriate and readily available standards is critical in supporting the interoperability, integration, and security of the Smart Grid. Hence, in 2007, the Energy Independence and Security Act of the US assigned the NIST the "primary responsibility to coordinate development of a framework…to achieve interoperability of smart grid devices and systems" (NIST, 2010, p. 7).

According to the NIST, it was realistic to expect public policies and business practices for the Smart Grid to evolve incrementally, given the regulatory framework and market structures. In order to accelerate the pace of this evolution, policy officials and business executives need to use consistent definitions, terminology, and analysis methods, and understand the implications of their practices for the Smart Grid and its interoperability (Thomas, Hamilton, & Kim, 2010). Therefore, the NIST developed a three-phase plan to expedite development of key standards:

- The first phase involved engaging utilities, equipment suppliers, consumers, standards developers and other stakeholders in a participatory public process to publish a report that documents the Smart Grid architecture, an initial set of interoperability standards, and a roadmap for addressing remaining standard needs.
- The second phase involved launching a formal public-private partnership to coordinate and facilitate development and evolution of additionally needed standards.
- The third phase involved developing an overall plan for testing and certification to ensure conformance of Smart Grid devices and systems. (Electric Power Research Institute, 2009a)

As the output of the first phase of the NIST plan, The "NIST Framework and Roadmap for Smart Grid Interoperability Standards" was developed to help guide and align the development of standards in the Smart Grid area (NIST, 2010).

4.2.2. Governance Structure

The NIST awarded the Electric Power Research Institute (EPRI) with a contract to engage Smart Grid stakeholders and develop a draft interim standards roadmap (EPRI, 2009a). As an independent, nonprofit organization representing the electric utility industry and its customers, EPRI conducts research on issues related to the generation, delivery, and use of electricity in the US

(EPRI, 2012). According to an interviewee, it had research expertise in the IntelliGrid program, which provided a good starting point for the process of developing the roadmap. The program created a structured process for roadmap development, called the Smart Grid Roadmap Methodology (SGRM), helping define the technical requirements of the future Smart Grid system technologies (McGranaghan, Von Dollen, Myrda, & Gunther, 2008).

Using SGRM as a basis, the NIST and EPRI worked with a broad spectrum of stakeholders in the industry to develop and evolve the framework and roadmap. The first version of the roadmap was developed in 2009 under the leadership of Dr. George Arnold, a Director of the NIST Smart Grid Team and also “Smart Grid National Coordinator” at the time. His career history involved not only working at Bell Laboratories addressing interoperability challenges and standardization issues related to telecoms network systems, but also representing the US in various international SDOs; his particular expertise and experience played an important role in gathering and commanding trust from various members of the Smart Grid community, both from the public and private sectors (O’Sullivan & Brévignon-Dodin, 2012).

4.2.3. Participants

The whole Smart Grid community was deeply involved in the process of developing the roadmap, throughout public workshops facilitated by EPRI and NIST, as well as through Domain Expert Working Groups (DEWGs) meetings. Hundreds of stakeholders participated in these workshops and represented a wide variety of perspectives, including transmission and distribution, markets, storage, smart buildings, businesses, finance, and policymakers. Then, by working on existing standards evaluation and use case development, they all contributed to refining and completing the framework and roadmap. (EPRI, 2009a; NIST, 2010)

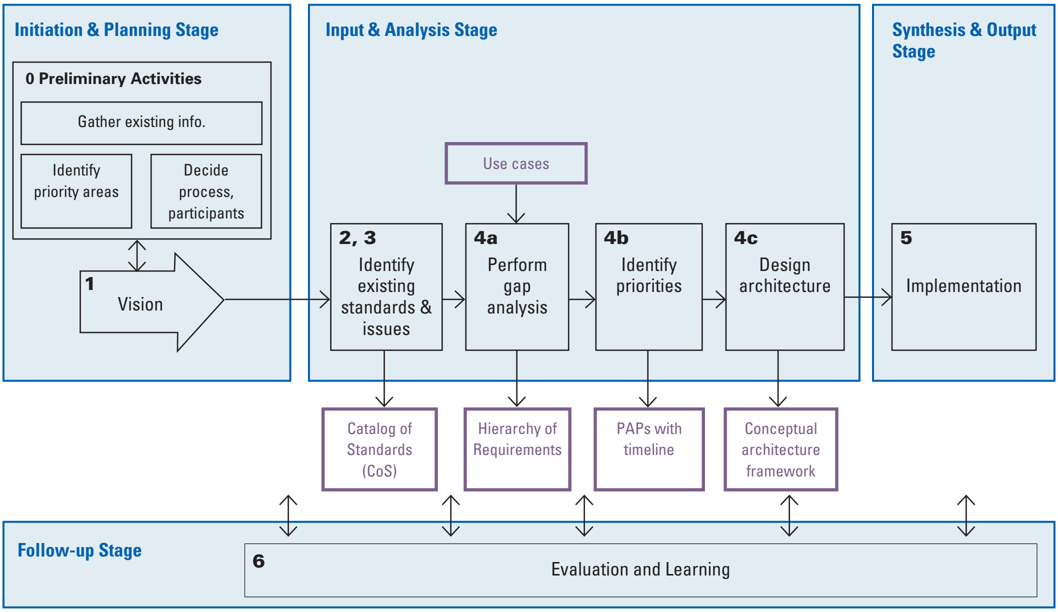
4.2.4. Roadmapping Process

Figure 7 summarizes the overall process of the Smart Grid roadmap development. The actual process, however, is less structured than the diagram. An interviewee noted that because the Smart Grid community had been working on a variety of things, many activities were actually carried out in parallel. Nevertheless, there was a general flow from left to right of the diagram, with many interactive activities and feedback loops in the input and analysis stage.

Step 0: Preliminary Activities

Before the actual process of roadmapping took place, the EPRI and NIST Smart Grid Team carried out a number of preliminary activities. First, existing information from previous work on the Smart Grid were gathered, such as the EPRI’s IntelliGrid program, the Modern Grid Initiative (MGI), and work done by the GridWise Architectural Council (GWAC) of the Department of Energy (DOE). Based on this information, a collective agreement was made among the DOE, NIST, and Federal Energy Regulatory Commission (FERC) to identify eight priority areas where standards were needed more urgently than others. Finally, the process and participants of developing the roadmap were decided. (NIST, 2010)

FIGURE 7. Roadmapping Process of Smart Grid Standardization Roadmap in the US



Source: the author, based on EPRI (2009a), NIST (2010)

Step 1: Identify Vision

Based on preliminary activities, the vision of Smart Grid was formulated, describing the destination for the technological and architectural paths to be described in the roadmap. The definition and characteristics of the Smart Grid were also articulated, representing widely accepted visions and principles among a variety of stakeholders on what the Smart Grid should be like in the future (EPRI, 2009a).

Input and Analysis Stage

According to interviewees, activities in this stage were generally carried out iteratively rather than linearly. This was because as more information was gathered from the community and the concept and technology of the Smart Grid evolved, things needed to be revisited and modified, resulting in the evolution of the framework and roadmap.

Steps 2 and 3: Identify Existing Standards and Issues

The first workshop was held, with focusing on defining basic architecture, identifying current issues, and evaluating existing standards. According to interviewees, the workshop was organized with multiple breakout sessions for each track, designed based on DEWGs. Participants identified existing standards that could be immediately applied to meet Smart Grid needs, or were expected to be available in the near future. Following this workshop and a public review, a strong stakeholder consensus was made on the identification of twenty-five existing standards, which were later included in Catalog of Standards (CoS). (NIST, 2010)

Step 4a: Perform Gap Analyses by Developing Use Cases

The second workshop was held with breakout sessions based on functional priorities as well as crosscutting sessions; additional standards requirements were identified by analyzing use cases, locating key interfaces, and determining Smart Grid interoperability requirements (Ibrahim, 2009). Use cases describe the interaction between a Smart Grid actor and a system when the actor is using the system to accomplish a specified goal. In the Smart Grid standardization roadmap, a descriptive black box use case method was used (see Table 1 for more information about the method). The focus on black box use cases not only allowed maximum innovation in Smart Grid applications, but also ensured their ready deployment and interoperability within the Smart Grid as it evolves. For each use case, participants discussed how systems within the Smart Grid would interact; they then sought to identify actors in their domains, define information exchanges that fulfill the scenario, and finally specify relevant standard requirements that could carry these information exchanges. Requirements collected from various use cases were organized and categorized according to their type, resulting in hierarchy of requirements. They were then analyzed and compared against CoS; the remaining requirements were assessed as known deficiencies, hence identified as standard gaps that needed to be considered in the future. (EPRI, 2009a; NIST, 2012)

TABLE 1. Comparison Between Black Box and White Box Use Case Methods

Classification	Black box use case	White box use case
Characteristic	Descriptive	Prescriptive
Method	Describes the user/system interaction and functional requirements to achieve the goal, leaving the details of the inner workings of the system to the implementer.	Describes the internal details of the system, in addition to the interaction and associated requirements, not allowing the implementer to change the internal system design.

Source: the author, based on EPRI (2009a)

Step 4b: Identify Priority Action Plans (PAPs)

Once future Smart Grid standard needs were identified, the NIST selected a set of priorities for developing or improving standards and specifications necessary for building an interoperable Smart Grid, using the following criteria: immediacy of need, relevance to high-priority Smart Grid functionalities, availability of existing standards, state of the deployment of affected technologies, and estimated time frame. In order to address these priorities through the establishment of Priority Action Plans (PAPs), a third public workshop was organized, engaging more than twenty SDOs as well as user groups; they reviewed each PAP, produced a list of tasks with action items, and set timelines for accomplishing PAP objectives. (EPRI, 2009a)

Step 4c: Design Conceptual Architectural Framework

Architectural principles were then defined, in order to better support communications between various stakeholders. Architecture is “the conceptual structure and overall organization of the Smart Grid from the point of view of its use or design,” embodying “high-level principles and requirements that designs of Smart Grid applications and systems must satisfy” (NIST, 2010, p. 19). Based on a basic, simpler version of architecture designed during steps 2 and 3, gap analyses from use cases identified gaps in the architectural principles and concepts, resulting in the refined conceptual architecture framework. The final architectural framework included the following: (i) architectural goals for the Smart Grid; (ii) a conceptual reference model, comprised of the conceptual domain models with their actors and applications; (iii) models for Smart Grid information networks; (iv) a Smart Grid interface to the customer domain; and (v) conceptual business services. (NIST, 2012)

Step 5: Publication and Implementation

Once the EPRI's interim report was submitted, a request for public comments was issued in the Federal Register. Almost a hundred public comments were received and reviewed, serving as resources as NIST progressed further into developing the Smart Grid standardization roadmap. The execution of the identified PAPs began, and NIST continues to update the framework and republish the roadmap as needed. (NIST, 2010)

Step 6a: Evaluation and Learning – Create Smart Grid Interoperability Panel (SGIP)

Clearly, as new technologies emerge and the concept of the Smart Grid evolves, hundreds of standards will be required to build a safe and secure Smart Grid that is interoperable. Although workshops worked initially for building consensus, a structured system was necessary for an ongoing process in which people could effectively engage and interact, according to an interviewee. The NIST therefore established the SGIP as part of the second phase of its three-phase plan, in order to provide ongoing coordination, acceleration, and harmonization of SDOs' efforts for the timely availability of new or revised Smart Grid standards. Consisting of twenty-two stakeholder categories designed to address all key players' perspectives, the SGIP conducts ongoing identification of additional standard gaps, PAP prioritization, and the construction of timelines for addressing remaining gaps. (NIST, 2012)

Step 6b: Evaluation and Learning – Program Management

According to an interviewee, the importance of managing the overall program was recognized during the roadmapping process, thus Program Management Officers (PMOs) were created. PMOs made sure that every process was followed smoothly, mitigating any problems incurred, modifying processes, and creating new processes if necessary, as they learnt and gained more experience throughout the development. With regular meetings, the PMOs not only managed the overall process, but also dealt with the political dynamics among participants.

4.3. Case B2 –Standardization Roadmap for Electromobility in Germany

4.3.1. Empirical Context

Electromobility is gaining global importance, as it provides solutions to energy security and a sustainable environment while satisfying our mobility needs at the same time. Standardization in the field of electromobility is very challenging, as it involves coordinating and integrating diverse activities in different sectors that have been viewed as separate domains. Resulting in new points of contact and interfaces, this calls for a strategic approach to standardization of electromobility, considering various perspectives of different actors in this sector – including automobile manufacturers, electrical industry, energy suppliers and grid operators, technical associations and public authorities. Reflecting a general agreement among all these actors, a strategic, technically-oriented standardization roadmap is developed, in order for Germany to improve its competitive edge in the international electromobility market. (National Platforn Elektromobilititat, 2010)

4.3.2. Governance Structure & Participants

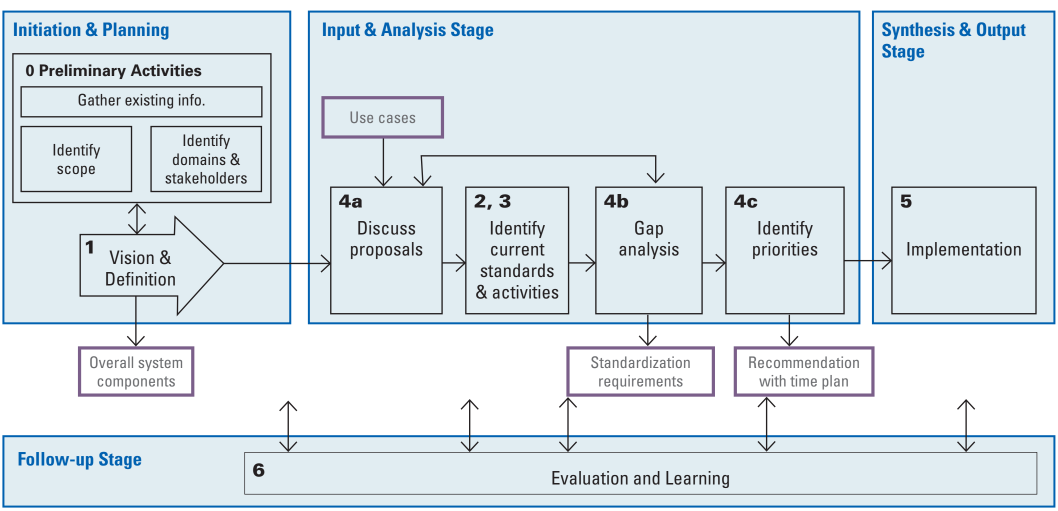
In order to coordinate activities in the electrical and automotive industries, a joint body of the DKE (the German Association for Electrical, Electronic & Information Technologies in DIN, the German Institute for Standardization) and NAAutomobile (the Road Vehicle Engineering Standards Committee of DIN), called the EMOBILITY steering group, was created. Issues concerning automobiles are dealt by NAAutomobile, while infrastructure issues are handled by the DKE; consisting of representatives from companies and associations in both electrical and automotive industries, the EMOBILITY steering group serves as an interface between the two. In addition, the government established a "National Platform for Electromobility (NPE)", involving a number of high-profile politicians and representatives of the industry. (NPE, 2010)

The roadmap was developed under the leadership of the EMOBILITY steering group, with participation of outside experts. DIN, DKE, and NAAutomobile used their network to gather experts from various parts of the industry, working on different topics of electromobility standardization. Since this was an industry-driven initiative, most of the participants were from the industry. The overall process of roadmap development was managed by DIN Electromobility Office, which supports work of the EMOBILITY steering group. (NPE, 2010)

4.3.3. Roadmapping Process

Figure 8 summarizes the overall process of developing the electromobility standardization roadmap. Similarly with the Smart Grid standardization roadmap, the actual process involves numerous iterations and feedback loops in the input and analysis stage. Multiple workshops were organized, with constant review of proposals and gap analyses to identify requirements.

FIGURE 8. Roadmapping Process of Electromobility Standardization Roadmap in Germany



Source: the author, based on Phaal et al. (2010), NPE (2010)

Step 0: Preliminary Activities

According to an interviewee, information was first gathered from previously conducted research and demonstration programs; some of these projects had to do with standardization, including the "ICT for Electromobility" program, "Key Technologies for Electromobility (STROM)", and the long-term "Innovation with Norms and Standards (INS)" program. Existing sources of information provided an overview of different aspects of electromobility that are considered in the roadmap, thus helping identify its scope. The participants of developing the roadmap were also invited at this step. (NPE, 2010)

Step 1: Vision and Definition

According to an interviewee, the first workshop was held in order to identify a common vision and the scope of the roadmap in detail. System components, domains, and subsectors relating to electromobility standardization – such as electric vehicles, charging infrastructure, and energy and data flows – were identified, along with crosscutting topics that affect all system components. Actors involved in various domains of electromobility standardization were also defined. (NPE, 2010)

Step 4a: Discuss Proposals for Standard Needs

A number of workshops covering different topics of electromobility were carried out repeatedly, with participants bringing in their proposals on what standards may be needed in the future. An interviewee noted that although developing use cases was not part of the workshop, experts would have certain use cases in mind that derived particular proposal. In addition, PricewaterhouseCoopers AG WPG (PwC), in cooperation with the Fraunhofer Institute and the Frankfurt University, carried out a study for DIN, adopting use case methods to determine the medium to long-term needs for standards (NPE, 2012a). Collected proposals were then discussed among participants to decide whether they were really relevant and necessary. In order to make sure that a consensus was made throughout the whole industry, participants further analyzed and verified needs for standards within their organizations after the workshop; hence, iterative discussions were carried out through several workshops.

Steps 2 and 3: Identify Current Standards and Activities

Once general agreements were reached on the validity of proposals, relevant national and international standards, along with other standardization activities that currently exist, were identified for each domain of electromobility (NPE, 2010).

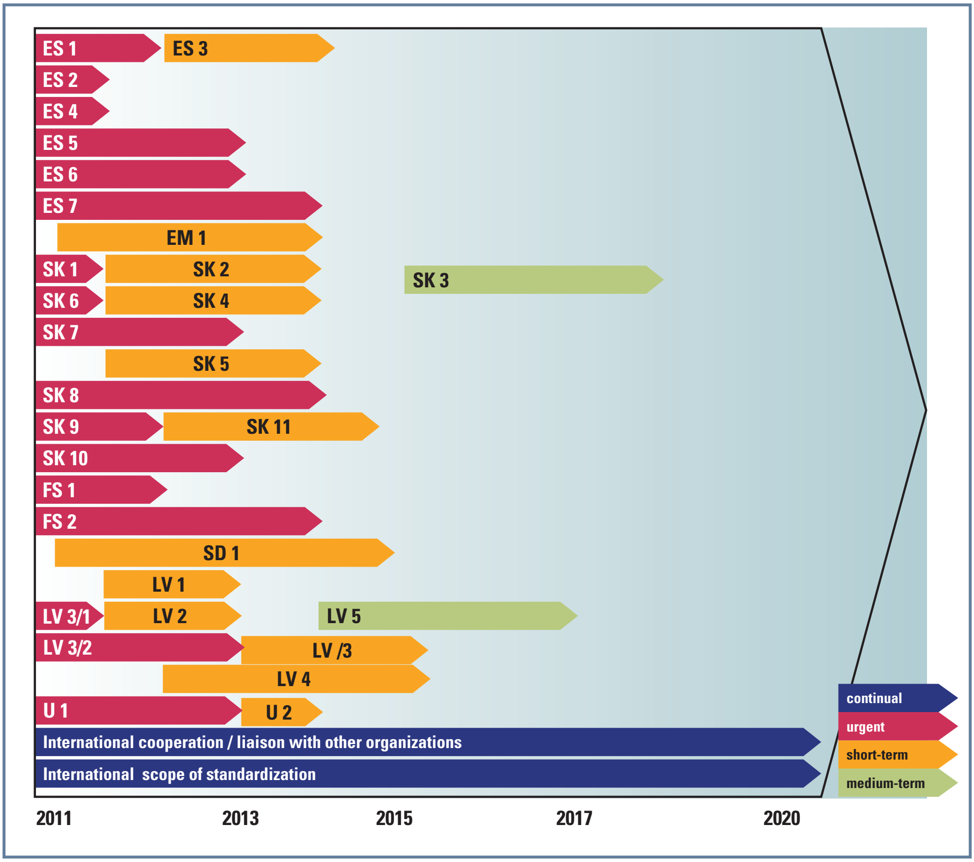
Step 4b: Gap Analysis

According to an interviewee, gap analyses were then carried out, by comparing the list of existing standards with the agreed standards proposals. The analyses helped define standards requirements that were not covered by existing standards or current standardization activities, for each domain of the overall system. Various aspects such as market trends and industrial contexts were also considered, when deciding whether these gaps were really necessary.

Step 4c: Identify Priorities

Finally, recommendations were made on what remains to be implemented as standards in order to close identified gaps, based on analyses of strengths and weaknesses with respect to national competence in electromobility. Interrelationships and linkages between various activities and projects were also considered when developing the final recommendations. Time schedules for implementations were then determined, based on priorities, required effort, necessity of clarifying the scope, and the need for more research, as shown in Figure 9. (NPE, 2010)

FIGURE 9. Time Schedule for the Implementation of Recommendations



Source: NPE (2012b)

Step 5: Implementation

The roadmap was published to form the core of standardization activities over the next few years at both national and international levels. The NPE had been participating actively in a number of international standardization communities that incorporated much of the content of Germany's standardization roadmap in their plans, including the Transatlantic Economic Council and the American National Standards Institute. (NPE, 2012)

Step 6: Evaluation and Learning

The roadmap is to be updated on a regular basis, in order to give experts the opportunity to take part in the roadmap by submitting comments and participating in standardization even after publication. According to an interviewee, updating the roadmap is essential, not only because more knowledge and experiences are gained, but also because the market and technology evolves; new topics may need to be addressed with the development of technology, or new standards may be required with the introduction of new services. (NPE, 2010)

5. CASE ANALYSES

Various aspects of standardization roadmaps in terms of their governance structure, participants, and roadmapping processes are examined through qualitative evidence collected from documents and interviews. Comparing and contrasting three cases, this chapter presents the similarities and differences between them, with particular focus on different strategic approaches adopted by different countries. Due to differences in maturity of both national standardization systems and technological capacity, the comparative study reveals interesting contextual and strategic variations between followers and leaders of standards and technology. This provides useful insight and inspiration for strategic approaches that Korea may consider adopting when developing its standardization roadmap, in its current challenges of transforming from a follower to a leader. Based on lessons learnt from effective practices of the US and Germany, along with comments from interviewees in Korea, this section finally suggests the ways in which the current approach of ICT standardization roadmapping in Korea potentially can be improved to overcome its limitations.

5.1. Key Findings on Standardization Roadmap Development

Comparing the three case studies, this section analyzes key findings on common characteristics of standardization roadmaps and roadmapping exercises in various contexts.

5.1.1. Roadmapping Process

Although the three standardization roadmaps were developed in different contexts at different levels, they all follow a general roadmapping process consisting of the following stages:

- Initiation and planning: to gather existing information, decide roadmapping processes and participants, and identify focus, scope, vision, and goals of the roadmap.
- Input and analysis: to identify the current status of relevant standardization landscape, analyze standard gaps, and establish action plans for standards development.
- Synthesis and output: to publish the roadmap and execute action plans.
- Follow-up: to receive feedback and implement any lessons learnt for the future.

5.1.2. Architectural Frameworks of the Overall System

In cases A and B1, visual representations of high-level views of the system were developed in the roadmapping process, in the form of conceptual models and architectural framework. According to an interviewee, the focus on architectural concepts helps participants understand how different domains and actors can be integrated into the overall system. This is important when different participants need to communicate with each other, as researchers and technical experts tend to focus on very specific and detailed areas of their expertise, which are small part of the whole system. In addition, as modern technologies are becoming more complex and interdisciplinary in nature, having a big picture of the overall system is particularly useful.

5.1.3. Different Roles Played by Different Stakeholders

Many interviewees have recognized the importance of selecting appropriate participants in developing the roadmap, as the roadmap heavily relies on the knowledge and insights they bring into the process. In addition, stakeholders from different types of organizations play different roles in developing the roadmap, hence selecting an appropriate mix of participants from various organizations is important in order to collect a balanced view of the industry.

According to interviewees in all three cases, participants from businesses – including manufacturers, service providers, and utilities – make substantial contributions on how systems actually work and what is really important in the industry, as they are usually at the cutting edge of the industry, with a better understanding of customer needs and current market trends. Meanwhile, participants from research organizations provide the latest technical knowledge in emerging areas that are still in research stages. They also contribute to areas where public good aspects need to be considered, as they are mostly nonprofit organizations funded by the government. For example, some interviewees noted that research organizations play critical roles in areas where interoperability standards are needed for communication between products and systems developed by different companies, such as smart work and cloud computing. Participants from academia also play important roles by not only providing varied perspectives to increase overall values in the industry and society, but also providing longer-term views that companies and research organizations may not yet be aware of.

As they all have different contributions and perspectives, participants from different organizations may play a more important role in developing standardization roadmaps at different stages of technology development. According to interviewees from Korea, opinions of researchers doing basic R&D may be considered more important at an early stage of industry, as the focus is given on the physical development of technology. On the other hand, manufacturers and service providers need to play a more active role during the stages of commercialization and market expansion, in order to improve efficiency of system management and customer satisfaction. Therefore, participants of standardization roadmapping also need to vary depending on the phase of technology and industry development, in order to better anticipate standard needs.

5.1.4. Sharing Information Among Participants

Many interviewees agreed that standardization roadmapping exercises provide important forums for technical discussions, where various participants share and exchange the latest technical and standards information. As different participants are experts in different fields of technology, such knowledge sharing activities are invaluable in facilitating innovation. Also, different participants may be active in different international SDOs, hence roadmapping is a good opportunity to share information and learn about standardization activities in various standards communities. In addition, an interviewee from Korea mentioned that roadmapping activities provide a place for networking opportunities, where constructive ideas may be shared, leading to collaborative innovation activities between participants from different organizations. Such activities all facilitate and strengthen knowledge diffusion and development, an important function of standardization in innovation systems.

However, interviewees from Germany and the US emphasized that when various stakeholders, who had not worked together before, are gathered to collaborate in multidisciplinary areas such as the Smart Grid and electromobility, it is extremely difficult to start discussions without first making everyone understand each other. The problem of speaking different terminologies was also raised in some interdisciplinary areas of the ICT standardization roadmap. Therefore, it is critical to make sure that everyone uses common definitions and has a common understanding of overall systems and structures, in order to facilitate discussions and the sharing of information.

5.2. Different Approaches Between Leaders and Followers

Comparing three standardization roadmaps, this section analyzes how different approaches were adopted by different countries, reflecting contextual variations in terms of both technological capabilities and history of standardization systems.

5.2.1. Different Purposes of Standardization Roadmaps

The principal purpose of the ICT standardization roadmap in Korea is to develop a time plan for developing standards, for which there is immediate need and strategic importance in increasing national competitiveness in technology and standardization. Many interviewees recalled that as a latecomer country with a lack of resources but a number of leading technologies in certain areas, Korea had to focus on a set number of areas to support standardization activities in international standards community. Therefore, the standardization roadmap was developed in order to examine current standardization activities in international SDOs, and select a few clear target areas where Korea can contribute to and benefit from the most. As a result, focusing on developing short-term strategies for standard gaps most of them already identified in international SDOs in certain areas of established ICT systems, the roadmap is developed every year for a timely reaction to fast-changing environment of ICT.

On the other hand, as experienced leaders in both technology and standardization, Germany and the US focus more on anticipating new standards that would be needed in the long-term future, in order to achieve interoperability for emerging, less developed technologies to be integrated within a large system. They adopt a normative approach, starting with preliminary views of possible futures through use cases and working backwards to identify gaps that need to be closed by standards. Hence, their roadmaps focus on a broader and more holistic view of the overall system, in order to systematically deal with higher risks associated with uncertain futures. According to interviewees from the US and Germany, participants typically foresee what standards they would need in the next five years. As a result, these roadmaps tend to be more process-oriented, where participants gather their insight to build consensus on foresight on uncertain futures, whereas the ICT standardization roadmap in Korea is more product-oriented, with strategies for standardization being final output of the roadmapping exercise.

5.2.2. Different Characteristics of Participants

As a more recently developed country, standardization activities in Korea have traditionally been led by the government. Simply adopting existing international standards and promoting their compliance in the industry was once an effective and efficient way of allowing Korean businesses to access international markets. Even today, it is the government that drives many standards-related initiatives, whereas companies played rather passive roles in standardization activities. This is very different from countries in Europe and North America, where most standardization activities are rooted in private sectors and industries; the difference is largely due to different histories and developments in industrialization. (Choi, 2013b; Song, 1995)

Such differences are also reflected in the development of standardization roadmaps. Although ICT Standardization roadmap in Korea is developed by an industry association, participants of roadmapping are largely from research organizations – conducting many projects funded by the government –, whereas participants from the industry represent less than 30%. In contrast, industry dominates participation in roadmapping in the US and Germany (see Table 2). This may have great impact on the final output as well. Many interviewees from Korea expressed their concerns that as the roadmap is mainly developed by researchers, input and analyses tend to focus more on technology perspectives, potentially leading to identifications of standard gaps that are more research-oriented rather than addressing real needs in commercial products, services, and applications in the market. On the other hand, according to an interviewee from the US, there is a possibility that dominant participation from the private sector may result in focusing on short-term economic benefit or conflict between different companies, as their main objective is to create economic value through their business models.

TABLE 2. Composition of Participants in Roadmap Development

Type of organization	Case A – Korea ICT	Case B1 – US Smart Grid	Case B2 – Germany Electromobility
Industry (companies, trade associations…)	96 (27%)	340 (79%)	34 (76%)
Research organizations	141 (39%)	59 (14%)	1 (2%)
Standards organizations	5 (1%)	5 (1%)	1 (2%)
Government agencies	45 (12%)	20 (5%)	6 (13%)
Academia	76 (21%)	5 (1%)	3 (7%)
Total	363 (100%)	429 (100%)	45 (100%)

Source: the author, with data from EPRI (2009)[1], NPE (2012a)[2], TTA (2013)[3]

5.3. Potential Improvements on Standardization Roadmapping Practices toward Becoming a Leader

Comparative studies of three standardization roadmaps in the previous section reveal different strategic approaches adopted by leaders and followers of technology and standardization, reflecting

[1] Data is extracted from the list of attendees in 1st Smart Grid public workshop.

[2] Data is extracted from the list of members in NPE WG4 and steering committee; hence, it may be different from the actual participants of the roadmap development.

[3] Data is extracted from the list of participants in Ver.2013

their contextual differences. Although they are not directly comparable to each other, such differences may inform and inspire Korea of ways to overcome challenges and limitations in the current roadmapping approach, as identified by interviewees. In order to transform from a follower in established sectors of ICT systems to a leader in more emerging areas, Korea might need to consider adopting a different approach in using roadmapping as a tool to support the effective management of standardization activities. Based on effective lessons learnt from the US and Germany, along with suggestions made by interviewees from Korea, this section proposes potential areas of improvement on the standardization roadmapping exercise in Korea, in order to help its transformation from a follower to a leader.

5.3.1. Holistic Approach Needed for Various Perspectives

As discussed in the previous section, the main participants in ICT standardization roadmap development in Korea are from research organizations that are experts in R&D and standardization of specific technical areas of expertise. While their technological perspectives are important, the industrial perspective is also critical, as standards can have significant impact when actually adopted in the market. However, a number of interviewees mentioned that with lack of participation from companies and industries, it is difficult to anticipate standard needs that can be applied to satisfy customer needs in real products, services, and applications in the market. This is because social acceptance cannot be created without considering the various perspectives of all stakeholders, hence resulting in lack of legitimacy.

Many interviewees have noted that such a lack of consideration for various aspects other than technology at the research level may lead to inappropriate guidance for policymakers and SDOs, resulting in developing standards that may not be useful in the actual market. As the current ICT industry becomes more interdisciplinary and convergent, with various activities in industry and innovation becoming integrated, it is important to observe and anticipate the complex dynamics between standardization and other innovation activities, in order to guide innovation systems in the right direction. Therefore, a more holistic approach that considers various perspectives – including those of industries, economists, market analysts, regulators, and patent lawyers – is needed, as suggested by roadmaps in the US and Germany.

5.3.2. Systematic Approach Needed for Interdisciplinary Areas

As modern technologies become more interdisciplinary and convergent in nature, many technologies that used to function separately now work together, providing integrated services where there are a lot of interfaces and links between each other. However, the current structure and process of developing the ICT standardization roadmap lacks a systematic approach to manage these interrelationships. A number of interviewees noted that the roadmapping exercise is rather fragmented, as contents of the roadmap including conceptual models are developed separately for individual technology focus areas, even though many of them are significantly related to each other. In addition, analyses and assessment of strategies are also carried out separately for each detailed area of identified standard gaps, meaning dependencies and interactions between relevant standard gaps are not easy to observe. Although they are supposed to be reviewed at a higher level, multiple interviewees mentioned that in many cases, individual items are simply merged in a roadmap without too much consideration of relationships and interdependences between them, due to lack of time and resources. Hence, knowledge diffusion and development, an important function of innovation systems, does not occur between different technologies and disciplines.

Such fragmentation of the roadmap between focus areas as well as standard gaps results in an inability to observe trends and impact in other relevant areas. An interviewee gave a good example where international standards developed by Korean technology failed to dominate in the market, due to lack of consideration of the direction and trends of different, but related focus areas. Korea was at the forefront of technology with its standardization in the area of Digital Multimedia Broadcasting (DMB), a digital radio transmission technology for sending multimedia such as TV, radio, and other data to mobile devices. However, as it focused on the evolution of DMB technology exclusively, it failed to observe trends in other mobile technologies such as the development of smart phones, which left a detrimental effect on the DMB industry. As service providers now prefer to provide similar services to consumers using smart phone technologies, DMB technology and standards became obsolete, despite significant effort put into developing the technology into an international standard.

In order to reduce the risk of such mistakes, it is important to observe activities in other relevant areas from a more systematic perspective; comprehensive review of relationships and inter-linkages between different standard gaps in various focus areas can help create a broader picture that is coherent and well aligned. This is done in the Smart Grid and electromobility standardization roadmaps through analyses of crosscutting areas where different disciplines meet each other. A number of interviewees suggest that more resources need to be provided for comprehensive reviews of interrelationships and linkages between different technologies, in order to support innovative ideas that appear in interdisciplinary and convergent areas.

5.3.3. Structured Method Needed to Anticipate Future

As the purpose of the current ICT standardization roadmap is to develop short-term plans for immediate standard gaps, it tends to focus on issues currently being raised in the international standards community when identifying standard needs. Sometimes companies use scenario planning to identify additional standard needs, but they usually focus on business services that are currently being provided to customers in existing markets, according to an interviewee. This makes the roadmapping activities typically focus on the immediate future, failing to anticipate and drive future standard needs or guiding innovation systems in the right direction of search. Some interviewees also noted that the current roadmapping process lacks a systematic method of developing and evaluating scenarios, resulting in a wide variety of different types of scenarios that do not consistently manage complexities associated with high uncertainties. In the case of the Smart Grid standardization roadmap in the US, various use cases were collected from previous studies and roadmapping participants, and comprehensively analyzed and validated through a rigorous method of evaluation, in order to identify future standard gaps that are highly rational and defensible. Therefore, in order to anticipate future directions of technologies and relevant standard needs in emerging areas with high uncertainties, a structured method of developing and assessing scenarios is needed.

6. DISCUSSION & CONCLUSIONS

From the analyses of the three case studies, a number of key findings and distinct differences between standardization roadmaps in various contexts of ICT systems are observed. It appears that such differences are largely due to different strategic approaches adopted by followers and leaders of technology and standardization, reflecting both the maturity of the ICT systems being standardized and the maturity of national standardization systems. Based upon these analyses along with suggestions from interviewees, this chapter presents a number of points to consider, focusing on the varying roles of the government in standardization activities, as well as policy implications and lessons for Korea in order to become a leader in standardization.

6.1. Different Roles of the Government in Standardization Activities

As discussed in the previous chapter, the role of the government in supporting standardization activities in Korea has been very different from that of the US or Germany. A centralized system of standardization around the government was effective when Korea was a developing country, as it provided more systematic and consistent standardization policies (Song, 1995). By aligning standards-related policies with other policies of R&D and technology development, the government could benefit the whole ICT industry through targeting certain niche areas where Korean firms have potential competitive advantages in both standardization and technology. In addition, a strong and consistent voice of the government could help Korea establish its presence in the international standards community, whereas companies may not be able to divert their resources for standardization activities as consistently.

However, such an active role of the government may not be appropriate as Korea is becoming a leader in technology and standardization. As new and innovative ideas are vital in emerging areas of ICT systems, the active participation of private industries, which are close to the market and customers, is important in standardization. The government can support their activities by listening to their voices and providing a supportive environment for their standardization activities. In addition, as the more interdisciplinary and systemized nature of modern ICT requires various stakeholders from different backgrounds to work together, the government can facilitate their collaboration by coordinating and aligning various actors in a more systematic way, promoting technological innovation. Such a mediating role of the government is especially important in areas of societal importance, such as electromobility or Smart Grid, where standards play a critical role in providing important national infrastructures.

6.2. Policy Implications – Lessons for Korea

As noted, the current ICT standardization roadmap was useful when Korea was a follower, but a different approach is suggested as it moves towards the frontier of technology and standardization. The new practice should have the following characteristics:

- A more holistic approach, considering various perspectives of innovation activities
- A more systematic approach, observing relationships and linkages between various areas
- A more structured method of anticipating future, managing complexity and uncertainty

Such standardization roadmapping practices potentially imply policy implications on more fundamental issues of standardization activities as well, in order for Korea to become a leader.

First, instead of driving standardization activities by themselves, the government needs to engage firms and other stakeholders of the industry to take an active role in standardization activities. It is important for the private sector to understand the importance of participating in standardization for the whole industry as well as their own benefit. The government can further encourage their involvement by providing incentives and resources to participate, or by more empowering industry associations in standardization activities.

Another policy implication for Korea is to put more emphasis on interdisciplinary areas. Many innovative ideas, especially in emerging areas of complex ICT systems, are generated in boundaries of existing categories of technology. Yet current policies on standardization are largely focused on core areas of existing technologies and services, without much consideration of interactions and linkages between them, making many opportunities in interdisciplinary areas creating high value difficult to anticipate. In order for Korea to become a leader in such emerging areas, more effort and resources need to be allocated into interdisciplinary areas, supporting collaboration and interaction between different organizations and disciplines, including various departments of the government.

6.3. Future Work and Concluding Remarks

The current research explores a variety of standardization roadmaps used as innovation policy tools, with particular focus on how national strategies differ between leaders and followers of technology and standardization in various areas of ICT systems. However, in order to provide more practical, generalized guiding principles for the effective management of standardization activities, more research needs to be done in other domains of emerging technologies, such as additive manufacturing and graphene. These are promising, but less established areas of technologies, with lots of associated risks. In order to manage such uncertainties to support innovation and lead international standardization, a more holistic, systematic, and anticipatory method of roadmapping is needed. There may be value in adopting a more structured roadmapping framework as developed by Phaal & Muller (2009), which provides a high level integrated view of complex innovation systems by drawing key themes and perspectives in a layered form. Such opportunities can be explored in future research.

REFERENCES

Allen, R. H., & Sriram, R. D. (2000). The role of standards in innovation. *Technological Forecasting and Social Change, 64*(2-3), 171–181. doi:10.1016/S0040-1625(99), 00104-3

Amer, M., & Daim, T. U. (2010). Application of technology roadmaps for renewable energy sector. *Technological Forecasting and Social Change, 77*(8), 1355–1370. doi:10.1016/j.techfore.2010.05.002

Beeton, D. A., Phaal, R., & Probert, D. R. (2008). Exploratory roadmapping for sector foresight. *International Journal of Technology Intelligence and Planning, 4*(4), 398–412.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2008). Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. *Research Policy, 37*(3), 407–429.

Blind, K. (2009). *Standardisation as a catalyst for innovation.* Inaugural Address Research in Management Series. Retrieved on November 26, 2012, from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1527333

Blind, K., Bührlen, B., Menrad, K., Hafner, S., Waz, R., & Kotz, C. (2004). *New products and services: Analysis of regulations shaping new markets. Karlsruhe*. Retrieved from http://www.proinno-europe.eu/promotion-pro-inno-europe-results/page/publication-detail-new-products-and-services-analysis-regulat

Blind, K., & Gauch, S. (2009). Research and standardisation in nanotechnology: evidence from Germany. *The Journal of Technology Transfer, 34*(3), 320–342.

Carlsson, B., & Stankiewicz, R. (1991). On the nature, function and composition of technological systems. *Journal of Evolutionary Economics, 1*(2), 93–118. doi:10.1016/j.tics.2008.03.003

Choi, D. G. (2013a). *Voluntary standards in Korea.* Seoul. Retrieved from http://www.ksa.or.kr/download. ddo?type=b&att_seq_n=5922

Choi, D. G. (2013b). *A primer on Korea's standards system: Standardization, conformity assessment, and metrology.* Gaithersburg, MD. Retrieved from http://nvlpubs.nist.gov/nistpubs/ir/2013/NIST.IR.7905.pdf

Choung, J.-Y., Hameed, T., & Ji, I. (2012). Catch-up in ICT standards: Policy, implementation and standards-setting in South Korea. *Technological Forecasting and Social Change, 79*(4), 771–788.

Choung, J.-Y., Ji, I., & Hameed, T. (2011). International standardization strategies of latecomers: The cases of Korean TPEG, T-DMB, and binary CDMA. *World Development, 39*(5), 824–838.

Council for Science and Technology Policy. (2010). *Japan's science and technology basic policy report* (CSTP). Retrieved from http://www8.cao.go.jp/cstp/english/basic/4th-BasicPolicy.pdf

Edquist, C., & Johnson, B. (1997). Institutions and organizations in systems of innovation. In C. Edquist (Ed.), Systems of Innovation: *Technologies, Institutions and Organizations* (pp. 41–63). London: Pinter.

Ehrnberg, E., & Jacobsson, S. (1997). Technological discontinuities and incumbents' performance: An analytical famework. In C. Edquist (Ed.), S*ystems of Innovation: Technologies, Institutions and Organizations* (pp. 318–341). London: Pinter.

Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of management review, 14*(4), 532–550.

Electric Power Research Institute. (2012). *Intelli grid smart grid roadmap methodology and lessons learned.* (EPRI). Retrieved from http://www.smartgridnews.com/artman/uploads/ 2/000000000001026747.pdf

Electric Power Research Institute. (2009a). *Report to NIST on the smart grid interoperability standards roadmap — Post comment period version*. (EPRI). Retrieved from http://www.nist.gov/smartgrid/ upload/Report_ to_NIST_ August10_2.pdf

Electric Power Research Institute. (2009b). *Smart grid workshop 1 agenda and attendees*. (EPRI). Retrieved from http://collaborate.nist.gov/twiki-sggrid/pub/_SmartGridInterimRoadmap/InterimRoadmapWorkshop1

European Commission. (2011). *A strategic vision for European standards: Moving forward to enhance and accelerate the sustainable growth of the European economy by 2020*. Retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0311:FIN:EN:PDF

European Industrial Research Management Association. (1997). *Technology roadmapping - delivering business vision* (EIRMA Working Group Report 52). Paris.

Galvin, R. (1998). Science roadmaps. *Science, 280*(5365), 803. doi:10.1126/science.280.5365.803a

Garcia, M., & Bray, O. (1997). *Fundamentals of technology roadmapping* (Vol. 4205). Albuquerque. Retrieved from http://www.sandia.gov/PHMCOE/pdf/Sandia'sFundamentalsofTech.pdf

Groenveld, P. (2007). Roadmapping integrates business and technology. *Research-Technology Management, 50*(6), 49–58.

Hanseth, O., Monteiro, E., & Hatling, M. (1996). Developing information infrastructure: The tension between standardization and flexibility. *Science, Technology & Human Values, 21*(4), 407–426.

Huh, H. H. (1998). *Research on status and directions of standardization systems for technology innovation.* Retrieved from http://www.stepi.re.kr/module/pubDownFile.jsp?categCd=A0201&ntNo=179&r=

Ibrahim, E. (2009, May). *Smart Grid Standards Interoperability Interm Roadmap Workshop Overview.* Retrieved from http://collaborate.nist.gov/twiki-sggrid/pub/_SmartGridInterimRoadmap/I nterimRoadmapWorkshop2/SG_may19-20_workshop_050809b_NISTapproved.ppt

Japanese Industrial Standards Committee. (2010). *Roadmap to international standardization for smart grid* (JISC). Tokyo.

Kostoff, R. N., & Schaller, R. R. (2001). Science and technology roadmaps. IEEE *Transactions on Engineering Management, 48*(2), 132–143. doi:10.1109/17.922473

Lundvall, B.-Å. (1992). *National systems of Innovation: Towards a theory of innovation and interactive learning*. London: Pinter Pub Ltd.

McGranaghan, M., Von Dollen, D., Myrda, P., & Gunther, E. (2008, July). Utility experience with developing a smart grid roadmap. Paper presented at the *2008 IEEE Power and Energy Society General Meeting* (pp. 1–5). Pittsburgh.

Miao, X., Chen, X., Ma, X., Liu, G., Feng, H., & Song, X. (2012, September). *Comparing smart grid technology standards roadmap of the IEC, NIST and SGCC.* The 2012 China International Conference on Electricity Distribution (pp. 1–4). Shanghai: IEEE.

Min, J.-H., Cho, P.-D., & Hahm, J.-H. (2012, May). *Framework for making standardization roadmap and strategy*. Paper presented at the Korea Information and Communications Engineering Conference (pp. 737–740). Busan.

Ministry of Commerce, Industry and Energy. (2011). *Basic plan for Korean national standards system*. (MCIE) Seoul.

National Institute of Standards and Technology. (2010). *NIST framework and roadmap for smart grid interoperability standards Release 1.0.* (NIST). Washington DC. Retrieved from http://www.nist.gov/public_affairs/releases/upload/ smartgrid_interoperability_final.pdf

National Institute of Standards and Technology. (2012). *NIST framework and roadmap for smart grid interoperability standards release 2.0.* (NIST). Retrieved from http://www.nist.gov/ smartgrid/upload/NIST_Framework_Release_2-0_corr.pdf

National Platform for Electromobility. (2010). *The German standardization roadmap for electromobility - Version 1.0.1.* (NPE). Retrieved from http://www.vde.com/en/dke/std/Documents/The German Standardization Roadmap for Electromobility2.pdf

National Platform for Electromobility. (2012a). *The German standardization roadmap for electromobility - Version 2.* (NPE). Retrieved from http://www.vde.com/en/dke/std/Documents/E-Mobility_Normungsroadmap V2_EN.pdf

National Platform for Electromobility. (2012b). *NPE Working group list*. (NPE). Retrieved from http://www.bmbf.de/pubRD/lenkungskreis_npe.pdf

O'Sullivan, E., & Brévignon-Dodin, L. (2012). *Role of standardisation in support of emerging technologies.* Retrieved from http://www.ifm.eng.cam.ac.uk/uploads/Resources/Reports/OSullivan_Dodin_Role_ of_Standardisation_June_2012__2_.pdf

Phaal, R., Farrukh, C. J. P., & Probert, D. R. (2010). *Roadmapping for strategy and innovation*. Cambridge: Institute for Manufacturing.

Phaal, R., & Muller, G. (2009). An architectural framework for roadmapping: Towards visual strategy. *Technological Forecasting and Social Change, 76*(1), 39–49. doi:10.1016/j.techfore.2008.03.018

Popper, R. (2008). Foresight methodology. In L. Georghiou, J. C. Harper, M. Keenan, I. Miles, & R. Popper (Eds.), T*he Handbook of Technology Foresight* (pp. 44–88). Cheltenham: Edward Elgar Publishing.

Rinne, M. (2004). Technology roadmaps: Infrastructure for innovation. *Technological Forecasting and Social Change*, 71(1-2), 67–80. doi:10.1016/j.techfore.2003.10.002

Sherif, M. (2001). A framework for standardization in telecommunications and information technology. *Communications Magazine, IEEE,* (April), 94–100. Retrieved from http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=917510

Smith, K. (1997). Economic infrastructures and innovation systems. In C. Edquist (Ed.), *Systems of Innovation: Technologies, Institutions and Organizations* (pp. 86–106). London: Pinter.

Song, W. (1995). *Research on standardization of information technology industry.* Seoul. Retrieved from http://www.stepi.re.kr/module/pubDownFile.jsp?categCd=A0201&ntNo=606&r=

Swann, G. M. P. (2010). *The economics of standardization:* An Update. Retrieved from http://www.bis.gov.uk/feeds/~/media/ED32CDA672764D7C8AC2F4E323581010.ashx

Tassey, G. (2000). Standardization in technology-based markets. *Research Policy, 29*(4-5), 587–602. doi:10.1016/S0048-7333(99)00091-8

Telecommunications Technology Association. (2013). *ICT standardization strategy map ver.2013.* (TTA).

Thomas, C., Hamilton, B., & Kim, J. (2010). *White paper - The smart grid and the evolution of the independent system operator.* Retrieved from https://www.smartgrid.gov/sites/default/files/doc/files/White_Paper_ mart_Grid_ volution_Independent_System_Operator_201001.pdf

Van de Ven, A. H. (1993). A community perspective on the emergence of innovations. *Journal of Engineering and Technology Management,* 10(1-2), 23–51. doi:10.1016/0923-4748(93)90057-P

White House. (2011). *A strategy for American innovation: Securing our economic growth and prosperity.* Retrieved April 29, 2012, from http://www.whitehouse.gov/innovation/strategy