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Participation in Technology Standards Development: A Decision Model for the Information and Communications Technology Industry

Ramin Neshati

Portland State University

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Participation in Technology Standards Development:

A Decision Model for the Information and Communications Technology Industry

by

Ramin Neshati

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Dissertation Committee:
Tugrul U. Daim, Chair
Timothy R. Anderson
Scott A. Schaffer
Robert R. Harmon

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Abstract

There is a dearth of decision-support models or frameworks to aid managers in the Information and Communications Technology (ICT) industry in uniformly assessing the key factors in the decision to standardize innovative technologies. Making the proper decision is consequential and potentially fraught with risks for the firm such as competitive exposure, high expenditures with inadequate returns, restrictive inbound or outbound patent licensing obligations, and related complications.

This study presents a framework to guide managers in the ICT industry in assessing the factors that inform the decision to participate in the development of technology standards. Using multi-criteria decision analysis and judgment data from panels of experts, a robust model is developed that comprehends the essential criteria and outcomes within the context of computer interconnect technologies. The resultant, generalizable model is validated against the case of the extant Universal Serial Bus (USB) interconnect standard and found to be congruent with the assessment of the experts.

Scholarship on technology standards development is rich and multifaceted—spanning numerous streams of inquiry. This research contextualizes technology standardization within the economic, strategic, organizational, and legal perspectives. The resultant model demonstrates that strategic planning is regarded by the experts as the principal driver in the decision to participate in a technology standardization effort. Furthermore, the primacy of commitment and leadership within the standards-setting

organization is unambiguously established through rigorous quantitative analysis. The proposed model verifies that the firm's desire to align its product roadmap to the emerging standard is the chief criterion in the decision to contribute to the standards development effort. Other criteria of high interest include the leveraging of network externalities to glean disruptive trends within the ecosystem, the exploration of opportunities to expand the total available market for the firm, and the availability and terms of IP licenses. Sensitivity analysis affirms the overall predictive strength and robustness of the model and its widespread applicability.

Future research on model expansion and application to other technologies, as well as the development of uniform patent valuation methods will further enrich the knowledge base.

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Chapter 1: Introduction

Innovative technologies produced by the ICT industry permeate all facets of modern human existence spanning education, scientific exploration, commerce, finance, law, medicine, sports, entertainment, social networks, and so on. The products that embody these technologies rest at the core of a vast array of devices and functions such as personal computers, cellular phones, communication networks, game consoles, digital media players, high-performance computers that form the backbone of the Internet, "cloud" services, controllers in modern automobiles and airplanes, mission-critical systems, industrial, medical and life-support equipment, point-of-sale registers and scanners in retail stores, electronic billboards and so on.

ICT firms such as Apple, Cisco, Google, HP, IBM, Intel, Microsoft, Oracle, Qualcomm, Samsung and others hold dominant positions in this industry—an industry that has been characterized by some scholars as "winner-take-all."[1] Ironically, in this dynamic, high-velocity industry no technology firm is "an island, entire of itself." This is especially true of firms whose products depend on technology standards.

A standard represents consensus among different agents operating within mutually acceptable practices. Thus, a technology standard can be rendered as an arrangement that enforces conformance of all elements of products, processes, formats, or procedures under its jurisdiction.[2]

Technology standardization reduces product incompatibility, increases interoperability, and accelerates broad diffusion and adoption of innovations in the ICT industry. A technology-intensive product such as a smartphone or a personal computer is built with many protected intellectual assets such as patents that are held by any number of ICT firms. While some firms may own impressive portfolios of intellectual assets, no one firm owns all of the patents involved in building a smartphone, a personal computer, or other complex devices.

The ideas and methods described by patents find their way into technology standards which are eventually adopted in a variety of products. However, as the complexities of technology markets and the uniform adoption of standards are too daunting for any ICT firm to influence or direct on its own, many firms are faced with IP-related uncertainties.[3]

To develop leading-edge, interoperable products ICT firms enter into standards coalitions to gain access to a broader array of intellectual assets, to interact with ready ecosystems of partners and complementors and to gain a voice in influencing the pace and direction of technology standards development. While beneficial, participation in SDOs can be fraught with risks that are poorly understood and seldom mitigated by these firms. How do ICT firms decide whether or not to join a standards development effort? This and related questions are explored and addressed in this treatise.

This study is organized as follows: Chapter 1 introduces the topic, provides a taxonomy and definition of terms, identifies the problems and explains the motivations for the research. Chapter 2 gives a broad survey of the academic literature, including various streams of direct and related inquiry. Chapter 3 outlines the gaps in the literature as well as the research questions that address these gaps. Chapter 4 explains the research methodology. Chapter 5 defines the decision model and the various levels of its hierarchy. Chapter 6 describes the design and framework of research, data collection, and cases analysis. Chapter 7 outlines the results and the sensitivity analysis performed on them. Chapter 8 furnishes a discussion of the findings as well as their import and implications. Chapter 9 summarizes the conclusions derived from the research, enumerates the limitations encountered during the research, and concludes with an agenda for future scholarly endeavors. References appear at the end of the document.

1.1 Overview of Technology Standardization

Without standardization there wouldn't be a modern economy![4] This bold assertion is not entirely hyperbolic. Indeed, the overwhelming majority of technological innovation occurs within the multi-invention context of standards, without which we could not uniformly use a wall outlet to power our electrical gadgets, fit the nozzle at any filling station into our automobile fuel tank, seamlessly and uninterruptedly use the services of transnational railways, swipe our debit or credit card at any retail store, use our computer to connect to the Internet for the electronic exchange of personal or commercial information and so on.

Likewise, users of technology-intensive products share and exchange information through compatible documents, databases and related interoperable tools provided by different vendors, all of which are built on foundations laid by technology standards. The QWERTY keyboard is a ubiquitous example of a timely and useful technology standard.[5]

The standardization of technological innovations is deemed sufficiently crucial to prompt government authorities in nearly all developed and emerging economies into taking an active interest in the establishment and guidance of national and international standards-setting organizations, and in evolving laws to institutionalize their charters, policies and practices.[6] One need not look farther than the Internet to be convinced of the crucial importance of technology standards as building blocks for a wide range of commercial and non-commercial applications.[7]

Thus, it is clear that standards are *sine qua non* in all facets of consumer and corporate life. Many benefits accrue to the producer and to the consumer of standards-based technology products. For the producer, standards enable the broad adoption of its products and hasten additional innovations through coordination with a network of collaborators that supply complementary products and services. For the consumer, standards foster early access to innovations and provide a tacit promise of interoperability among products and services from a heterogeneous mix of vendors.

Technology standards development can be a strategic activity for many firms in the ICT industry since it promotes distributed innovation and inter-firm collaboration.

Adherence to technology standards is critical for building modular and interoperable products. It allows firms to concentrate on innovations that add incremental or unique value. To wit, keystone firms rely on standards as a means to reduce investments through distributed innovation while concomitantly preserving their technology leadership. Standards spawn complementary innovations that enhance the value of interoperable products emanating from a horizontally disintegrated ecosystem.[8]

Firms that lead in the development of technology standards are ahead of the pack on the path to dominant market positions; indeed in some cases they *become* the standard.[9] Consider, for instance, that in 2009 Microsoft held sway over 94 percent of the global desktop operating system market, Intel had roughly 83 percent market segment share in PC microprocessors and Apple dominated more than 82 percent of the portable music market. However, the perceived best technology does not always gain prominence or become a *de facto* standard. The ICT industry is witness to many failures, including the IBM PS/2 operating system and the Apple Newton personal digital assistant.

Technology standards eliminate incompatibility between similar products from different vendors, and thereby enhance the overall value of the offering by enabling the incremental supplementation of features and functions to basic "vanilla" products.[10] This value is a consequence of the network effects engendered through the process of technology standards development by firms that provide complementary products and services that conform to these technology standards.[11]

Standardization plays a crucial role in the broad diffusion of technological innovations. Arguably, standards accelerate technology adoption by enabling “the timely deployment of value-added functionality, followed by the broadest possible industry support for the necessary infrastructure to deliver the next level of innovations.”[12]

If a technology can be instantiated in multiple different ways with dissimilar interface points, there is the potential for proliferation of incongruent methods for accomplishing the same task or end result. Such proliferations in turn can lead to inefficiencies and lower returns for the firm or to confusion and higher costs for the consumer, or to both. Thus, technology standards are essential for the coherence of research investments as well as the compatibility and interplay of heterogeneous offerings from multiple product integrators worldwide.[13]

Technology standards are infused with the intellectual assets and the protected innovations of firms that may or may not participate in the definition and diffusion of such standards. Every technology-intensive product contains a multitude of standards-based technologies that are covered by some form of Intellectual Property Rights (IPR) regime.[14]

The rents accrued from the licensing of IP constitute sizeable revenue streams for many firms in the ICT industry. For example, IBM has historically earned a sizeable portion of its total annual revenues from royalties derived from the licensing of its large and diverse IP portfolio.[15] [16] In 2009, it was estimated that IBM earned well over $3-4 billion in licensing revenues from its IP portfolio, and that sum is on the rise.[17] Qualcomm has a similarly lucrative revenue stream from the licensing of its IP portfolio. In 2011 it racked up over $6 billion in IP royalties.[18] [19] This sum is noteworthy since in 2007 IP-related earnings accounted for only a third of Qualcomm revenues. Other ICT firms are replicating this recipe for revenue growth and strategic advantage. Table 1 depicts the top 5 ICT firms being awarded patents in the United States in 2011:[20]

Table 1 - Top 5 ICT firms awarded U.S. patents in 2011.

Rank	Firm	Number of Patents Awarded
1	IBM	6,478
2	Samsung	5,081
3	Canon	3,174
4	Sony	3,032
5	Panasonic	2,769

1.2 The Nature and Scope of the Problem

Technology firms invest in Research and Development (R&D) which invariably results in the creation of IP that is safeguarded by the firm and protected by regional, national and international law. Much of this IP consistently finds its way into technology standards as a result of inter-firm collaboration and contribution during the process of standards definition and development.

The complex phenomenon of the integration of IP from various sources into innovative products via multiple technology standards is depicted in Figure 1 below:

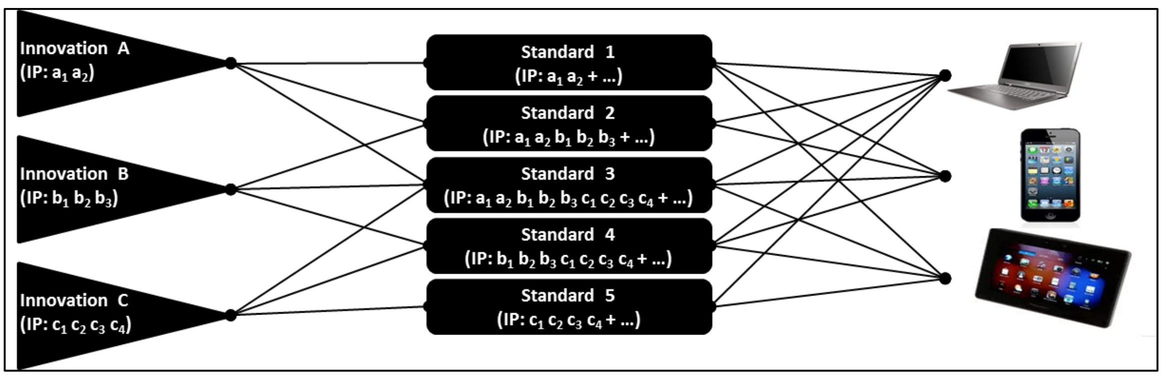

Figure 1 - Propagation of IP in technology products through standards.

To ensure fair and equal access to the essential IP required for building compliant and interoperable products, organizations that develop technology standards manage and administer Intellectual Property Rights (IPR) as part of their charter as outlined in bylaws or similar legal instruments. All members of these organizations are bound by the same rules and policies.

The privileges and obligations that IPR policies bestow on the licensor and the licensee, respectively, vary in clarity of scope and linguistic precision, and are usually non-uniform across different organizations, national laws or international agreements.[21]

In the ICT industry a firm's position in the innovation chain, whether upstream to IP innovation or downstream to it, is a major factor in determining licensing and royalty policies.[22] Another concern is the size of the firm, where small and medium entities (SMEs) have a more intense need to protect their intellectual assets in order to ensure their long-term survival.[23]

The accelerated pace of innovation in the ICT industry, the increasing complexity of semiconductor and software technologies, the changing shape of markets, the fluctuating positions and ranks of various firms and other market uncertainties, combinationally can hinder innovation through standardization.[24]

Standards setting organizations usually operate without regard to the imperatives that drive business priorities. Thus the friction inherent in the co-evolution of standards organizations and IPR policies in the ICT industry is real and unchecked. In particular, tensions can escalate when the instantiation of a standard calls for the integration of protected IP whose holder will either not grant a license or may require exorbitant rents. Such outcomes can result in revisions to the standard to remove the IP, which concomitantly elevates risk, uncertainty and inefficiency.

1.3 Terminology and Taxonomy

Familiarization with commonly used technical terms and their descriptions may prove instructive before delving deeper into the subject at hand. There are many definitions for what constitutes a technology standard as outlined below:

a) "A specification or a design with a dominant market position in the industry for its product class."[25]

b) "A common language that promotes the flow of goods between buyer and seller …" and the process of standardization is the pursuit of conformity of all elements of products, processes, formats, or procedures that make up an industry standard, with the objective of increasing the efficiency of economic activity within a generally defined industry or narrowly defined sub-sector of an industry.[26]

c) "A technological format that has been agreed to by either one firm or a set of firms, that has come into existence, may be promoted as a basis for reference and use outside the firm(s), and/or at least one or more of the relevant potential users have adopted the format."[27]

d) "A formulation established verbally, in writing or by any other graphical method, or by means of a model, sample or other physical means of representation, to serve during a certain period of time for defining, designing or specifying certain features of a unit or basis of measurement, a physical object, an action, a process, a method, a practice, a capacity, a function, a duty, a right, a responsibility, a behavior, an attitude, a concept or a conception, or a combination of any of these, with the object of promoting economy and efficiency in production, disposal, regulation and/or utilization of goods and services, by providing a common ground of understanding among producers, dealers, consumers, users, technologists and other groups concerned."[28]

Furthermore, technology standards can be classified into three kinds: reference, minimum quality, and interface.

Reference and minimum quality standards indicate that a product conforms to the content and level of certain defined characteristics, whereas interface standards provide the requisite aplomb that an intermediate product can be successfully incorporated into a larger system given specified inputs and outputs.[29]

The establishment of technology standards comes about either through unsponsored activities where no identified originator holds a proprietary interest, or sponsored activities where one or more entities hold a direct interest, or agreements facilitated through organizations, or governmental mandates.

Unsponsored and sponsored activities emerge through market-mediated processes and are generally referred to as *de facto* standards, whereas agreements and governmental mandates emerge through political deliberations or administrative procedures and are generally referred to as *de jure* standards. This classification is shown in Table 2 below:

Table 2 - The typology of SDOs (David, 1987).

Type	Output	Explanation
de facto	Unsponsored standard	Specifications with no identified originator holding a proprietary interest
	Sponsored standard	Specifications with one or more identified originators holding proprietary interest
de jure	Contracted standard	Specifications developed and published by a voluntary standards developing organization
	Mandated standard	Specifications promulgated by governmental agencies with regulatory authority

Throughout this study, therefore, a *de facto* standard will refer to that which is developed by loosely formed consortia of technology firms with a vested interest in its adoption and diffusion, while a *de jure* standard will refer to that which is developed by a formal consortium or authority-wielding agency of a national government or an internationally recognized association. The extent of this study embraces *de facto* technology standards that are defined and promulgated in the ICT industry as this is an acutely under-researched area.

The American Society for Testing and Materials, now ASTM International, identifies four types of standards as shown in Table 3 below:[30]

Table 3 - Types of standards (ASTM International, 2005).

Standard	Description	Participants
Company	Consensus among employees of an organization (i.e. a business firm)	Some or all employees of the company
Consortium	Consensus among a small group of like-minded firms	Some or all participating members of the consortium
Industry	Consensus among a large group of firms within an association of firms or an industry	Some or all participating members of the industry
Government	Consensus enforced by government mandate or policy	Some or all entities with business interest within the jurisdiction of the government

1.4 Intellectual Assets

The United States Patent and Trademark Office (USPTO) defines Intellectual Property (IP) as "creations of the mind - creative works or ideas embodied in a form that can be shared or can enable others to recreate, emulate, or manufacture them."[31] Patents, copyrights, trademarks and trade secrets are distinct ways that firms or individuals may protect their intellectual assets.

Patents describe novel and non-obvious inventions and gives its owner exclusive rights to exploit that invention. Copyrights protect creative expressions such as books, music, software programs and other such creations. Trademarks provide unique and differentiable identity to a brand, logo or other such constructions. Trade secrets, unlike the other forms of intellectual assets, are kept confidential and are not disclosed. They are the unique methods, designs, formulations, and other such inventions that the firm considers to be too important to be made public.[32]

A patent grants the inventor exclusive rights for a limited period of time in exchange for public disclosure of the invention. Patents are of various types such as Design, Dress, Plant, Utility and others. The design of an automotive engine is a good example of a component that is protected under multiple patents. A Plant patent covers distinct, sexually produced plants with a variety of cultivation techniques, new seedlings or other original advances. A Dress patent covers the visible look, feel, appearance or packaging of a product, while a Utility patent covers a new machine, process manufacture or composition of matter. The bulk of the patents in the ICT industry are of the Utility type and thus they form the locus of this study.

A copyright grants exclusive right to the holder to copy or distribute the protected material for a limited period of time in exchange for public disclosure. Books, movies, technology specifications and software are typical examples of copyrighted IP.

A trademark is a unique name, logo or image used to distinguish the source of the product offering and to promote brand identity. The Apple "bitten" logo, the Nike "swoosh" logo and the NBC tri-note chime are examples of well-known trademarks.

A trade secret is classified information held by a firm or legal entity and is used in the creation of product offerings. Given its confidential nature, a trade secret is not publicly disclosed. The design of circuits in microprocessor chips or the formulae used in soft drinks, such as Coca Cola, are typical examples of trade secrets. *Sans* trade secrets, these intellectual assets are summarized in Table 4:[33]

Table 4 - Summary of intellectual assets (Metzger, 1992).

Feature	Patent	Copyright	Trademark
Scope of protection	Novel, non-obvious and useful inventions	Wide range of creative works that are fixed and original	Trademarks, service marks, certification marks, and collective marks of sufficient distinctiveness
Registration requirement	Yes	Copyright exists absent registration; registration necessary for infringement suit	Unregistered marks protected under section 43(a); registration necessary for infringement suit under section 32(1)
Duration	17 years from issuance or 20 years from filing	Life of author plus 70 years	10 years, with possible 10-year renewals
Transferability	By assignment or license	By assignment or license	Limited
Infringement	Making, using or selling patented invention or its substantial equivalent	Violation of owner's exclusive right to produce, prepare derivative works, distribute copies, perform or display; fair use defense available	Use of mark in connection with advertisement or sale that is likely to cause confusion, mistake or deception regarding origin

Patents, the focus of this study, were originally established by the medieval Venetian state in 1474 which defined the basic features of the law still in practice today. The intent behind the law was to spur innovation through the incentive of limited-time exclusivity. In 1787 the United States Constitutional Convention recommended that Congress be given the power to promote the progress of sciences and useful arts by securing to the inventor, for a limited time, the exclusive right to his inventions. This recommendation was unanimously adopted and incorporated into the final draft of the United States Constitution.[34] The importance of the patenting system as a source of economic return for innovative firms has been documented in the scholarly literature.[35]

Two distinct views are germane when considering a portfolio of intellectual assets such as patents. The portfolio can be viewed as a defense or shield-like mechanism and used primarily for protection by the firm against competition through cross-licensing arrangements as a hedge against potential patent assertion or infringement suit. This allows the firm to maintain focus on its core business of generating value through commercialization of innovations. On the other hand, the portfolio can be viewed as an offensive or sword-like mechanism and used primarily as a revenue-generating asset by the firm. In this way, firms can assert their rights and derive revenue through licensing rents and royalties, entering into joint ventures and other strategic ventures. This allows the firm to harvest value from the exploitation of its intellectual assets.[36] This IP portfolio strategy is depicted in Table 5:

Table 5 - IP portfolio strategy.

Consideration	Portfolio-as-Protection	Portfolio-as-Asset
Strategy	Defensive (used as a "shield")	Offensive (used as a "sword")
Usage	The firm can protect itself from competitive attack	The firm can derive value or position itself for joint ventures
Application	Protection from patent infringement suits through cross-licensing	Source of revenue through licensing rents, joint ventures, etc.
Benefit	Allows the firm to focus on core business and to commercialize its innovations	Allows the firm to harvest value from the exploitation of its intellectual assets

The adoption of technology standards entails the process of design, implementation and seamless inter-operation of heterogeneous products from a variety of firms. The computing industry, comprehending IT goods and services such as personal computers, operating systems, databases, and so on, and the communications industry, comprehending telecommunications goods and services such smartphones, data or media services, and so on, have historically operated with different assumptions and requirements with regard to IP contributions in technology standards. It requires no further elaboration that these two industries have recently blended together, leaving open a number of vexing questions about the cross-dependent and dissonant strategies of many firms that operate across multiple industrial boundaries.

1.5 Standards Developing Organizations

An SDO, sometimes referred to as Standards Setting Organization (SSO), operates under the aegis and sponsorship of a consortium of like-minded firms or a national organization, and may draw its membership through representation from a variety of firms, institutions or individuals with an interest in the field. Examples of SDOs include IEEE, ANSI and ECMA. An International Standards Developing Organization (ISDO) operates at the multi-national level with representation determined by a national organization, governmental bureau or imprimatur, and generally carries a high level of legitimacy and influence. Examples of ISDOs include ISO and ITU. SDOs and ISDOs generally issue *de jure* technology standards.[37]

A Special Interest Group (SIG) is a special-purpose, legally constituted consortium of firms to advance the collaborative development of narrowly-focused technology specifications. By construct, a SIG is an informal and decentralized standards developing association. As an incorporated, legally recognized entity, a SIG may operate as a mutual-benefit, non-profit corporation with bylaws, a governing board, elected officers and so on, similar to most SDOs.[38] In the United States, for instance, a tax-exempt SIG is legally recognized under Section 501(c)(6) of the Internal Revenue Code.[39] Examples of SIGs include Bluetooth and USB. SIGs generally issue *de facto* standards.[40]

On the origin of technology standards consortia in the ICT industry, Hawkins (1999) maintains that the first such consortium was formed in Europe in 1963 called the European Computer Manufacturers Association (ECMA).[41] ECMA defined much of the organizational practices of SDOs in use today and was held in high regard by international organizations such as the ISO and the ITU. These practices include membership rules, IPR policies, committee processes, finances, specification development procedures, and so on.

It took changes in US laws starting in 1988, specifically the *Omnibus Trade and Competitiveness Act* and the 1993 *National Cooperative Research and Production Act*, that encouraged closer collaboration among American technology firms to develop standards within the structure of SDOs. Figure 3 below depicts the SDO taxonomy discussed herein:

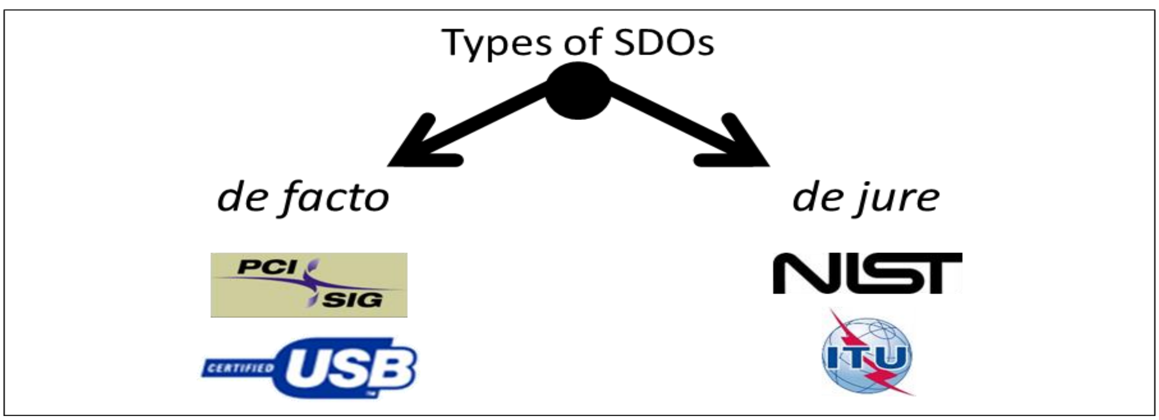

Figure 2 - SDO taxonomy.

Technology standards mitigate technical uncertainty, lower transaction costs, increase the efficiency of information sharing among participants, reduce trial and error in design and improve overall productivity.[42]

The collective learning infused through network externalities and ecosystems reduce “nonstrategic sources of variety in design” by providing focus and clarity in a sea of technological options.[43] However, the convergence of the computing and communications industries and the incongruency of the prevalent IPR policies governing the standards organizations in each of these market segments, together with the growth of IP-related problems such as undeclared essential IP in standards, vague *ex post* licensing terms and royalty expectations, “troll” or “non-practicing” firms, “holdups,” “ambushes” and the growing number of IP-related law suits in recent years, pose serious financial and strategic challenges to firms that wish to operate across industrial boundaries.[44]

Moreover, the omnipresent potential of collusion in standards organizations, the repercussions of antitrust law, as well as the economic impact of IP-induced injunctions on commerce can be distracting, if not debilitating, to technology firms irrespective of size or market power.[45]

1.6 Risks and Issues in Technology Standardization

As technological diffusion through standardization comes into conflict with the assertion of IPR, innovation and leadership are jeopardized, giving rise to potentially dire consequences for many firms. Working around IP holdups and minefields is a risky proposition since it is not clear if the innovation that replaces it is adequate and available. This in turn results in confusion over the marketability of the technology and to delays in the adoption and diffusion of the standard.

Many ICT firms view IPR as a "necessary evil" owing to the requisite investments in building and protecting IP portfolios for defensive purposes while resorting to other means to recoup investments in standards-based innovations.[46] Many other problems persist, including the undeclared ownership of IP within standards organizations to prevent inadvertent infringement, IP monetization, royalty stacking, and so on.

Acknowledging these issues, the United States Department of Justice and the Federal Trade Commission released a joint report in 2007 aimed at the promotion of innovation and competition by issuing clarifications over IPR antitrust enforcement.[47] Also in 2007, the European Commission began to probe several questionable IP-related practices on the parts of RAMBUS and Qualcomm after complaints were lodged against those companies alleging breach of rules and unfair exploitations of IPR.[48]

The Global System for Mobile Communications (GSM), developed by the European Telecommunications Standards Institute (ETSI), with a broad scope to define the technical specifications for digital cellular networks, brought many of these issues to the forefront on a global scale starting in the late-1980s and into the 1990s.[49]

More recent examples that embody IPR infringement comprise high-profile law suits, including the cases of the BlackBerry smartphone and the Apple iPhone. In the case of the former, BlackBerry was found to have infringed on patents held by a small company called NTP, among others, which was at first awarded $53 million but BlackBerry fiercely resisted payment. Having exhausted all of its legal appeal options, BlackBerry eventually settled for over $600 million, a nearly twelve-fold penalty![50] In the case of the latter, Apple was sued by cell phone giant Nokia, again for patent infringement. Apple fought back but eventually settled for an undisclosed amount believed to be around 2 percent of iPhone sales plus ongoing royalties.[51] Other examples that portend of the "IP wars" phenomenon include Apple vs. Samsung, Oracle vs. Google, Microsoft vs. Motorola and many other such entanglements.[52] [53] [54]

In the ICT industry many firms are entangled in "IP wars" over infringement and licensing issues. For example, Apple was sued by Nokia and is in turn suing Samsung. Apple and Google have locked horns many times over the past few years. Google acquired the Motorola Mobility patent portfolio to buttress its IP holdings and Microsoft followed suit with its purchase of the Nokia patent portfolio. Oracle and Google are in litigation over various IP-related issues, and the list goes on. This litigious environment represents a recent phenomenon in the ICT industry which has been attributed to the increasing value of intellectual assets and the unwillingness of large IP portfolio owners to enter into cross-licensing arrangements or to join SDOs.

With the stated uncertainties over the protected intellectual assets of innovating firms, the incongruency of IPR regimes in the various standards organizations and the dependence of ICT products on a growing number of technology standards, what challenges await firms whose products contain inventions couched in numerous technologies that span multiple standards and IPR policies?

The complexity of this problem amplifies with the requirement for product interoperability across a broad spectrum of offerings from multiple vendors, many of whom are rivals and not readily cooperative. There are a number of other problems enumerated in the following sections that span a broad spectrum from the acknowledged to the obdurate.

Many patent-related problems are known, albeit not adequately addressed. These problems include ambush, holdup, thicket, vague licensing terms, and so on.[55]

An ambush arises when the owner of essential IP knowingly contributes it, *prima facie*, without asserting any rights or claiming that it will not assert rights, only to change course and assert rights after products have implemented the essential IP. The case of RAMBUS Incorporated illustrates this problem.[56]

A holdup arises when the owner of essential IP refuses to license irrespective of rents and royalties, and thus shackles the products that depend on that IP and ultimately impedes innovation. The case of Dell Corporation typifies this problem.[57]

A thicket materializes when the essential IP is embedded as part of a web of overlapping IP which complicates isolation of the essential IP and gives rise to confusion and the "stacking" of multiple assets from multiple sources, thereby curbing imitators and impeding innovation. The case of Xerox Corporation exemplifies this problem.[58]

Collusion and antitrust issues can develop when multiple influential firms cooperate among themselves to define the rules of standardization and IPR policies to the exclusion of the broader ecosystem, including their closest rivals, thus giving themselves an unfair advantage by erecting barriers to innovation and competition.

Standards-based product development necessitates careful management and navigation around a plethora of technological, commercial and legal risks. When choosing a technology standard, a firm must pay close attention to economic models that measure risk. These models take into account the number of firms active in the initiative since firm size and the number of participating firms has an effect on the market risk as accounted for by a change in the β value as well as the idiosyncratic risk as represented by a change in the Mean Square Error (MSE).[59] The value $\beta$is a measure of the volatility of an entity, such as a firm's stock value, in relation to the collective, such as an index or a market of other stocks, whereas the MSE is a measure of the difference between an estimating function and the estimated quantity.[60] In general, firms electing to participate in large standardization efforts can expect a reduction in market risks but an increase in idiosyncratic risks when compared to firms choosing to participate in smaller standards group or attempting to unilaterally standardize their own technologies and products.

At the industry level, incongruent IPR licensing terms across SDOs or those that are ambiguous and open to interpretation engender a raft of problems that are without precedent and thus carry indeterminate risk for ICT firms. For example, the term "reasonable" in the Reasonable and Non-Discriminatory (RAND) IPR policy is imprecise and open to interpretation. The owner of the essential IP can demand uniform rents that may be reasonable in one industry but not in another, thus giving it a legally accepted tool to limit competition in carefully chosen industries and market segments.

At the firm level, the problem of IP valuation gives rise to a number of strategic and commercial risks with broad implications for technology managers, absent a universally applicable IP valuation method. The fecundity of this area of scholarship is acknowledged but understood to be out-of-scope for this treatise.

1.7 Technology Standards Development

A technology standard is developed and maintained by a consortium of representative firms, individuals or legal entities operating within an industry. In the ICT industry, for instance, there are a number of standards organizations with varying levels of openness, authority, influence, charter and function.

In this context, openness refers to the degree of availability of participation to an individual, a legal entity, a firm or a governmental agency. Further, the development of technology standards must meet several goals such as the proper form, fit and function of the products built to the standard, the precise definition of compliance to facilitate the interoperability of products, and, most importantly, the lowest possible cost in the development of standards-based products.[61]

Since technology standards development entails the integration of protected IP, the implementation of the standard may give rise to IP infringement in the absence of a licensing regime. The production of low-cost, standards-based products thus necessitates availability and affordability of licenses to the essential IP required for its implementation.

Several factors interact in the complex, multi-dimensional undertaking of technology standards development such as business-driven innovation, IPR protection and enforcement, organizational and institutional structures and practices, and the regulatory environment spanning consumer and environmental protections.[62]

Inter-firm cooperation within the context of a SDO represents the ultimate evolution of a collaborative structure due to its ability to retain broad representation of vested firms in the industry.[63]

Technology standards development follows a lifecycle comprised of three phases: Development, Diffusion, and Adoption.[64]

In the Development phase, the technical content of the standard is created. The issue in this phase centers on the ownership and licensing of the IP. Firms are motivated to know who owns what piece of essential IP.

In the Diffusion phase, the technology standard is broadly disseminated to the ecosystem. The issue in this phase is the protection and retention of the value of the IP contained in the standard. Firms are motivated by the revenue potential of licensing the essential IP they hold.

In the Adoption phase, the technology standard is instantiated in various product offerings. The issue in this phase has to do with compliance to the published standard and whether or not any firm in the ecosystem holds a privilege or advantage in this regard. Firms are motivated by the process and timing of conformance to gain time-to-market advantage over their rivals.

1.8 Intellectual Property Rights Models

IP protection and license availability is an intrinsic aspect of technology standards development. The monetary potential for IP is sufficient motivation for the holder of these intellectual assets to devise elaborate policies to protect them from unwanted or illegal use. There are on-going conflicts between industrialized and developing regions of the world, and the controversies surrounding the variant levels of protection of intellectual assets.[65]

There exists a variety of IPR models in the ICT industry which span the polar opposites of “no license” to “free license.” The former is clear: the IP holder has no motivation or obligation to license its intellectual assets to any entity in any manner. The latter is equally clear: the IP holder has no intention to bar any entity from using its intellectual assets and will not impose any monetary obligations for its use. However, most IP holders use other models that grant them the potential to derive monetary gain should they choose to assert their rights to the essential IP in their possession.

The IPR model is set by the standards setting organization and it plays a crucial role in the diffusion and adoption of the technology standard defined by the organization. Typically, it meets several conditions such as identifying the scope of the essential patent(s), including the unambiguous availability of license terms covering the patent(s), and providing commitment to license the essential patent(s).

While the IPR policies of the various ISDOs, SDOs and SIGs are not always uniform, most organizations have gravitated towards the RAND licensing policy as it is the most preferred option available. There are variations in RAND, such as RAND with royalty-free (RAND-RF) terms, sometimes referred to as RAND with zero royalty (RAND-Z), and others such as RAND with covenant not to sue (RAND-CNTS).

The “non-discriminatory” part of RAND is clear: IP licensing must be available to all takers. The “reasonable” part of RAND, however, is not clear and is subject to varying interpretations. There is no uniform semantic for reasonableness, especially across industrial boundaries. This is one example of the difficulty in setting and adhering to an IPR policy. On the other end of the scale, the “Just Publish” model is rarely used as it can expose the adopter to potentially onerous terms, and it does not meet the aforementioned criteria. In this model the owner makes the IP in question publicly available with or without the protections afforded by law and may, at an indeterminate time, assert rights against it absent prior notice. The increased uncertainty inherent in this model renders it unpopular.

1.9 Research Motivation

The co-evolution of IPR policies with standards setting organizations in the ICT industry and the uncertainties and challenges posed by these trends has the potential to hinder technological innovation and the free flow of information across firm boundaries. Technology standardization is beset by IP concerns that create conflict and pose challenges for technology managers. Much of these threats emanate from the nuanced differences in the entrenched IPR models across standards developing organizations.

Moreover, IPR policy impacts competition in a number of ways such as the pace of innovation and its impact on the evolution of market structures.[66]

The ineffectiveness of static structures, such as antitrust enforcement, in a dynamic and evolving setting like the ICT industry highlights the need for vigilance in managing the relationship between competition policy and IPR.[67] My motivation in undertaking this research is to probe the various considerations that inform the decision to participate in SDOs by ICT firms and to develop a decision-support model to fill an existing void. Reliable and generalizable models to guide decisions on technology standardization and IP portfolio valuation, and their integration into the firm's innovation strategy, have not received adequate scholarly attention.

Chapter 2: Literature Review

The literature on the impact of standards development on product and process innovation builds on the groundbreaking work of Utterback and Abernathy (1975), in which they recorded patterns of innovation within technology firms and developed various models to explain the rate of innovation of products and processes on the basis of the firm's chosen business and competitive strategy.[68] One of the main upshots of this research suggests that technology firms race to propagate their own implementation of a technological innovation in order to establish *de facto* standards which others will have to emulate. In applying the Utterback and Abernathy model to the firm's strategic alliances, Mauri and McMillan (1999) find that technology-intensive firms form alliances as the level of technology complexity and cross-dependencies increase.[69] Their findings buttress the Uterback and Abernathy product and process innovation models and contradict a large body of research which contends that technology firms avoid alliances to protect their intellectual assets from exploitative and opportunistic behaviors of their rivals, partners and others in their ecosystem. In the sections below, I shall detail the mainstream literature on technology standardization as well as provide a brief review of some supporting streams of inquiry.

2.1 Mainstream Standards Literature

David and Greenstein (1990) catalog a comprehensive survey of literature on technology standardization with a focus on the economics of compatibility standards.[70]

One of the main themes emerging from their study highlights the so-called "bandwagon effects" which explicates the economic gains from the coordination of different agents to achieve interoperability of components within a system. This is the phenomenon where ICT managers mimic the technology standardization behaviors and actions of keystone firms without deep analysis of their implications.

Another theme is centered on the concept of "positive feedback," where the increased adoption of a technology standard reinforces even broader adoption over time. This finding poses an interesting question: given positive feedback, will the market gravitate towards optimal standards on its own? When a presumably new compatibility standard is introduced, is it systemically bound for failure in its formulation, adoption and evolution? These researchers point out that markets which are characterized by consumption externalities do not always an optimal choice in a technology standard since choices made by early adopters wield an unduly large influence over late adopters.

Ozsomer and Cavusgil (2000) discuss the effects of technology standardization on network externalities and show that once a standard has emerged its rapid adoption can trigger competition in the short term leading to lower cost in the long term.[71] Zhu, *et al*. (2005) examine how network effects promote the diffusion of technology standards through switching costs and path dependencies by developing an integrative model that includes influential factors in the migration to open standards, and argue for migration from proprietary to open standards across organizational boundaries.[72]

The importance of technology standards development for the purpose of reinvigorating the US economy and renewing the competitiveness of US technology firms is strongly emphasized by Burnside and Witkin (2008) who confirm the futility of the go-it-alone approach and point to alarming statistics concerning the decline of US technological prowess.[73] For instance, measured as a percentage, in 2004 the US was overtaken in the issuance of science and engineering degrees by China, Japan and Ireland. Further, in 2005 US R&D as a percentage of Gross Domestic Product (GDP) was below that of China, Ireland, Russia and the EU. These researches contend that the lack of an IP licensing arrangement between university R&D and the industry is the key obstacle in maintaining a steady flow of technological innovation and business collaboration. These findings parallel the contention of Cohen, *et al*. (2002), that patent spillover and associated R&D diffusion is stronger in Japan than in the U. S.[74] Echoing similar sentiments, Pisano and Shih (2009) draw a bleak picture of the gradual decline of the US technology industry in its inability to produce its own innovations and inventions.[75] These researchers call for focused research and development as well as closer collaboration between business, academia and government to restore US technological competitiveness. This advice hearkens to a few decades back when a similar alarm was sounded over the declining US prowess in semiconductor manufacturing, which gave birth to the collaborative arrangement called Sematech.[76]

As a consortium of the leading semiconductor manufacturing firms, Sematech members pool their research and development in a collaborative manner for the benefit of the consortium in order to ward off the perceived unfair advantages of government-subsidized R&D by overseas competitors.[77] Collaborative innovation is not alien to American firms. However, the evolving process of technological change has a profound effect on the development, diffusion and adoption of technology standards.[78]

In studying the increasingly rapid pace of technological innovation, Coyle (2005) finds that technology standards can pace innovation by providing stability in a time of constant change.[79] Thus, standards organizations must maintain a steady beat rate of technological innovation and reach across other standards organizations for coordination and influence to build consistency and dependency within the ecosystem. Using the paradigm of a pyramid, Coyle maintains that technology standards form its base through which firms can specialize in the development of tools and other technology-based products to enable the development of more advanced innovations and applications, a layer above on the pyramid.

Consider that semiconductor manufacturers rely on a host of sophisticated factory tools, such as reliability and measurement equipment, to streamline and automate their operations. In turn, these tools may be based on certain standards in order to engender multiple sourcing and choice. Thus, technology standards facilitate competition as well as innovation.

In an award-winning study on the diffusion of competing standards in two-sided markets, Sun and Tse (2006) find that network effects overshadow technological superiority in determining the outcome of conflicting standards, in that strong network effects locked in an inferior standard even though a superior standard was available.[80] This implies that in defining technology standards new entrants must have superior technologies or financial resources to succeed as latecomers or when there is already a standard in place. By coining terms such as “single-home” (i.e. the adoption of one standard by a firm) and “multi-home” (i.e. the adoption of multiple standards by a firm) these researchers draw distinctions between a variety of models where a given standard can merely survive in the face of multiple options or completely dominate the field and drive out other standards. One clear implication from this study is particularly instructive: the tendency to multi-home will result in multiple standards, but there will be a gradual convergence of multiple standards towards a harmonious steady state. The reigning in of a potentially obstreperous environment into focus and predictability is requisite to the organic evolution of a business ecosystem. In this manner, a firm that is contemplating investing in technology standards development or participating in an existing standards activity can have a better sense of its potential payback.

Riley (2007) likens technology standards to elements of a competitive strategy in which market and firm-specific factors moderate the effectiveness of decisions and actions taken in the development of standards.[81] This firm’s history of standards activities, its assets, the characteristics of the technology in question and the characteristics of the market are all influencing factors in the success achieved by the firm in pursuing a technology standard.

An interesting, but often overlooked, point about the willingness and funding of personnel for technology standards development activity is raised by Blind (2006) who contends that standards work results in the flow of R&D primarily from large, well-funded and resourced firms to smaller and less-resourced counterparts.[82] The implication being that industry leaders with high R&D output must be wooed by the standards developing ecosystem with favorable licensing terms as incentive to counterbalance the net outflow of R&D output from large to small firms. Another implication is related to the resource requirements of technology standards development. Large firms are more able to afford assigning their talented employees to these tasks while the same may be apocryphal for small or medium-sized firms. Thus, the latter may be chronically under-represented in influencing the direction of technology standards development which may necessitate external policies, such as government, to goad these firms into active participation and positive contribution.

Waguespack and Fleming (2009) examined the role of startup firms in technology standards development and found that participation in standards activities greatly accelerated a "liquidity event."[83] The surprising finding here is that technology adoption, per se, was not the sole benefit for the startup but that simply attending standards organization meetings and conferences provided a sufficient level of exposure to exert influence, establish relationships with others in the ecosystem, and thus gain traction for the startup firm's technological innovations. This important finding highlights the impact of relationships within technology standards developing regimes.

Consistent with this finding, Harryson (2008) reports on the importance of relationship management for startup firms to balance technological explorations with industrial exploitations.[84] An implication of this study suggests that by building relationships, R&D managers can establish bridges to "previously disconnected disciplines and areas of value creating activities to drive creativity, innovation and entrepreneurship."

2.2 Multiple Perspectives

A substantial portion of the academic literature on standards development and its association to technological innovation in the ICT industry is organized along various perspectives such as Economic, Strategic, Organizational, and Legal (ESOL). These perspectives indicate the primary emphases and foci of the scholars. There are ancillary streams of inquiry such as innovation management, modularity and so on. Here, I shall outline the key findings in the ESOL perspectives.

2.2.1 Economic

Farrell and Saloner form a duo of economists with prolific contributions to the standards literature. In a seminal study, Farrell and Saloner (1985) examine the standardization trap to determine if the process of standards development can confine an industry on an obsolete or inferior technology path.[85] In a follow-up study (1986), these same researchers expound on the network effects of compatibility standards and show the effect of established technologies and the incentives for the adoption of newer standards-based technologies.[86] They posit that in the presence of an installed base, the early adopters of a new technology standard bear a disproportionate transition cost. In examining compatibility through converters overlaid on a standard, Farrell and Saloner (1992) establish that compatibility is a matter of degree and that a degree of compatibility can be achieved *ex post* at a cost.[87] Their findings imply that the economic benefit of converters is limited, at best, and the models they proffer are static in nature and do not comprehend the issues inherent in a dynamic milieu. Along the same stream of enquiry, Simcoe (2003) acknowledges the high-stakes nature of standards development in the presence of strong network effects and studies the Internet Engineering Task Force (IETF) to determine the relationship between the commercial stakes of the standards process with the length of the decision-making process in a standardization committee.[88]

In examining the economic and technological significance of standards organizations, Rysman and Simcoe (2008) consider patent disclosure distributions and find that SSOs play a key role in the adoption of the standards they develop.[89] Simcoe (2006) further explores the inherent tensions between cooperation and competition in the standards creation process and finds that the shift towards an "open innovation" model by some technology firms has increased controversy surrounding IPR strategy and licensing policy. Simcoe believes that aggressive IPR strategies can reduce the expected value of a technology standard.[90]

Katz and Shapiro form another duo of economists with copious contributions to the standards literature. In a ground-breaking study, Katz and Shapiro (1985a) consider R&D rivalry and find that major innovations will not be licensed but that minor innovations constitute better candidates for licensing by efficient firms.[91] These same researchers (1985b) show that the desire for standardization by a firm can vary with its position in the market (i.e. its market share).[92] In an important subsequent study Katz and Shapiro (1986a) analyze technology adoption in industries with strong network externalities and find that adoption depends on sponsorship and that sponsors exercise great influence on the ecosystem through investments to promote their technologies.[93] In a related study, Katz and Shapiro (1986b) examine the optimal licensing strategy of research labs that compete with their licensees and show, inter alia, that a profit-maximizing strategy is not always in the licensor's advantage.[94] In studying the behavior of rival firms in a dynamic setting, Katz and Shapiro (1987) find that the dissemination of innovation through licensing is only pursued if the innovation is deemed to be of minor value by the innovating firms in order to discourage imitation by its rivals.[95] Continuing to expound on their network externalities model, Katz and Shapiro (1992) find, counter-intuitively, that markets exhibit a propensity to rush into new, incompatible technologies and that the firm introducing the new technology is biased against compatibility as it establishes its own product as the standard.[96] In another important study, Katz and Shapiro (1994) explore the economics of complementary innovations. They highlight the need to further analyze linkages between hardware and software to better understand the dynamics of standards adoption in light of the ambiguity over the formation of coalitions and the behaviors of standards consortia, and to develop a more sophisticated grasp of incentives for innovation in the face of uncertain technological progress.[97]

Sherry and Teece (2004) investigate the changing value of patents and find an increase in value as patents are infringed upon or lead to litigation.[98] This has a direct bearing on the desire on the part of ICT firms to participate in SDOs in order to take advantage of the available IPR protections. In their investigation of the optimal licensing fee structure and model, Kulatilaka and Lin (2006) find the investment threshold to be monotonically decreasing in the intensity of network effects and the level of uncertainty as the investing firm pursues technology standards.[99] Further, Lin and Kulatilaka (2006) show the impact of network effects on licensing choice and find that a fixed-fee regime is optimal in the presence of strong networks. In other words, with increasing intensity of the network externalities, the optimality of licensing shifts from a royalty regime to a fee regime.[100] Lin (2011) delves deeper into the problem of patent “thickets” and mathematically demonstrates the compound effect of patent stacking, where one patent depends on another and can lead to excessive royalty burdens for the licensee. She shows that patent thickets do not necessarily lead to “double marginalization” but depend on the form of license.[101]

Grossman and Lai (2004) examine the incentives used by governments to protect IPR by considering two hypothetical countries, “north” and “south,” and develop economic models to explain the trade-off between increased innovations that result from a dynamic policy in an open economy with the competitive pricing of IP that ensue from a static policy in a closed economy.[102] Their findings confirm that large markets for innovative products compel governments to grant strong IP protection, while smaller economies have virtually no incentives to grant such protections. Schmalensee (2009) and Gilbert (2010) consider the problem of royalty stacking and patent holdup by examining policy questions related to participation in standards organizations, and concludes that SDOs must conduct *ex ante* IPR pricing "auction" to determine royalty rates before standards are approved.[103] [104]

An overlooked aspect of standards work is the process through which funding and financing are procured for its development. Spring and Weiss (1995) have but barely attempted to address this issue through the development of a framework which requires further quantitative analysis to yield useful and actionable cost-benefit assessment to address the chronic under-provisioning problem faced by most technology standards.[105]

2.2.2 Strategic

The landmark study of Teece (1986), addressing the question of the benefactors of innovation, underpins an important body of research that informs much of the standards literature focused on strategy.[106]

Figure 3 below depicts the Teece model:

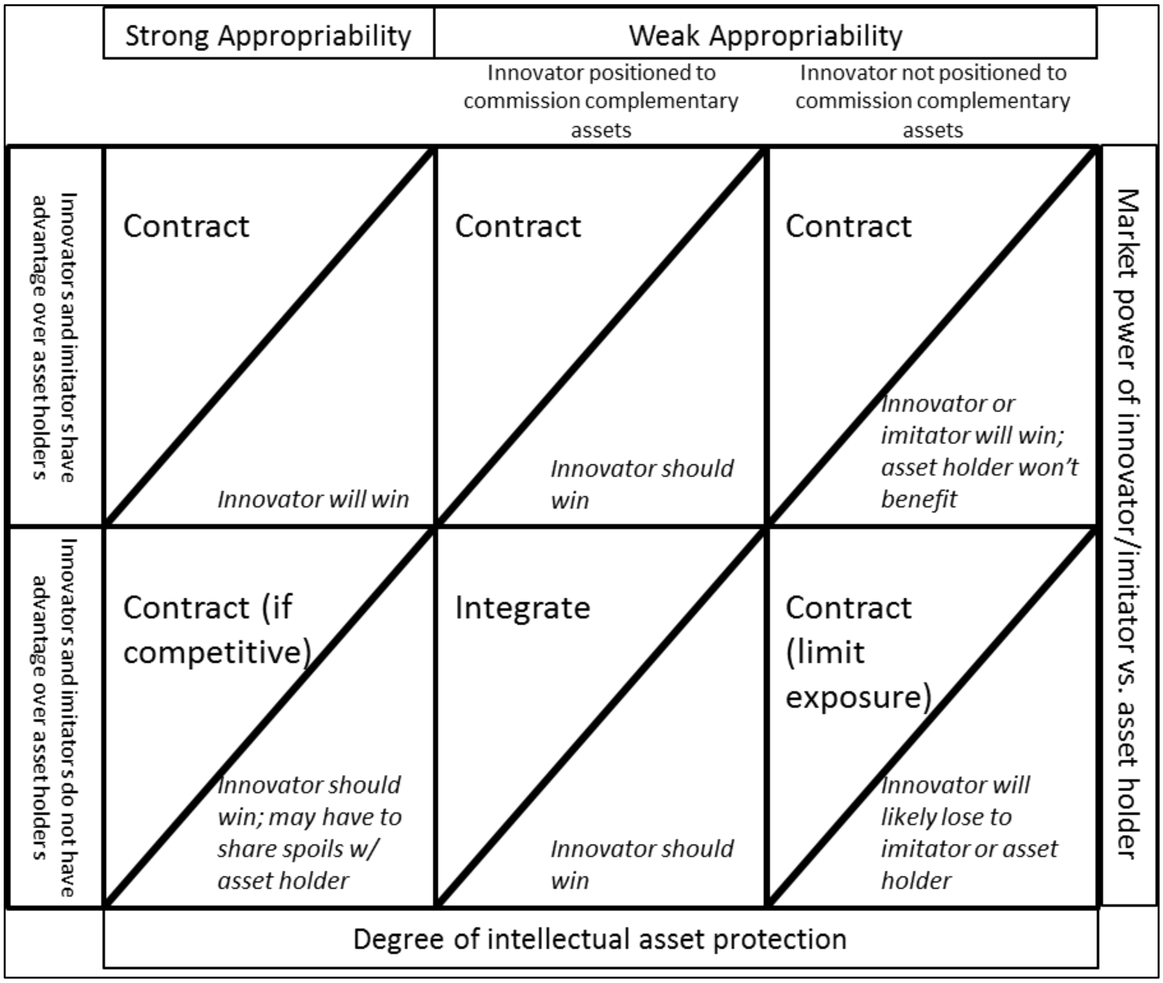

Figure 3 – The Teece "Profiting from Innovation" model.

Teece points out that when imitation is easy the financial benefits of an innovation can accrue to providers of complementary assets rather than to the originator of the innovation. The Teece framework maps the market power of innovators against the degree of protection of IP appropriability. Teece's key contribution in this regard is the strategic roadmap for innovators and imitators as they interact with complementary assets providers to increase the value of the original innovation. In a subsequent study, Teece (1998) proffers important models for the optimal exploitation of intangible assets such as knowledge, competence and IP, and observes that these assets form the basis of competitive differentiation in many sectors of the ICT industry.[107]

Many scholars have built on Teece's landmark findings. For instance Egyedi (1996) observes that standardization of technology is an endogenous factor for the firm engaged in its development.[108] In other words, participation in standards consortia enable the firm to be aware of its ecosystem and to react quickly to its feedback loop by adjusting internal strategies and resource allocations. This is largely in agreement with Schmidt and Werle (1998) who maintain that standardization facilitates and coordinates technology development in an orderly and predictable manner within the firm.[109] Jacobides, *et al*. (2006) extend Teece's original question of ways to protect innovation for reaping maximum benefits, and reshape the argument to one of finding value regardless of imitation by proposing structural dynamics of efficiency over control and by providing concrete templates for consideration by managers.[110]

Tao, *et al*. (2005) posit a set of strategies to organize intellectual assets to facilitate value extraction beyond that created by implementing these assets in technology-intensive products and services.[111] Pisano (2006) re-examines the notion of appropriability and shows that a "tight" regime, that is one with strong IP protection, is not advantageous to the firm given the changes in the industry brought about by the open source phenomenon.[112] Rose, *et al*. (2007) posits that a properly constructed IP policy will benefit the firm and its shareholders by boosting the firm's stock price.[113]

Egyedi (2010) points to some dysfunctional behaviors in the market that require active involvement by the government to mitigate, such as the non-standard use of cell phone chargers, which in 2008 alone were estimated at 1.2 billion worldwide, or competing standards that seek to accomplish the same result which, without corrective intervention by governments, can result in market confusion and sub-optimal user experience.[114] These failures in standardization can lead to lack of market transparency, incompatibility, inefficiency and waste in resource usage, and the dampening of innovation.

Besen and Farrell (1994) analyze the determinants of, and proffer strategies for, firms that participate in standards development in a horizontal market model.[115] They point out that by promoting or preventing the adoption of their preferred technology standards firms drastically affect competition and ascribe large benefits for themselves by prevailing in the establishment of an "architectural franchise" through which their chosen standards gain dominance. Farrell and Simcoe (2012) examines the tradeoffs between speed and quality of outcome within formal standards organizations and finds that consensus-building in a voluntary organization can lead to war of attrition and ultimately to suboptimal outcomes.[116]

Updegrove (1995) was among the first to outline the strategic intent behind keystone firms' participation in standards organizations for market advantage, the emerging IPR policy issues, as well as the evolutionary trajectory of standards organizations into national or international consortia.[117] With regard to the strategic investment in technology standards development, Kulatilaka and Lin (2004) consider firms with temporary monopoly opportunities and find a tipping point for licensing fees that can assure the investing firm an adequate return as well as the coalescence of the industry around a single standard, thus avoiding the repercussions of fragmentation that can result from multiple and competing standards.[118]

Tassey (2000) discusses the effects of standardization on technology innovation and diffusion and confirms that US industry and government managers are beginning to rethink their laissez faire attitude towards technology standards by realizing that standards constitute a form of technical infrastructure and thus have considerable public good.[119]

Blind and Thumm (2004) explore the relationship between patenting and standardization strategies and report, counter-intuitively, that firms with higher patent intensity have a lower propensity to join a standards developing organization.[120] This finding implies that if keystone firms with strong technological base stay away from the standardization process then both the quality of the standard and its diffusion will suffer.

Seo (2007) considers the process by which organizations make decisions about involvement in standards work by integrating the “Actor Network” and the “Self-Organized Complexity” theories into a framework for a holistic understanding of this decision-making process.[121] Seo identifies six fundamental elements for an organization to consider in ICT standardization, one of which is IPR, and confirms that essential IP provides a strategic advantage to its holder in this context.

In addressing the attempts to mitigate patent holdups, to force the disclosure of essential patents by their holders prior to the adoption of a standard, and to amend RAND terms with proportionality and maximum rents, Geradin (2006) argues that these measure ossify bilateral negotiations between patent owners and their implementers, constrain the licensing strategies of firms with large IP portfolios, create delays in the implementation of technological innovations, and lead to flawed mechanisms in allocating royalties among owners and users of IP.[122]

With a perspective on the impact of globalization on business competition, Basu and Waymire (2008) show that intangible assets such as ideas and knowledge embedded in patents and other forms of IP have taken on dramatic importance as value drivers of business in developed economies.[123] They contend that these intangible are a potential source of revenue but that few companies actually report stand-alone valuation of these assets due to challenges in current accounting practices.

In recognizing the great disparity in technology standardization and IPR policy setting between the West and the emerging markets elsewhere in the world, DeNardis (2009) argues for greater openness in ICT standards development through government procurement policies and corporate strategies.[124]

2.2.3 Organizational

The standardization of technology implies an agreement to do certain things in an open, prescribed and uniform manner, in contrast to a closed environment. Farrell, Monroe and Saloner (1998) confirm that firms prefer closed vertical organization to open vertical organization even though the latter may be socially more desirable.[125] Farrell and Saloner (1988) consider the question of coordination within committees of standards organizations and find that committees are by and large efficient means of coordination in standards development.[126]

Nelson, Shaw and Qualls (2005) find that industrial groups increasingly leverage the use of non-profit, voluntary-consensus standards development consortia to proliferate technology standards.[127] These researchers propose a model that that disaggregates technology standards development into six distinct activities.

Regazzoni and Rizzi (2011) introduce organization structures for the autonomous management of IP portfolios.[128] Using the TRIZ methodology, these researchers seek to map out the process of IP creation and look for sensitivities and optimization points in the overall creative process of IP generation. By studying patents in this way, organizations can examine patterns and continuously look for innovation possibilities through incremental optimizations in processes and organizations.

Ancona and Caldwell (1992) demonstrate that innovation teams can efficiently interact with outsiders, such as standards development organizations, and discuss the nature of the external activities and their link to the organizations overall performance.[129] Rindova, Petkova and Kotha (2007) discuss the continuous morphing of organizational structures to remain competitive in fast-moving environments and draw parallels to technology standards organizations.[130] Lichtenhaler (2008) shows how absorptive and desorptive capacity can be used to transfer technology across organizational boundaries with implications for technology standards bodies.[131] [132]

2.2.4 Legal

Hall and Ziedonis (2001) examine patenting behavior of the top 100 semiconductor firms during the “pro-patent” shift in the United States legal environment and find, paradoxically, a dramatic rise in patenting of intellectual assets among semiconductor firms that are historically not known for reaping returns on R&D investments through patenting.[133] Lemley (2002) provides a comprehensive survey of the legal aspects of technology standardization vis-a-vis the law and outlines four basic tenets: 1-the practical uses of IP and the rules that govern such use, 2-the organic diversity among standards organizations in the way they treat IPR, 3-the restrictive nature of age-old antitrust rules in a dynamic environment such as technology standardization, and 4-the role standards organizations play in ameliorating overlapping policies in multiple industries.[134] Related to this research, Gibson (2007) highlights the issues of the proper disclosure of IPR and the clear declarations concerning licensing of these assets as major impediments to the internationalization of technology standards.[135]

In a seminal study Reitzig (2004) outlines recent trends in the use of patents and the rise of thickets as an IP strategy adopted by ICT firms. Essentially, thickets are formed when several patents are bulked that may be separable into individual rights but cannot exclusively be assigned to an economic unit. Reitzig makes an important distinction in the way patents can be used as strategic leverage between discrete and complex technologies.[136] Simcoe, Graham and Feldman (2009) examine the use of IP by small and large firms within standards organizations and find that for small firms the probability of filing a lawsuit increases after the disclosure of essential IP, while the rate is unchanged for larger firms. Thus, standardization increases the difference in litigious behavior between small and large innovative firms because smaller firms cannot seek rents in complementary markets in which larger firms participate.[137]

From a policy perspective, the government ought to exercise extreme reluctance to intervene or influence the direction of technology standards development and IPR policies. This is the view advanced by Baird (2007) in affirming that the ICT industry is sufficiently sophisticated in regard to standards setting. The U.S. government has a long historical preference for market independence, international trade agreements limit the role of government in free enterprise markets, and the ability of governments to stay informed and to make correct decisions at crucial junctures in technology lifecycle is severely constrained.[138] Baird's advice is for government to encourage market solutions through incentives where possible and only intervene where a mandatory technology standard would provide substantial benefit through the minimization of deviations from market norms and the provision of flexible and efficient processes for the revision of standards to account for technological innovation and evolution. This view is somewhat countered by Bird (2006) who claims that the U. S. government is showing strong interest in protecting IP in developing economies, particularly in Brazil, Russia, India and China (collectively called BRIC).[139] China, in particular, is taking a renewed interest in setting national policy on the development of standards and IP.[140] [141] [142]

Commenting on the growing importance of IP assets in high-growth industries such as software and electronics, Wang (2010) cites Rivette and Kline in observing that IP law has transformed from dormancy to the driving engine of growth in high-technology companies.[143] Wang stresses, again citing Rivette and Kline that it is a "rare company … that has any clue whatsoever about how to value, analyze, and structure … IP asset transfers."

The weight and magnitude of standards setting in a modern, knowledge-based economy, according to Layne-Farrar (2010) comes into focus when considering the crucial role of IPR in setting standards.[144] In particular, the author discusses the disaggregation of the technology industry into design, manufacturing and testing that is scattered across the globe and is ever more reliant on technology standards as well as the role of non-practicing entities with large patent portfolios who adopt an offensive IP licensing strategy. The author cites the case of eBay v. MercExchange where the concurring opinions of Supreme Court Justices Kennedy, Stevens, Souter and Breyer held "…An industry has developed in which firms use patents not as a basis of production and selling goods but, instead, primarily for obtaining licensing fees. …For those firms, an injunction, and the potentially serious sanctions arising from its violation, can be employed as a bargaining tool to charge exorbitant fees to companies that seek to buy licenses to practice the patent."[145] [146]

In confirming the dynamic capabilities and the Shumpeterian notion of innovation-based competition advanced by Teece, Pisano and Shuen (1997)[147] and the sustainable competitive advantage made possible through the resource-based view of the firm first advanced by Barney (1991), Bagley (2008) argues that technology managers must remain astute to the provision of the law to create and capture value for the firm, including its intellectual assets.[148] Sagers (2010) cautions technology managers to be aware of antitrust regulations and the liabilities of SDO participation when standardizing technologies.[149] Anton and Yao (1995) provide further insight on these issues. Courts are likely to find antitrust liability where there are exclusionary provisions or egregious processes, particularly when those exclusions or processes are not germane to the development of the standard itself.[150]

Rai (1999) points out that the issues of IPR in technology research is not limited to the ownership of intellectual assets but also extends to social norms that govern claims of ownership. In general, the evolution of law is outpaced by rapid technological change, legal rules for the application of IPR policy sweep broadly and thus may be inefficient in doing so, and legal professionals do not always have adequate access to relevant information pertaining to technological change.[151]

Finally, in studying the determinants of essential patent claims, that is those patents that are deemed indispensable for designing and manufacturing products, Bekkers, Bongard and Nuvolari (2011) empirically establish that the content of the claims and the involvement of the claimant in the standardization process itself are *de rigueur* in the eventual success of the standard.[152]

2.3 Summary of the Mainstream Literature

From the preceding survey of the academic literature on technology standards, it can be surmised that keystone firms influence the direction and pace of technology innovations through the development of standards (Cusumano and Gawer, 2002), that technology standards development requires significant investment with high risk of inadequate returns and is not always a rational choice (Kulitalaka and Lin, 2004), and that the adoption and diffusion of technology standards is dependent on and facilitated through network externalities, complementary innovations and market timing (Schilling, 2002). These findings are further buttressed by Gandal (2002).[153] Further, it can be seen that standards-based innovation creates interdependence between firms and facilitates the pooling of intellectual assets, that complementarity and network effects of ecosystems is necessary for success of the standardization effort, and that the legal and regulatory environment for collaboration in SDOs is dynamic and ever-changing.

The key themes that emerge from the review of the mainstream literature on technology standardization are:

1. The optimal exploitation of intellectual assets such as knowledge, competence and IP by the ICT firm to differentiate itself from its competitors;
2. The influence wielded by keystone firms in setting the direction and pace of technology innovation through the development of technology standards;
3. The timely facilitation of technology diffusion and the enabling of its adoption through network externalities and ecosystems associated with SDOs; and
4. The requirements for significant investments for the development of technology standards with high risk of inadequate returns.

There are several peripheral streams of inquiry that are inter-related to the mainstream literature on technology standardization and are mentioned below for completeness.

2.4 Auxiliary Streams of Inquiry

In the context of New Product Development (NPD), a large portion of the literature on standardization in the ICT industry covers compatibility standards. Sahay and Riley (2003) provide additional perspective by addressing customer interface standards.[154] These researchers show that appropriability regimes have different impacts on the pursuit of customer interface and compatibility standards. There exists a considerable body of literature that highlights the advancements and shortcomings of the notion of modularity and reuse in various technology-based product design and development. Many research streams are directly or indirectly related to technology standardization. In particular, there exists a rich set of literature on product innovation and modular architecture, some of which is included below. Other bodies of scholarly work use game theory to probe into inter-organizational collaborations on SDOs. Some of this research is built on the Resource-Based View (RBV) of the firm where the participating organization's economic and human resources and strategic capabilities are found to be crucial in its ability to participate in technology standardization.

2.4.1 Innovation Management

In a seminal paper, Henderson and Clark (1990) point out that the traditional bifurcation of technology innovation as either 'incremental' or 'radical' is incomplete and potentially misleading.[155] They methodically distinguish between the components of a product and the ways in which innovations are integrated into that product through platform architectures and standardized interface points.

Iansiti and Richards (2006) show that technology-intensive industries are organized as complex and dynamic networks of suppliers, customers, competitors, assimilators, and value-added resellers.[156] Firms in these networks often take on one or more of these roles at any given time, thus adding to the complexities of collaboration and communication. Iansiti and Levien (2004) document the phenomenon of the clustering of technology-based firms into business ecosystems and the roles and functions discharged by the leader of this coagulation (also called "keystone").[157] The relationships between firms in an ecosystem often change or morph in unanticipated ways. A supplier one day can be an assimilator the next and so on. The integrative model that captures these complex relationships is articulated by Porter (1983).[158] [159]

Porter's "five forces" model has been further extended by Burgelman (2002)[160] and is used by business strategy consultants for the cogency by which it establishes one central tenant: the interdependence of firms in an ecosystem. This interdependency is bidirectional and equally applicable to the keystone as it is to the other firms that belong to the network.

Sawhney and Prandelli (2000) explain the phenomenon of distributed innovation, whereby firms in an ecosystem—ranging from competitors to complementors—pool their resources to collaboratively develop and sustain technology innovation, including standards, for the benefit of their ecosystems.[161] By using the multiplicative benefits inherent in a business ecosystem, technology firms can justify continued investments for sustained technology innovation and value-added differentiation. Sawhney and Prandelli have established that for technology-intensive firms, cooperation and co-dependence are more attractive alternatives to self-reliance, as market and economic pressures drive firms to constrict their knowledge base, maximize their expertise and streamline their operations around a band of core competencies.

Chesbrough (2003) is among the first to identify "open innovation" as a trend among technology-intensive firms where those firms that cannot afford to invest on their own innovate by licensing or buying intellectual assets from other firms.[162] Hamel and Prahalad (2005) further highlight a trend where some technology firms beat out their competition through collaboration with a network of complementors.[163] Ernst

(2005), in confirming Pavitt's (1999) argument on the link between complex innovations, such as chip design, and the internationalization of semiconductor manufacturing, discovers that the methodological changes intended to improve chip production instead yield increased cognitive and organizational complexity such that some products require a large number of designers with specialized and diverse capabilities. He further establishes that geographic proximity can become a disadvantage by empirically confirming the Granstrand, *et al*. (1993) and Cantwell (1995) suggestions that the "centrifugal" forces of geographical decentralization are stronger than the "centripetal" forces of geographic centralization that link multiple, dispersed innovation centers.[164]

Technology standards development facilitates inter-firm collaboration by providing well-understood interface points. Commenting on the emerging modular market structure in the technology industry, Iansiti (2005) posits that "the days of the lone wolf are over," and "standing alone is no longer a viable business model."[165]

2.4.2 Modularity

Modular product design has ushered in a continuous stream of innovations around common product platforms and architectures that enhance product variety and mass customization capability, enable rapid upgradability to meet changing market needs, provide for economies of scale and scope, increase the pace of parallel development, improve product design flexibility while decreasing development costs, facilitate shorter product development times and allow for efficient recombination of resources to achieve corporate strategies.

Modularity—the technique that enables the disaggregation of a monolithic structure into discrete and atomic parts, one or more of which can be juxtaposed to form a variety of products based upon a common, standardized architecture using known interface points, which can be scaled along several axes such as functionality, reliability, price, etcetera, to satisfy varying usage models and market needs—is an intrinsic byproduct of technology standards development. Ulrich (1995) defines modularity as "the relative property of a product's architecture." [166] For Ulrich, the physical elements that comprise a product are chunked along functional components that implement one or more functions in their entirety and the inter-chunk interactions are well-defined along interface points. Further, Ulrich sees modular product architecture as one that "…includes a one-to-one mapping from functional elements in the function in structure to the physical components of the products."

Baldwin and Clark (1997) define modularity as "building a complex product or process from smaller subsystems that can be designed independently yet function together as a whole."[167] In adapting McClelland and Rumelhart (1995), Baldwin and Clark (2000) further state that "…a module is a unit whose structural elements are powerfully connected among themselves and relatively weakly connected to elements in other units. Clearly there are degrees of connection, thus there are gradations of modularity."[168] The Baldwin and Clark definition of modularity is premised on the relationship between structures and not on functions, while Ulrich emphasizes the functional characteristics of the structural modules.

Product architecture enables the systematic and predictable proliferation of a family of products that are sourced from a common set of well-known interface points, components, parts and other technology building blocks. Zwernik, *et al*. (2007) consider product architecture as “a translation of functional requirements into physical definitions of building blocks.”[169] In a sense, product architecture facilitates the methodical and the procedural development of technology-intensive products by bringing together experiential knowledge and techniques with the theoretical underpinnings of proven methodologies to create a common base of technologies, or a platform, which can shorten development time, enhance design quality and enable the firm to meet a broad range of customer preferences and needs. The iPod from Apple is a recent example of a well-architected product platform. The Apple iPod classic, iPod nano, iPod shuffle and iPod touch, to name a few, constitute different models of a product family, all of which are constructed from a common platform and modules, with each member of the product family having a variable range of capabilities and functions.

Ulrich and Eppinger (2008) documented the concept of product architecture and consider a technology-based product to be comprised of functional and physical elements. The former are the operations associated with the product, while the latter are the parts, components and assemblies that implement the product’s functions.[170] Ulrich (1995) bifurcates product architecture into “modular” and “integral” types and stratifies modular architecture into “slot,” “bus” or “sectional” typology.[171] According to Ulrich, a modular architecture includes “a one-to-one mapping from functional elements in the function structure to the physical components of the product, and specifies de-coupled interfaces between components." An integral architecture, on the other hand, includes "a complex, non-one-to-one, mapping from functional elements to physical components and/or coupled interfaces between components." The automobile radio is an example of slot modularity, while the addition of an expansion card in a personal computer is deemed as bus modularity, and office partitions and piping typify sectional modularity.

In whatever form, modular architectures facilitate product change, enable product variety, increase component standardization, and reduce product development time. The so-called "delayed differentiation" of a product, according to Ulrich and Eppinger (2008), is a key benefit of a modular architecture that allows decisions to be deferred about localization or customization of products to maximize appeal to customers and to enlarge the total available market.[172] Technology innovation through modular design principles is possible only if there are standards that clearly define interface points and provide agreed-upon interoperability guidelines.

Beginning in the early twentieth century, the concept of modularity in technology-based product design took on added importance, especially in the development of automotive,[173] aircrafts,[174] household appliances,[175] IT and enterprise computers and computing solutions,[176] [177] [178] [179] [180] [181] as well as other technology-based industries. [182] [183] [184] [185] [186] [187]

Studies have shown the manner in which modularity can influence market evolution and induce product proliferation through rivalry and competition. Modularity leads to products that can be systematically upgraded to meet evolving customer needs that modular product development positively impacts the innovation capabilities of the and that modularity hastens organizational learning through concentration on a few set of interface points and well-defined modules.[188] [189] The counter-argument, put forth by Chesbrough and Kusunoki (2001), posits that focused learning can lead to a myopic viewpoint which in turn can engender a loss of focus on the broader learning and innovation opportunities that could otherwise be available.[190] Greater degrees of design modularity and higher levels of IT infrastructure flexibility enhance the operational performance of the firm through optimized supply chain responsiveness.[191] In this vein, modularity is attributed to the co-evolution of vertical outsourcing and horizontal consolidation in electronics manufacturing and the rise of the contract manufacturing industry.[192] [193]

To recap, modular designs facilitate the outsourcing of non-critical components through network alliances, thereby resulting in the efficient operation of the firm through focus on higher priority activities.[194] Modular designs allow large conglomerates to obtain operational dexterity in responding to dynamic market changes by recombining resources to maintain their market presence and competitiveness.[195] There are multiple linkages between product architecture and industry structure, and these linkages explain the observed intra-industry heterogeneity across firms.[196] [197] The reduction in the volume of information and the amount of knowledge sharing made possible through the codification of standardized design rules allows the firm to pursue outsourcing strategies within its ecosystem. [198] [199] [200] [201]

2.5 Summary of Research Streams

The literature referenced above describes how standards-based product architecture benefits the firm and positions it for market success through the rapid proliferation of innovative products made possible by open standards. Technology standards facilitate revenue opportunities for firms that invest in innovations which end up in open standards and thus grant the innovating firm the opportunity to derive revenues from the licensing of its intellectual assets. Licensing terms depend on the marginal costs prevalent in upstream and downstream markets. The literature on technology standards affirms that upstream firms in the ICT industry do not experience high marginal costs but that downstream firms can run into a variety of problems such as ambushes and thickets. Much of this research employs economic theories to describe various stimuli that engender standards development in the ICT industry. Table 6 below shows a non-exhaustive selection of the research streams already discussed:

Table 6 – Select research streams in the academic literature (non-exhaustive).

Author(s)	Title	Focus	Perspective
David, Greenstein	Economics of compatibility standards	Broad survey of literature on technology standardization	Economic
Cohen, Goto, *et al*	R&D spillovers and incentives to innovate	Patent sharing (intra-industry R&D knowledge) more in Japan than US; patents used for negotiation in Japan	
Tassey	Standardization in technology-based markets	Effects of standardization on technology innovation and diffusion	
Spring, Weiss	Financing the standards development process	Framework for examining the financing of technology standards development	
Lin, Kulatilaka	Network effects and tech licensing w/ fixed fee	Impact of network effects on licensing choice; fixed fee found to be optimal in strong networks	
Kulatilaka	Investment in technology standardization	Optimal licensing fee and investment threshold	
Farrell, Saloner	Standardization, compatibility and innovation	Can standards trap firms into becoming inferior	
Gandal	Compatibility, standardization & network effects	Economics of compatibility and standardization is mainstream	
Gans, Sterns	Incumbency and R&D incentives	Threat to engage in imitative R&D increases leverage, incumbents research more than entrants	
Gruber, Verboven	Evolution of markets under entry and standards	Effect of government policies on evolution of an industry; single standards accelerates technology adoption	
Teece, Pisano, Shuen	Dynamic capabilities and strategic management	Sources and methods of wealth creation; wealth not created by blocking competitors	
Besen, Farrell	Choosing how to compete: strategies and tactics in standardization	Strategy to compete within a standard vs. competing between standards	Strategic
Hax, Wilde	Delta model: adaptive management for a changing world	Triangle: three strategic options (low cost, differentiation, lock-in)	
Szykman, *et al*	A foundation for interoperability in next-gen …	Enhanced interoperability for backwards and future product development	
Clark	Interaction of design hierarchies and market	Nature of technology evolution impacts dynamics of competition and management of innovation	
Krogh, Cusumano	Three strategies for managing fast growth	The key to healthy corporate life is steady growth; scaling, duplication, granulation	
Cusumano	How Microsoft makes large teams work like small teams	How smaller teams can be more effective than larger teams in product innovation	
Porter	Strategy and the internet	Importance of companies to differentiate through strategy; internet is only an enabling strategy	
Harrigan	Joint ventures and competitive strategy	Impact of particular industry traits upon firms' options in pursuing them	

Dosi	Technological paradigms and technology trajectories	Continuous changes and discontinuities in technological innovation	
Schilling	Technology success and failure in winner-take-all	Technology standards driven by network externalities AND the firm's learning and market timing	
Teece	Profiting from technological innovation	Innovative firms often do not benefit from innovation due to strategy, licensing and public policy	
Simcoe, Graham, Feldman	Competing on standards?	IP strategies for small and large firms	
Chellappa, Shivendu	Economic implications of variable tech standards	Analytical model to study implications of maintaining different/incompatible technology standards	
Hemphill	Firm patent strategies in US technology standards development	Firm patent strategy matrix	
Soh	Network patterns and competitive advantage …	Central firms w/ high ego density and willingness to share knowledge achieved better innovation	
Ancona, Caldwell	Bridging the boundary: external process and performance	How teams interact with outsiders; nature of external activities and link to performance	
Lichtenhaler	Technology transfer across org boundaries	Absorptive and desorptive capacity	
Zhu, *et al.*	Migration to open-standard inter-organizations	Migration from proprietary to open standards across organizational boundaries	
Hirtz, Stone, *et al.*	Functional basis for engineering design	Integrates research from NIST and universities	
Farrell, Monroe, Saloner	The vertical organization of industry	Preferences of firms for closed vertical standards setting organizations	Org
Farrell, Saloner	Coordination through committees and markets	Coordination within committees of standards setting organizations	
Nelson, Shaw, Qualls	Interorganizational system standards development	Industrial groups leveraging the use of non-profit, voluntary-consensus standards development consortia	
Regazzoni, Rizzi	A TRIZ based approach to manage innovation and intellectual property …	Organizational structures for the autonomous management of IP	
Bekkers, Duysters, Verspagen	Intellectual property rights, strategic tech…	Investigates the role of IP rights in shaping the GSM standard	
Simcoe	Open standards and intellectual property rights	Investigates the inherent tensions between cooperation and competition	Legal
Funk, Methe	Market- and committee based mechanisms in standardization	Influence of governments on creation of standards-based products	

Hall, Ziedonis	The patent paradox revisited: an empirical study of patents in the ICT industry	Examines patenting behavior of the top 100 semiconductor firms during the “pro patent” shift in the US legal environment	
Lemley	Intellectual property rights and standards setting organizations	Comprehensive survey of the legal aspects of technology standardization vis-à-vis the law	
Gibson	Globalization and the technology standards game	Disclosure of IPR and declarations concerning licensing of patents as impediments to international standardization	
Reitzig	The private value of thickets and fences	Recent trends in the use of patents and the rise of thickets	
Baird	Government at the standards bazaar	Analytical framework for government involvement in technology standards	
Wang	Rise of the patent intermediaries	IP law transformation from dormancy to the driving engine of growth in high-technology firms	
Layne-Farrar	Business models and the standards setting process	Role of IPR in defining technology standards	

Chapter 3: Research Gaps and Questions

From the thoroughgoing review of the academic literature, I have identified several gaps that will be discussed in this section and linked to the research question that lies at the core of my research.

3.1 Gaps in the Academic Literature

The most prominent deliberation in the literature on innovation and technology standardization can be traced to Teece (1986) and his "profiting from innovation" model which boils down to the following question: should technological innovations that are subsumed in standards be licensed and for how much, or should these innovations be given away as open standards to engender broad adoption by the industry, even by competitors? Some scholars such as Kulitalika and Lin (2004, 2006) have proposed mathematical models to optimize licensing fees for the innovating firm, while other scholars such as Katz and Shapiro (1985), Leibowitz and Margolis (1994) and Shapiro and Varian (1999) believe that network effects alone can accrue sufficient value and utility from the use of standards for both the investing firm as well as the consumer of such goods.

Pisano (2006) highlights a major gap in the Teece model whose formulation takes for granted an IPR appropriability regime that is determined exogenously to the firm. Pisano points out that this formulation misses the shift to endogenous regimes where the behavior of the firm can significantly vitiate or bolster its IPR appropriability and the total value of its innovation through complementary assets. Simcoe (2005) echoes Teece when he debates the tension between value creation and value capture inherent in the creation of technology standards.[202]

David and Greenstein (1990) discuss two distinct themes that reflect the robust debate on the economic issues in the mainstream standards literature. To wit, competition among products that adopt differing standards engenders interoperability and compatibility problems for the consumer, and results in inventory proliferation for the firm. Also, ICT firms are faced with intense pressures to make their product compatible with rival offerings in order to provide choice and variety. The upshot of these trends puts downward pressure on innovation and the spillover effect negatively impacts recoupment of R&D investments. Soh (2010) has shown that ICT firms that exhibit transparent intent and flexibility in adopting and promoting product compatibility stand a better chance of market success.[203]

Aside from Gawer and Cusumano (2002), there is little attention paid to firms' incentives to provide resources to advance the work of standards organizations, and even less work has been done to probe the manner in which technologies are selected to be standardized by these organizations. Lemley (2002) and Gibson (2007) point out a major gap in the rules governing IPR disclosure and licensing in a sweeping survey of forty-plus standards organizations. While the heterogeneity in these IPR rules are a recognized gap that have been the topic of studies by other scholars, including the ambiguous definitions for the various licensing regimes, the issue of IP valuation is not adequately addressed.

Other streams of inquiry expose the debates on the merits and pitfalls of SDO formation. These consortia provide a counterweight to large keystone firms with significant market power, such as Microsoft (Hawkins, 1999); however, cooperation among large firms on defining standards can give rise to collusion and run afoul of antitrust laws. Most scholars are agreed that when it comes to evaluating IP for monetary value or for deciding whether to contribute IP to facilitate downstream business opportunity, the literature and research-based models are sparse. These scholars include Cerqueti and Ventura (2009), Vickers (2009), Langlois (1999), Pitkethly (1997), and others.[204] [205] [206] [207] Given the richness of the literature surrounding technology standards, the most germane gaps pertaining to my research question are summarized in Table 7 below:

Table 7 - Gaps in the academic literature.

Research Theme	Findings	Gaps
Optimal exploitation of intellectual assets (knowledge, patents, etc.)	Technology standards development requires simultaneous coordination across several stages of innovation and production	Model to assess risks and benefits of investments in IP development and contribution to technology standards
Influence on the direction and pace of technology innovation	Keystone firms set standardization agenda and create ecosystems to drive innovations, despite the necessity to share IP with rivals	Key determinants of the decision to participate in organizations that define technology standards
Facilitation of technology standards adoption through ecosystems	There is no uniform model to link technological innovation and the development of IP to the standardization these innovations	Holistic framework through which ICT firms assess various perspectives before joining standards organizations
Significant investments with high risk of inadequate returns	IPR policies of various SDOs are non-uniform, creating confusion in the ICT industry over technology standards development and adoption	Risk mitigation and investment recoupment considerations in the decision to join standardization effort

3.2 Research Objective

There are no extant decision support models or frameworks to help technology managers in assessing the relevant criteria in the decision to join or not join a technology standardization effort. For instance, what factors are relevant? How should these factors be prioritized and weighted in the decision? Are there different sets of factors depending on the technology, the standards organization, the market segment, and other such considerations? Is there a holistic framework by which managers in ICT firms can assess competing perspectives and other germane considerations in such a decision? How do these managers quantify benefits and mitigate risks? Most technology managers operate with insufficient information and analysis in this regard.

In addition, technology managers have no deterministic way to judge whether a product-focused or royalty-focused strategy will better serve the firm in harvesting value from its IP portfolio. Nor are there any studies to show whether an *ex ante* or *ex post* arrangement serves as the optimum IPR policy for a standards organization. In fact, the esoteric and variant nature of IPR contracts in different SDOs is flaccid in the view of most technology managers.

Thus, the paramount objective of this research is to develop and validate a model to assist technology managers in deciding whether or not to participate in the standardization of their innovative technologies, taking into account the important decision criteria with a diligent appraisal of all available alternatives and outcomes.

This research framework is depicted in Figure 4 with the gaps previously outlined in Table 7 above:

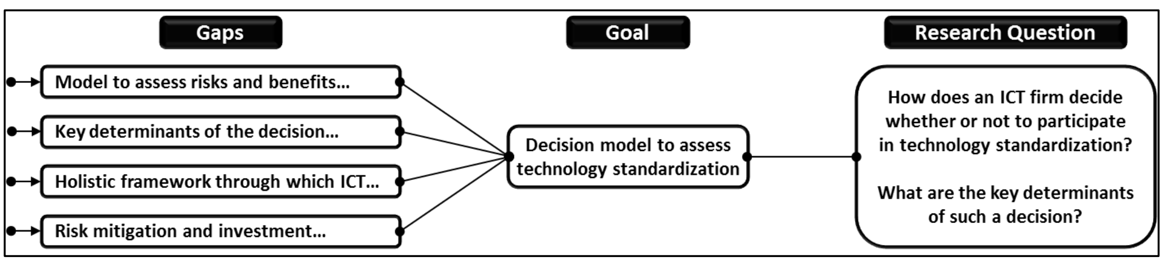

Figure 4 - Research framework.

3.3 Perspectives Derived From the Literature

Ab initio, four distinct perspectives emerge from the review of the academic literature on technology standardization. These perspectives are depicted in Figure 5:

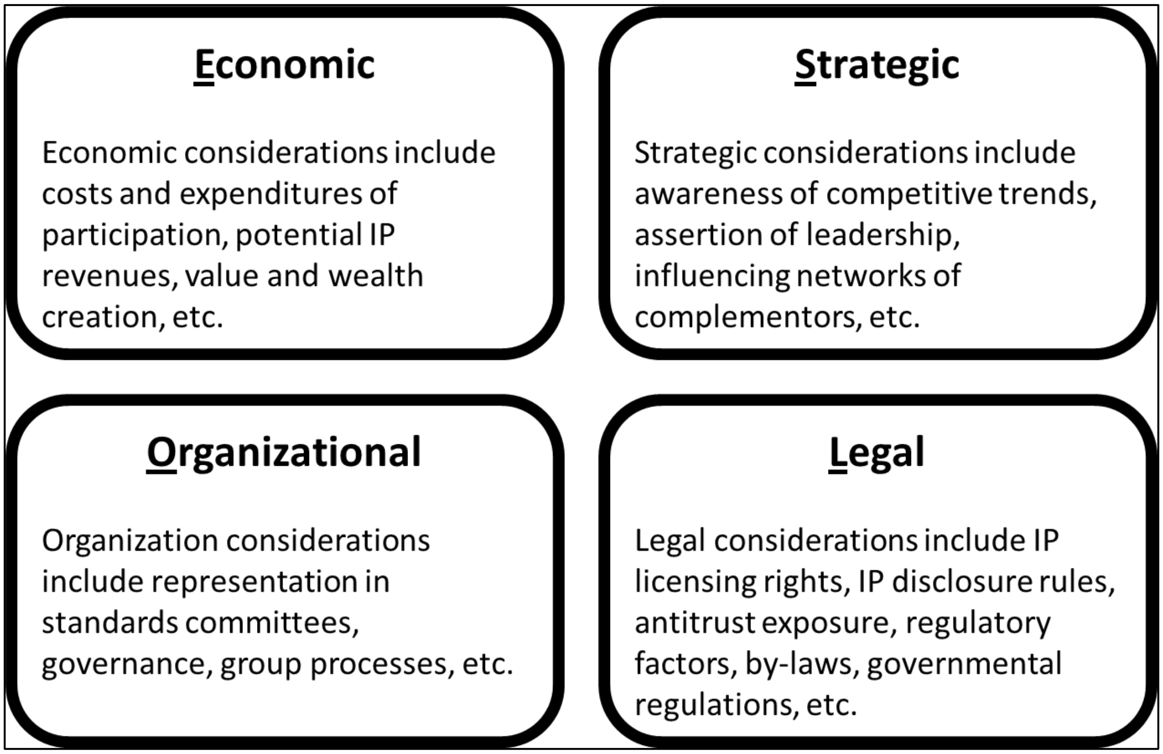

Figure 5 - Perspectives gleaned from the academic literature.

The application of multiple perspectives in managerial decision-making is well established in academia.[208] Thus, the derivation of the Economic-Strategic-Organizational-Legal (ESOL) perspectives is the initial unique contribution from my research and will be referenced as the ESOL framework throughout this study.

3.4 Research Question

The dissimilarity of IPR regimes in SDOs and the dependence of ICT products on a growing number of technology standards are formidable challenges faced by firms whose products contain inventions couched in numerous technologies that span multiple standards. In such an environment, how should a firm evaluate its IP portfolio to determine whether or not to participate in the development and diffusion of technology standards? How does a firm know that it has arrived at optimal licensing terms for harvesting maximum value from its IP portfolio? What is the strategic framework that informs a firm's IPR policies? What are the impacts of the firm's IPR policies on investments in innovation? I intend to research these and related questions.

To explore this space, the following question is germane: How does a firm decide whether or not to participate in standards development, and thereby to commit its IP portfolio to licensing obligations? There are a number of related questions that flow from this query. For example, how is an IP portfolio valued and monetized? In other words, how much is a given piece of IP worth and how is that value determined?

My research question constitutes a qualitative assessment of the factors deemed essential within a strategic decision-support framework.

Chapter 4: Research Methodology

From the literature-based gap analysis above, it is clear that ICT firms are faced with formidable decisions related to the management of innovations and the standardization of technologies such as whether the firm should participate in the definition or adoption of a technology standard by joining a SDO. Invariably such decisions are made in the face of imperfect information and uncertainties, and are impacted by a variety of criteria that require precise and up-to-date analysis as well as astute managerial experience and judgment.

4.1 Multi-Criteria Decision Analysis (MCDA)

Complex managerial decisions have many interrelated components. These form a network of interacting factors that necessitate the synthesis of diverse sets of data and information. In such a context, it becomes difficult to differentiate causes and effects and the decision is often taken in the face of risks and uncertainties.[209] The central question addressed by this study pertains to strategic decision making in a complex, multivariate environment with uncertainty and risk. There are many methods that use numeric techniques to differentiate and distinguish among a discrete set of alternatives and outcomes.[210] [211] [212] Usually, this is done through the assessment of the impact of various interacting criteria in the presence of several decision choices.

The Analytic Hierarchy Process (AHP) is one methodology used by decision analysts and managers in multi-criteria decisions. It has been used extensively for over

30 years in a variety of managerial decision-making applications and has been found to be robust, reliable and flexible.[213] [214] [215]

The premise behind the AHP is simple: a decision maker is faced with a number of alternatives and a set of criteria by which to assess each alternative to achieve a desired objective.[216] AHP disaggregates a decision into a hierarchy and enables the use of ratio scales in mathematically-grounded structures to assess the decision.[217] The outcome with the highest aggregated weight is evaluated for optimality.

AHP provides a structured approach for making decisions based on scores and weights from a multicriteria scoring model. It incorporates the three principles inherent in problem solving: decomposition, comparative judgments and synthesis of priorities.[218] AHP hierarchically decomposes the decision such that the factors or criteria can be compared in a pairwise manner against all possible outcomes. In many cases, experts provide the necessary matrices of comparison data, which are then mathematically transformed into a normalized eigenvector of weights associated with each element in the comparison matrix.[219]

AHP is a consistent, intuitive and time-tested framework for formulating and analyzing multicriteria decisions and within many contexts and applications.[220] [221] [222] For this research, the model and dataset availability are well aligned with the disaggregation of the decision framework and the quantification of expert judgments, respectively. Thus AHP is a suitable research methodology in this case. A disadvantage to the AHP methodology is its reliance on human choice and judgments that can be prone to reversals and inconsistencies, especially when experts are asked to re-evaluate their preferences after the initial elicitation of pairwise data.[223] There is a substantial body of research by many scholars, including Tversky, Kahneman and others, that delves into the issue of preference reversal.[224] [225] [226] Preference reversal will not be an issue in this research as the experts will not be asked to reconsider their original elicitations.

Other quantitative methodologies include descriptive statistics, Data Envelopment Analysis (DEA), other mathematical programming techniques such as integer linear or integer non-linear, fuzzy set theory and a number of other methodologies.[227] [228] [229] [230] [231] [232] DEA is primarily used to assess the relative efficiency of an associated set of Decision Making Units (DMUs). Mathematical programming is used extensively in modeling and solving a variety of optimization problems. Fuzzy set theory is an extension of set theory that is used chiefly to assess members of a set. Some scholars combine multiple methodologies. For example, AHP and DEA can be combined in decision support frameworks to overcome information loss or model insensitivities.[233] [234] [235] [236] [237] In this study, I intend to use AHP alone since information loss will not be an issue. The resultant model will be rigorously analyzed for consistency.

4.2 Model Definition

AHP requires the setting of a goal and the enumeration of the alternative ways to achieve that goal. The criteria and sub-criteria for the decision are identified. The decision variables are arranged in a hierarchy and the priorities of each alternative are determined with respect to the decision criteria and all sub-criteria within the hierarchy.

The hierarchy is comprised of the priority matrix linking each decision criterion to the goal as well as the priority matrix linking each decision criterion to each alternative outcome.[238] Data is derived from a variety of sources including data bases, expert opinions, literature reviews, and so on. After the data computation has passed checks for transitivity and consistency, global weights are assigned to each alternative to determine its rank in the decision hierarchy.

The AHP scoring model is based on the intensity of importance and ranges between 1 and 9, with 1 indicating that both options have equal importance, and 9 signifying that one option is extremely more important than the other.[239]

A derivative of AHP called the Hierarchical Decision Modeling (HDM) is employed for this study in which the constant-sum method of spreading 100 points in the pairwise comparison comprises the main difference with the AHP scoring scale. The relative weight assignments of the compared elements derived through the HDM computation algorithm is similar to the priority vector of the principal eigenvalues in AHP. Also, HDM mitigates for disagreements and inconsistencies, thus removing one of the known issues with AHP-based methods termed Condition of Order Preservation (COP).[240]

The AHP steps are followed sequentially as depicted in Table 8 below:[241]

Table 8 – AHP steps and actions.

Step	Action
AHP Step 0	Disaggregate the problem and build a hierarchy of the decision objective, criteria, alternatives and other factors germane to the decision
AHP Step 1	Create pairwise comparison matrices for each decision alternative per criterion
AHP Step 2	Normalize the matrices of pairwise comparison data
AHP Step 3	Compute the consistency index, ratio, eigenvector and related statistics
AHP Step 4	Compute weighted average scores for each decision alternative

Chapter 5: Research Design

A complex managerial decision process typically involves the identification of a desired objective, the implementation of situational analyses, and the evaluation of potential outcomes until one of the available alternatives is adopted and put into action. Sometimes, the chosen course of action is further analyzed for sensitivity to perturbation and unexpected effects to ensure that the optimum decision has been taken, and if not for corrective actions to be evaluated. The research to address this question will be conducted according to the plan outlined below.

5.1 Research Plan

The research plan is defined in nine serial, incremental steps shown in Figure 6:

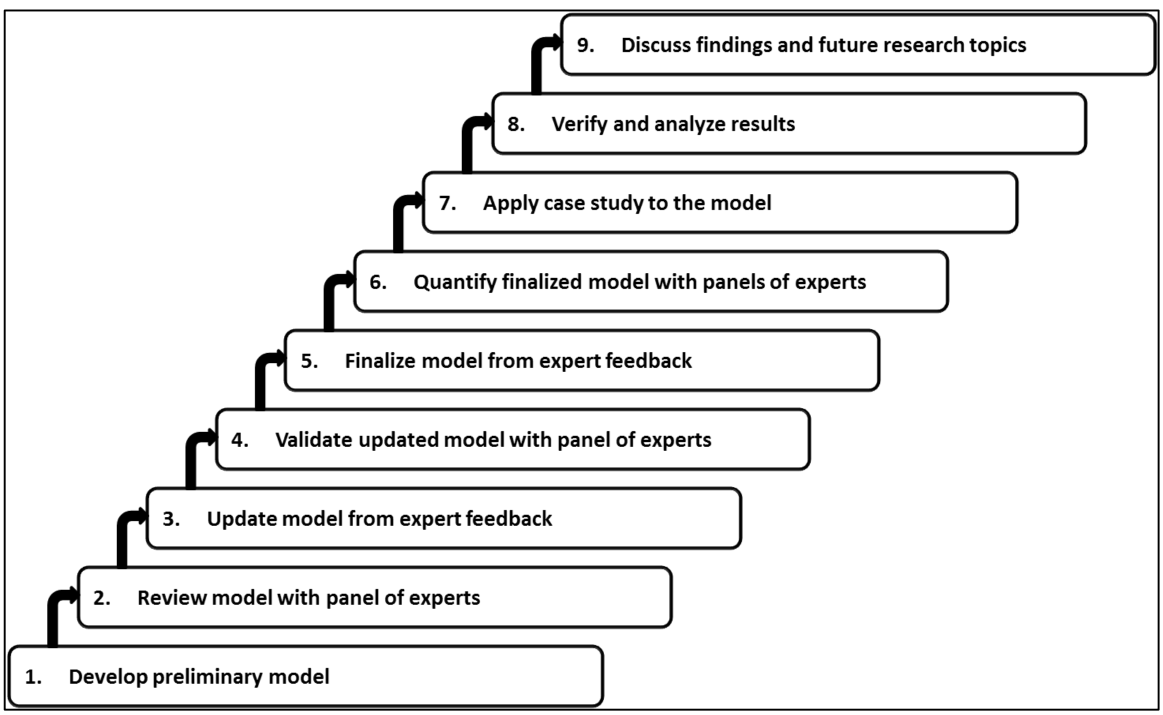

Figure 6 - Research plan.

These steps are further described in Table 9 below:

Table 9 - Research activities.

Step	Activity
1-2	After the development of a preliminary list of decision criteria derived from the literature, the initial AHP model shall be reviewed for completeness with a panel of experts in the field of technology standards
3-5	The updates from the reviews with the panel of experts shall be applied to the model and once again validated by the panel for agreement and corroboration
6	The final, validated model shall be quantified with pairwise comparison data, also supplied by panels of experts
7	The case of an extant technology standard shall be applied to the model as a final check for applicability of the general model to a specific case
8	The results shall be analyzed for consistency and sensitivity to gauge the strength and robustness of the model. The software application to carry out the computation of weights from the pairwise data shall be provided by the Engineering and Technology Management department at Portland State University
9	Related managerial implications, limitations of the study and a research agenda for future scholars shall be proposed to round out the findings

The objective is to standardize a technology which implies participation in the relevant SDO. The preliminary framework contains ten decision criteria and four decision alternatives. The criteria are consistent with the literature along the ESOL perspectives identified in the literature review section. These criteria shall be validated with the panel of experts as described above and other layers of the hierarchy shall be developed in the same manner.

Figure 7 below depicts the mapping of the research perspectives to the criteria:

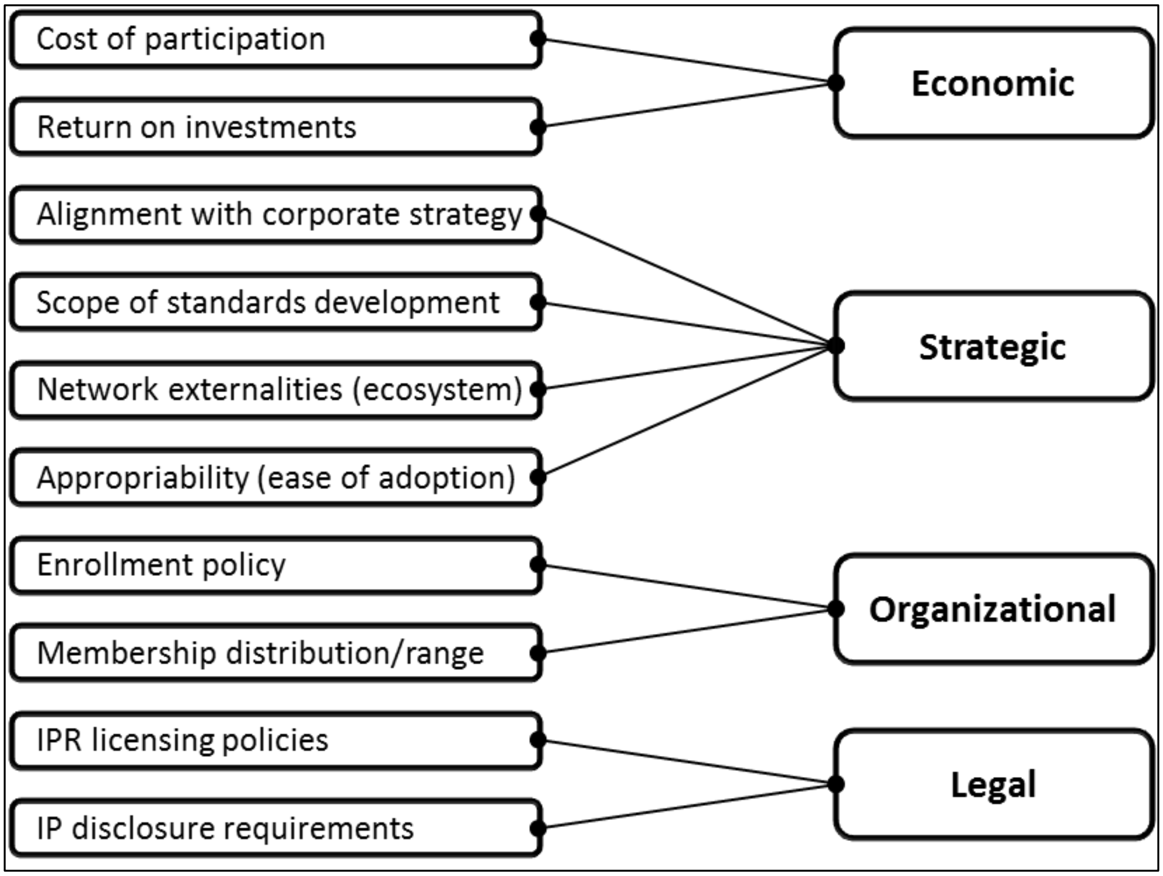

Figure 7 - Mapping of ESOL perspectives to decision criteria.

The various criteria are defined below as they map to the ESOL perspectives.

Economic

Criteria that pertain to costs inherent in technology standards development and the return on that investment (ROI) are mapped to the economic perspective.

Cost is a measure of the long-term expenditures and financial outlays that would be committed by the ICT firm in its pursuit of technology standards. Since the development and on-going maintenance of technology standards can span multiple years, the ICT firm needs to adopt a long-term horizon relative to this criterion. Cost is comprehensive of R&D, labor, capital and any other business expenditures in this context.

ROI is a measure of benefits that accrue to the ICT firm in its pursuit of standards activities. It can comprehend tangible and intangible benefits, all of which must be converted to quantitative metrics for uniform assessment. The valuation of IP portfolio is germane to this criterion since it provides added precision to the assessment of ROI.

Strategic

Criteria that pertain to the alignment of the technology standards development activity relative to the corporate strategy, the scope of the technology standards development, industry ecosystem interactions and network externalities as well as the IP appropriability regime are mapped to the strategic perspective.

The offensive-oriented firm will seek to join standards activities and contribute its IP for incorporation into multiple technology standards for the express purpose of exploiting the opportunity to collect rents and royalties from the licensing of its intellectual assets. The defensive-oriented firm will join standards development activities for the express purpose of obtaining licenses for the IP that it would be integrating into its standards-based products, and to protect itself from inadvertent infringement of said intellectual assets.

The scope of the standards development activity pertains to corporate strategy as it can include or exclude portions of a firm's IP portfolio with its attendant implications.

Network externalities can be deemed strategic in that they can expose the ICT firm to an ecosystem of partners, customers and complementors that could greatly enhance the function and value of its standards-based offerings.

The appropriability regime in this regard pertains to the degree to which IP licensing is available for appropriation by the ICT firm. This concept is discussed in the literature and is germane to a decision-support framework.

Organizational

Criteria that pertain to the enrollment policy and the membership range, or depth and breadth, of the organization, as well as the geographical coverage of the standards development organization are mapped to the organizational perspective.

The enrollment policy of the SDO can take many forms with implications to the management of the organization itself as well as the strategy of the ICT firm interested in joining the organization. It can be a completely open organization, a closed organization or somewhere in between these polar opposites where a firm could be invited to join based on certain desirability factors or ecosystem dependencies.

SDOs attract a range of members. This can include commercial firms, government institutions, educational establishments, individuals and so on. This membership range has implications to the management of the organization itself as well as the strategy of the ICT firm interested in joining the organization.

Legal

Criteria that pertain to the IPR licensing policy and the IP disclosure requirements of the SDO are mapped to the legal perspective.

The IPR policy of the standards organization has a direct bearing on the decision of the firm to join a standards effort. IPR policy is explained in depth elsewhere in this paper. Essentially, the standards organizations can obligate the IP owner to license its IP free of royalties or it may not impose any such onus, thus enabling the firm to charge rents on its IP if it chose to do so. Many ICT firms have shown a distinct preference for a RAND IPR policy where royalties are not precluded.

Rules governing IP disclosure vary from one organization to the next. This can be important since knowledge of IP reading on the technology standard can greatly influence the decision of the ICT firm in its pursuit of technology standardization. In general, IP disclosure can be completely passive and voluntary or actively required.

Having defined the decision criteria, the preliminary hierarchical construct for my research question is shown in Figure 8 below:

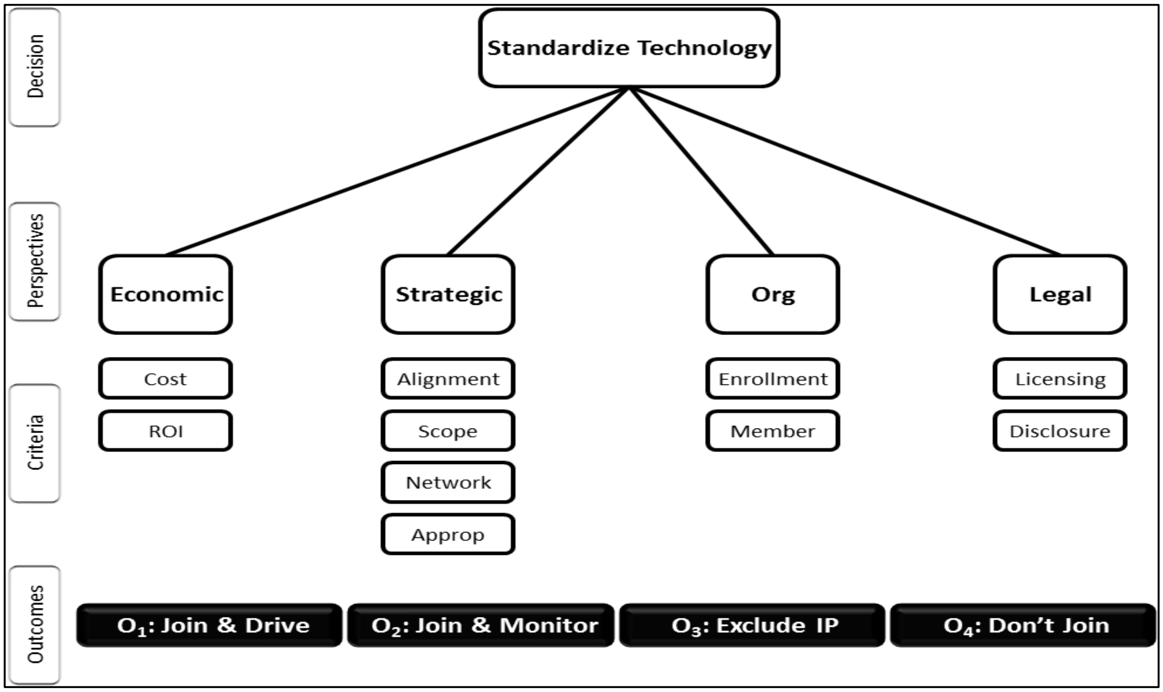

Figure 8 – Preliminary hierarchy of the decision model.

Four decision outcomes are identified. The first outcome (O_1) is to join and strongly participate in, influence and drive the development of the standard. The second outcome (O_2) is to join but to not actively participate and simply monitor the progress of the standards development as necessary. The third outcome (O_3) is to join but only after exclusionary carve-out of certain intellectual assets have been negotiated from licensing obligations to protect the firm from committing the portion(s) of its portfolio that it deems to be too valuable to make available. The fourth outcome (O_4) is to not join the standards development activity. Note that in the first two alternatives, the firm may be committing the relevant portions of its IP portfolio to licensing obligations. These decision alternatives were derived through interviews of IP attorneys at various ICT and law firms familiar with technology standardization.

5.2 Case Selection

The proposed decision-support framework shall be corroborated with an extant technology standard. This will confirm the generalizability of the proposed decision model. The validity of the model is confirmed when the general and case-specific applications are deemed to be consistent. The case in question is that of the Universal Serial Bus (USB).

5.2.1 Universal Serial Bus (USB)

In the early 1990s peripheral devices that connected to a Personal Computer (PC) such as scanners, printers, personal digital assistants, cameras and so on, each had their own complicated installation procedure. In fact, many such connections required the complete shutdown of the system, manual installation of the hardware and requisite software, and a restart of the entire system followed by post-installation adjustments, before a simple data transfer could take place between the PC and the peripheral device such as a printer.

With the growing popularity of the PC as a desktop printing and digital communications platform and the ever-increasing demand for connectivity with the burgeoning worldwide network of PCs connected to the Internet, conditions were ripe for a more efficient and convenient method to move data on or off devices without the hardship and the inefficient interruptions of the PC shutdown and reboot sequence.[242]

In recognizing this problem, Intel Corporation contributed technology from its research facilities to enable the low-cost and high-speed connectivity of peripheral devices to the PC platform with easy, plug-and-play simplicity. Intel spearheaded the formation of a group of influential industry leaders in developing an industry specification with royalty-free IP licensing made available to all adopters of the technology. This technology was dubbed the Universal Serial Bus (USB) and architected for the movement and storage of digital information between PCs and other digital devices through a cable. Intel led the integration of this technology in its chipset products and hosted many interoperability events to facilitate the adoption of the technology by other members of the USB ecosystem. The USB Implementers Forum (USB-IF) was formed in 1995 and later incorporated as an industry standards organization to support and accelerate the market adoption of USB-compliant products.

Today, USB is a household name and is the preferred connectivity standard for nearly all major electronic and personal computing devices worldwide. The USB standard has displaced older and competing means of connectivity such as the parallel port or the 1394 (also known as FireWire) technology. In 2007, the *Maximum PC* magazine named USB the premier PC technology innovation of all time![243] By 2018, it is estimated that USB device shipments will exceed five billion units.[244]

The selection of USB is justified given my considerable *a posteriori* acquaintance with this technology, access to knowledgeable experts, and the facile collection of reliable data. I collected data from technology managers involved in standards development to analyze the relative priority of the various factors that were identified as important to the development of USB technology. Six factors—cost, usability, compatibility, synergy, longevity, leadership—were identified by these managers and ranked for importance to the decision to standardize USB. The results of the pairwise comparison computation are shown in Table 10 below:

Table 10 - Factors influencing USB standardization (Neshati, 2009).

Statistics	Cost	Usability	Compatibility	Synergy	Longevity	Leadership
Max	0.21	0.24	0.26	0.19	0.23	0.15
Min	0.09	0.14	0.17	0.13	0.10	0.08
Mean	0.16	0.19	0.20	0.17	0.16	0.12
Std. Dev.	0.04	0.03	0.03	0.02	0.04	0.02
Rank	4 (Tie)	2	1	3	4 (Tie)	6

The respondents rated compatibility with existing standards and infrastructures as the highest priority consideration in the development of USB, followed closely by functionality and usability as well as strategic synergy with business objectives. Contrary to expectations, cost of development and longevity of the standard were rated lower, tied for fourth place in the rankings, with leadership opportunities for the firm bringing up the rear. The key learning from this study highlights the importance of continuity, through generational compatibility, when developing a technology standard like USB.

5.3 Validating the Model

The proposed model will be verified for construct, content and criterion validity. Construct validity pertains to the relationship between various measurable metrics within a model and verifies that the proposed model construction is relevant to the research at hand. Content validity pertains to the scope and comprehensiveness of the measurable metrics within a model and verifies that the proposed model content provides for sufficient research depth and breadth. Criterion validity pertains to the instrumentality and relevance of the various decision criteria and sub-criteria that appear in the model. This is shown in Table 11 below:

Table 11 - Model validation.

Validation Type	Description
Construct	The degree to which theoretical concepts and the structure of the model conform to praxis and/or expectations of the experts
Content	The degree to which the inclusion of individual model elements relate to praxis and/or expectations of the experts
Criterion	The degree of the effectiveness of the model in prioritizing current/future considerations and/or expectations of the experts

Validation of the model construct and content is accomplished through interviews and feedback received from Panel 1. This validation is performed after the development of the preliminary model using instrument I.3 (Model Development Instrument) shown below. Validation of the model criteria is accomplished through interviews and feedback received from Panels 2a and 2b. This validation is performed after the development of the updated model using instrument I.4 (Model Validation Instrument) shown below. These validation steps are performed prior to the compilation of the judgment quantifications from the experts and the *post facto* model analysis.

Furthermore, two important scores, Inconsistency and Disagreement, are used to vet the model as described below and shown in Table 12:

Table 12 - Inconsistencies and disagreements in pairwise comparisons.

Inconsistency	Disagreement
Measures consistency in the judgment of an individual expert (member of a panel)	Measures agreement among judgment results of the group (a panel of experts)
By convention, tolerance threshold is 10%	By convention, tolerance threshold is 10%
$\frac{1}{n}\sum_{i=1}^{n}\frac{1}{n!}\sqrt{\sum_{j=1}^{n!}(\bar{r}_i - r_{ij})^2}$	$\sqrt{\frac{1}{n.m}\sum_{j=1}^{m}\sum_{i=1}^{n}(R_i - \bar{r}_{ij})^2}$

Despite inconsistencies and disagreements in judgment quantification, scholars have shown that the principal eigenvector is a reliable measure for differentiating ranks of the matrix elements provided that the threshold is less than or equal to the 10% benchmark.[245] [246] The sections below describe mitigation methods for inconsistencies and disagreements.

5.3.1 Inconsistency

As judgment quantification relies on the knowledge of experts, putatively, data from human subjects may be inconsistent at times. Inconsistency is measured as the variance in the values of each orientation relative to the mean.[247] Consider that in pairwise comparisons, for n decision elements n! orientations exist, such as abc, acb, bac, bca and so on, representing the various comparison matrices. These orientations may have slight variance in the relative values of the elements in the presence of judgment inconsistency.

A score of 0 implies perfect consistency by the expert. By convention, the tolerance threshold for inconsistency is set at 10% (0.1).

In this analysis, discordant judgment data will be removed from consideration. In effect, data from an inconsistent expert will not be used in the final quantified model.

5.3.2 Disagreement

In judgment quantification it is possible for panelists to disagree with each other in their pairwise assessments of the same pair of elements. Given m experts and n decision elements, disagreement is computed as the variance in the value of the mean value assigned by the j^{th} expert to the i^{th} element relative to the group.[248]

A score of 0 implies perfect agreement among the panelists. By convention, the tolerance threshold for disagreement is set at 10% (0.1).

In this analysis, where there is significant disagreement among the panelists the assessments of the experts will be further reviewed and, if necessary, the panels will be reconstituted with experts along similar levels of expertise or job functions to mitigate the group disagreement.

5.4 Data Collection

Data for this study is primarily supplied by panels of experts immersed in technology standardization. This expert panel methodology is commonly used in qualitative research spanning several disciplines, including business, medicine, social sciences and other fields of scholarly enquiry as demonstrated by Mervis (1993), Smith and Ford (1993), Kiernan (1994), Strickland and Berman (1995), and others.[249] [250] [251] [252]

5.4.1 Data Collection Instruments

Table 13 describes the various data collection instruments used in this research:

Table 13 - Data collection instruments.

Phase	Instrument	Purpose	Data Collected	Method
0	Model Development (I.1 and I.2)	Review the preliminary model and provide feedback on additional Perspectives and Criteria	Broad spectrum of responses on model ingredients and numerous suggestions for the inclusion of additional Criteria and one new Perspective	Open-ended questions to elicit a wide range of responses on the preliminary model and leeway to edit the model
1	Model Validation (I.3)	Validate the updated model for construct, content and criteria, and generate the final model	Binary checklist expressing experts' [dis]agreements w/ inclusion of model elements from Phase 1	Computation of µ for each element and elimination of elements w/ < 67% (i.e. 2/3 majority)
2	Model Quantification – Perspectives (I.4)	Quantify the model at the Perspectives layer of the hierarchy	PCM data for Perspectives when judged against the Objective layer (i.e. root) of the hierarchy	Constant sum, w/ 10% threshold for Inconsistency and Disagreement
3	Model Quantification – Criteria (I.5)	Quantify the model at the Criteria layer of the hierarchy	PCM data for Criteria when judged against the Perspectives layer of the hierarchy	Constant sum, w/ 10% threshold for Inconsistency and Disagreement
4	Model Quantification – Outcomes (I.6)	Quantify the model at the Outcomes layer of the hierarchy	PCM data for Outcomes when judged against the Criteria layer of the hierarchy (each criterion)	Constant sum, w/ 10% threshold for Inconsistency and Disagreement

All of these instruments are produced in Appendix A. All panelists were required to read and acknowledge instruments I.1 (Subject Recruitment), and I.2 (Informed Consent).

5.4.2 Expert Panels

As shown in Table 14, five panels of experts are used to collect data for analysis:

Table 14 - Expert panel composition.

Panel	Composition	E:S:O:L Breakdown	Function
Panel 1	36 experts	10:10:9:7	Review preliminary model, update & validate the model
Panel 2a	29 experts	9:9:6:5	Quantify the Perspectives & Criteria for the General case
Panel 2b	15 experts	2:6:3:4	Quantify the Perspectives & Criteria for the USB case
Panel 3a	10 experts	2:3:1:4	Quantify the Outcomes for the General case
Panel 3b	7 experts	1:1:1:4	Quantify the Outcomes for the USB case

The panels are representative of several areas of expertise in the ICT industry such as technology managers, corporate executives with decision-making authority in matters related to technology standardization, engineers with substantial experience in SDO participation, and IP attorneys with expertise in patent and antitrust law, SDO incorporation and related legal issues. Panelists are drawn from various ICT firms representing diverse job functions to ensure balanced input in the dataset as well as from a variety of sources, including silicon component manufacturers, integrated systems developers, software vendors, measurement analysis tools providers, and so on. Figure 9 below depicts the panel functions:

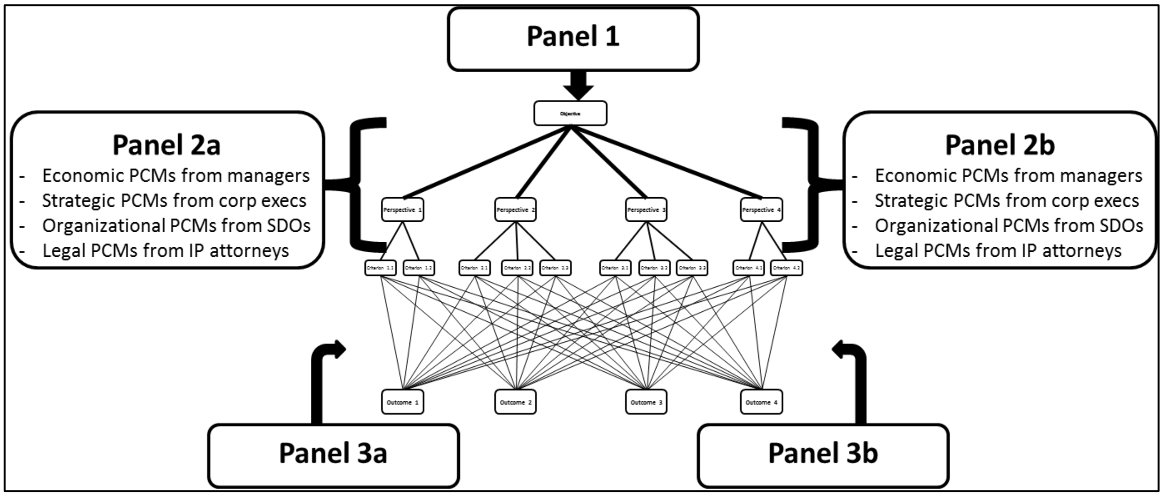

Figure 9 - Panels of experts and their functions.

Panelists are selected using these constraints to ensure balanced representation:

- Proven expertise in technology standardization in the ICT industry
- Broad representation comprising hardware, software and integrated systems
- Knowledge of other panel participants to compensate for individual bias
- Absence of conflict between panel participants to avoid skewed data
- Avoidance of overly passive and overly active panelists to ensure fair participation

The distribution of the participating ICT firms, the job functions of the panelists mapped to the ESOL perspectives and their geographical spread is depicted in Table 15:

Table 15 - Expert panel distribution.

Company	Job Function				Geography
	Manager (E)	Executive (S)	Engineer (O)	Attorney (L)	
IBM	X				USA
TI		X			USA
Intel			X		USA
Intel		X			USA
Toshiba			X		EU
Intel				X	USA
Intel			X		USA
TI			X		EU
Intel	X				USA
Intel				X	USA
Intel		X			USA
AMD	X				Canada
Cadence	X				China
Marvell	X				EU
Intel		X			USA
VTM			X		USA
Intel		X			USA
Broadcom	X				Vietnam
NEC/Renases			X		Japan
HP		X			USA
Intel				X	USA
Intel				X	USA
VTM		X			USA
Agilent	X				EU
Qualcomm			X		India
Intel		X			USA
Qualcomm	X				USA
Synopsys	X				USA
Intel			X		USA
Intel		X			USA
SWW				X	USA
Dell			X		USA
VTM	X				USA
Microsoft		X			ME
MM				X	USA
KS				X	USA
TOTAL	10	10	9	7	

The four job functions, Manager, Executive, Engineer and Attorney, are mapped directly to the ESOL perspective, respectively. In this context, a manager is any person with people or project management responsibilities and thus closer to the economic aspects of the decision to participate in technology standardization. An executive is any person with leadership responsibilities and thus closer to the strategic aspects of the decision to participate in technology standardization. An engineer is any person with technology innovation and development responsibilities and thus closer to the organizational aspects of the decision to participate in technology standardization. And, finally, an attorney is any person with advice and council responsibilities and thus closer to the legal aspects of the decision to participate in technology standardization.

In obtaining PCM data for the assessment of criteria within each of the ESOL perspectives, panelists data will be used in the following manner: data from managers will be used to assess the economic criteria, data from executives will be used to assess the strategic criteria, data from engineers will be used to assess the organizational criteria, and data from attorneys will be used to assess the legal criteria. In this way, any bias that inadvertently may creep in to the judgment quantifications will be avoided as a result of a panelist providing data in an area not considered to be their primary job.

While the panelists are drawn chiefly from ICT firms based in the US (72%), there are many panelists from other regions such as the EU (11%), the Asia-Pacific region (8%), and other geographies. Semiconductor manufacturers (47%) and system integrators (14%) comprise the majority of the panelists, but there are significant participants from the services industries, including the legal profession (19%) and SDO administration firms (8%). From an ESOL perspective, the panelists are fairly evenly distributed.

The geographical, business and ESOL perspective are shown in Figure 10:

Geography	#	%
USA	26	72.22
EU	4	11.11
Canada	1	2.78
APAC	3	8.33
Mid East	1	2.78
Japan	1	2.78

Business	#	%
Semiconductor	17	47.22
Systems	5	13.89
IP & Test	3	8.33
Software	1	2.78
Law	7	19.44
Services	3	8.33

ESOL Perspectives	#	%
Economic	10	27.78
Strategic	10	27.78
Organizational	9	25.00
Legal	7	19.44

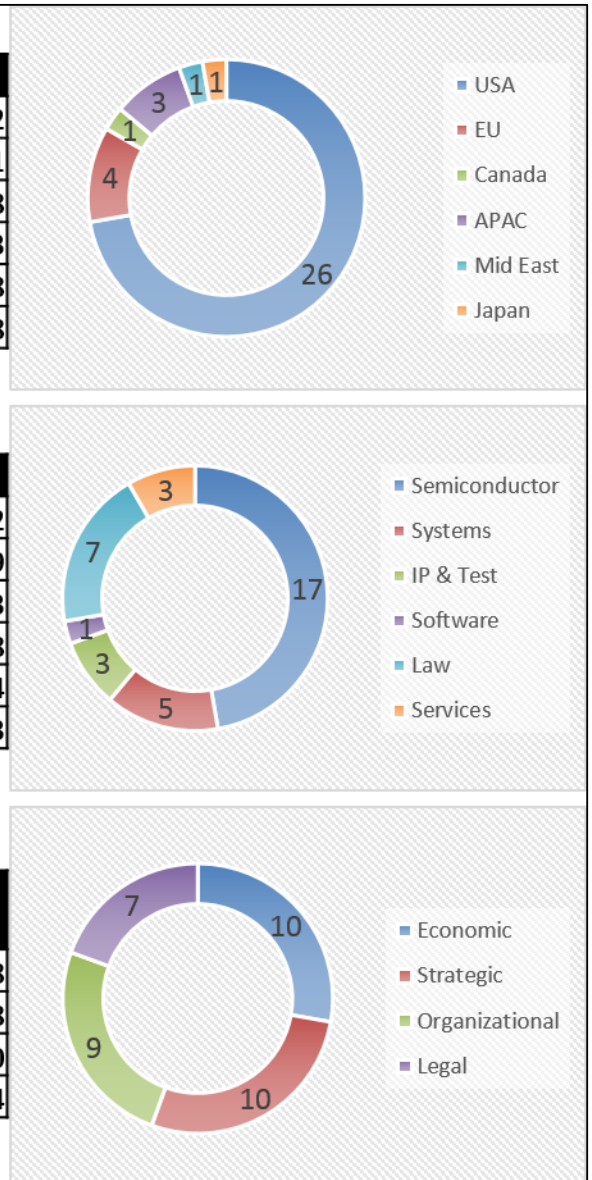

Figure 10 - Expert panel breakdowns.

5.4.3 Model Progression Process

The model progression followed the process as shown in Figure 11 below:

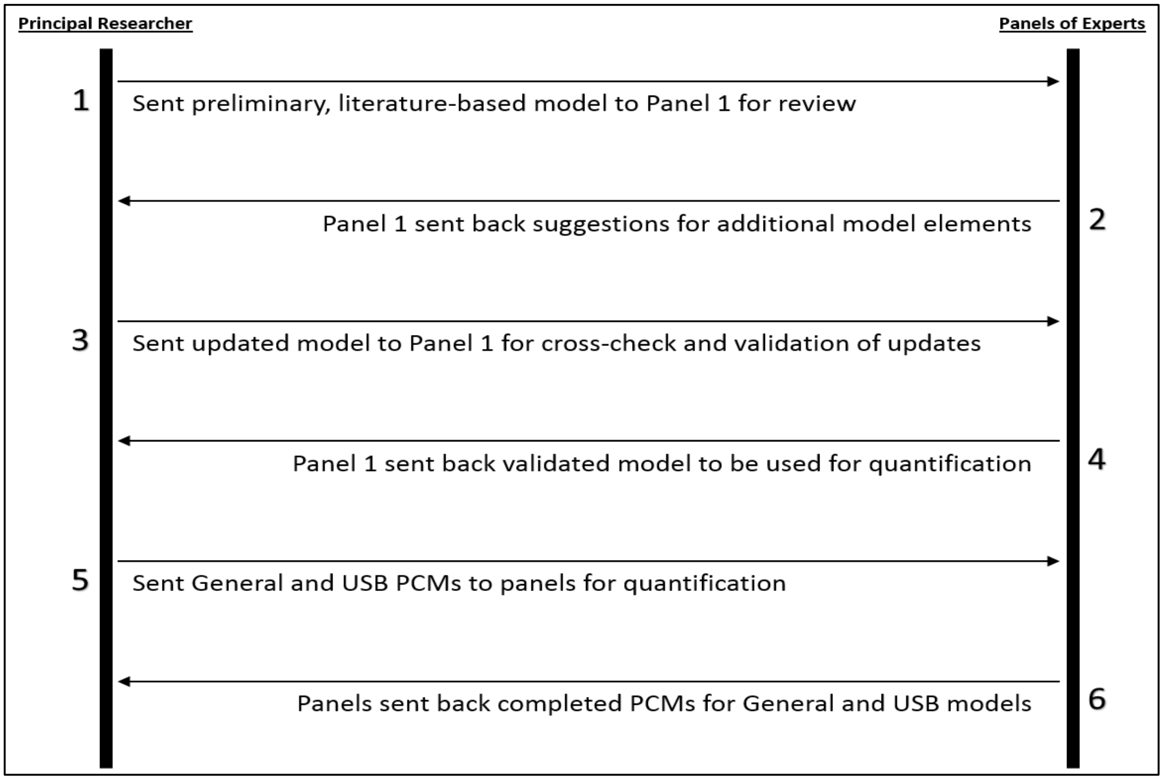

Figure 11 - Model progression steps.

Panel 1 reviewed the preliminary model, provided updates and validated the final model. This is shown as steps 1-4 above. Panels 2a and 2b provided judgment data to quantify the perspectives and criteria layers of the hierarchy, for the General and USB models respectively. Panels 3a and 3b provided judgment data to quantify the outcomes layer of the hierarchy, for the General and USB models respectively. These are shown as steps 5-6 above. The complete model development process is documented in the next chapter.

Chapter 6: Model Development and Results

From a thoroughgoing review of the academic literature, I have identified four perspectives on technology standardization relevant to ICT firms. These perspectives are: Economic, Strategic, Organizational and Legal (ESOL). Each of the perspectives are cogently explained and integrated into the AHP model. The cataloging of these perspectives is the first in a series of results from my research.

The preliminary model was sent to the panel of experts who were asked to review and to suggest improvements to it. The updated model with the integration of input from all panelists was sent back to the experts once again and this time they were asked to validate the various elements of the model. The resulting validated model was quantified at all levels of the hierarchy by different panels of experts for the General case and for the chosen USB case application. Finally, the General and the USB models were contrasted and analyzed for congruency, consistency among panelists and for sensitivity to arbitrary change.

These outcomes are explained in greater detail below.

6.1 Model Development

In this phase of research, experts on Panel 1 were asked to complete I.3 (Model Development instrument). The updated model is shown in Figure 12:

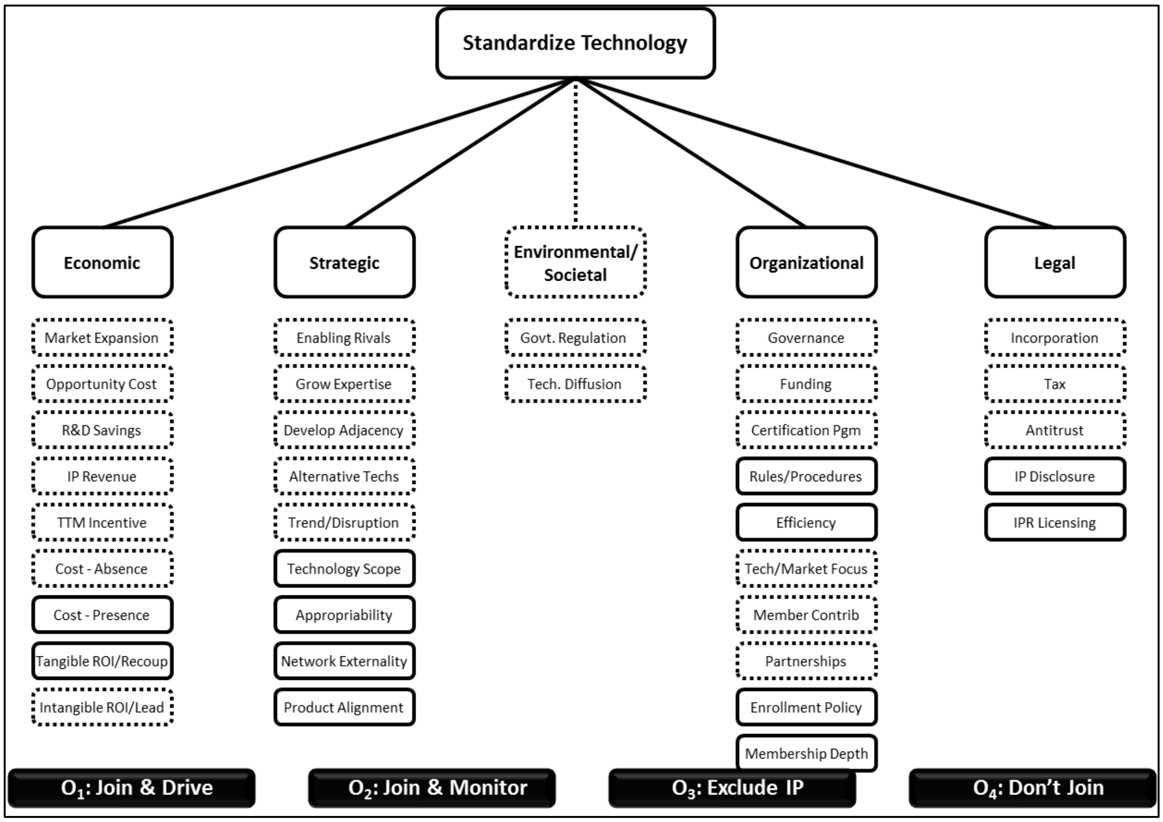

Figure 12 - Updated model.

Relative to the preliminary model, this version contains 1 new perspective and 25 new decision criteria. None of the input from the panelists was ignored or omitted and thus the revised model is comprehensive of all input.

The new perspective was identified as environmental/social, which is a perspective that is not pervasive in the extant academic literature. *Ipso facto*, this could be due to the recent significance of the role of technology standardization as an environmental or societal phenomenon.

Since this updated model was a compilation of blind input by all panelists, it needed to be validated by the group as a whole as described in the following section.

6.2 Model Validation

In this phase of research, all experts on Panel 1 were asked to complete I.4 (Model Validation instrument). The validation data used to finalize the model is shown in Table 16 below:

Table 16 - Model validation data.

Perspectives	Agree	Disagree	%
Economic	28	1	97
Strategic	29	0	100
Organizational	27	2	93
Legal	29	0	100
Environmental	19	19	66
Economic Criteria	Agree	Disagree	%
Market Expansion	27	2	93
Opportunity Cost	26	3	90
R&D Savings	23	6	79
IP Revenue	23	6	79
TTM Incentives	20	9	69
Cost of Absence	24	5	83
Cost of Presence	23	6	79
Tangible ROI	23	6	79
Intangible ROI	26	3	90
Strategic Criteria	Agree	Disagree	%
Enabling Rivals	17	12	59
Growing Expertise	28	1	97
Developing Adjacency	20	9	69
Alternative Technologies	19	10	66
Trends/Disruptions	26	3	90
Technology Scope	20	9	69
Appropriability	27	2	93
Network Externality	28	1	97
Product Alignment	27	2	93
Organizational Criteria	Agree	Disagree	%
Governance	28	1	97

Funding	24	5	83
Certification Program	29	0	100
Rules/Procedures	27	2	93
Efficiency	27	2	93
Technical/Marketing Focus	28	1	97
Member Contribution	28	1	97
Partnerships	27	2	93
Enrollment Policy	23	6	79
Membership Depth	20	9	69
Legal Criteria	Agree	Disagree	%
Incorporation	26	3	90
Tax Status	15	14	52
Antitrust Enforcement	25	4	86
IP Disclosure Requirement	27	2	93
IPR Licensing Policy	28	1	97
Environmental Criteria	Agree	Disagree	%
Government Regulation	22	7	76
Technology Diffusion	24	5	83

All elements that did not garner the consent of a simple majority of the panelists (2/3 or approximately 67% agreement) were eliminated from further consideration. The resultant model is shown in Figure 13 below:

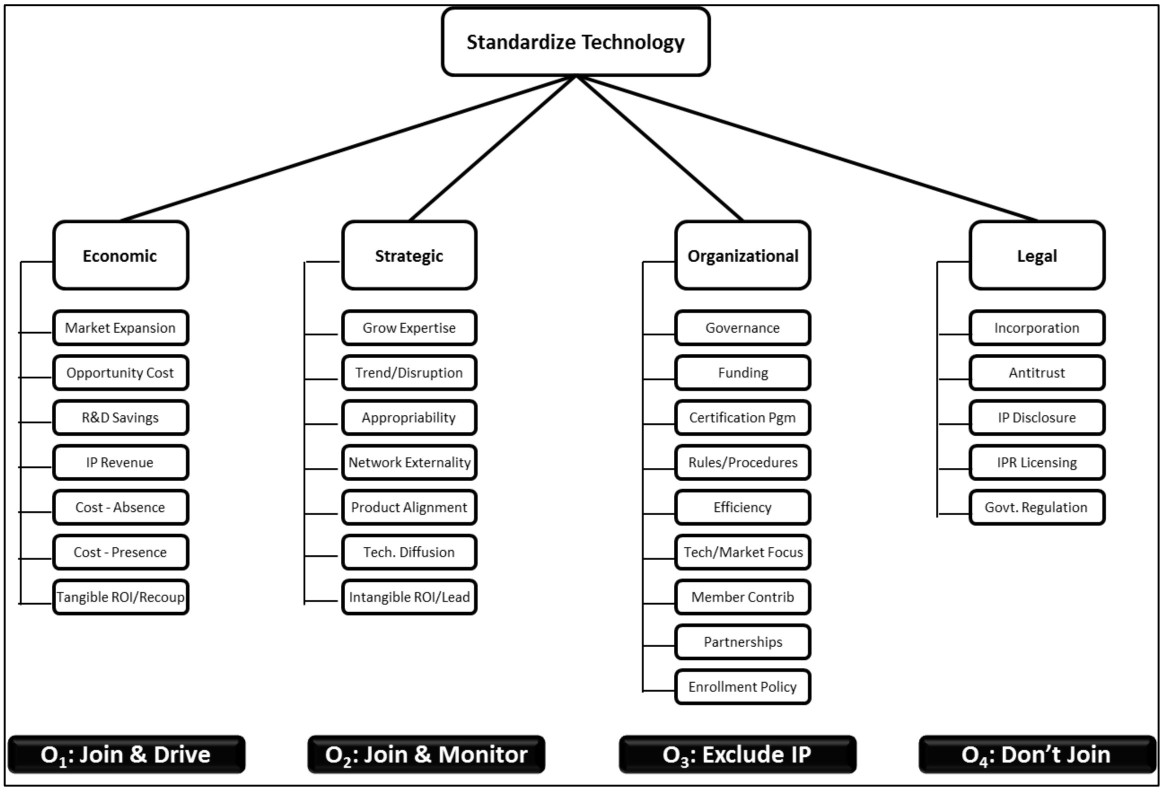

Figure 13 - Final, validated model.

The final, validated model is comprised of the 4 ESOL perspectives, 28 criteria and 4 outcomes.

The definitions of the decision criteria are depicted in Table 17:

Table 17 – Definition of decision criteria.

Perspective	Criterion	Abbr.	Definition
Economic	Market Expansion	ME	Access to new markets and opportunity to expand standards-based products to adjacent markets
	Opportunity Cost	OC	Financial assets that could be used for activities other than technology standardization
	R&D Savings	RD	Savings in R&D investments arising from access to contributed technologies by other firms in SDOs
	IP Revenue	IR	Revenues generated as a result of the licensing of intellectual assets to other members of the SDO/industry

	Cost of Absence	CA	Total estimated cost of missing out on standardization over the life of the technology
	Cost of Presence	CP	Total estimated cost of participating in standardization over the life of the technology
	Tangible ROI/Recoupment	TR	Total estimated return or benefit from the investment in standardization over the life of the technology
Strategic	Grow Expertise	GE	Growth of hitherto unavailable technical expertise from participation in standardization
	Trends & Disruptions	TD	Ability to detect emerging trends and technological disruptions from participation in SDOs
	Appropriability	AP	License availability for the critical IP for interoperable product development and ease of technology adoption
	Network Externality	NE	Exposure to networks and ecosystem of customers, complementors and competitors
	Product Alignment	PA	Alignment of product plans and roadmaps to the emerging technology standard
	Diffusion of Technology	DT	Ability to broadly diffuse technologies to gain advantage through familiarity and dependencies on IP portfolio
	Intangible ROI/Leadership	IR	Non-financial returns on investment such as industry leadership, prestige and other visible forms of status
Organizational	Governance	GO	Accountable leadership and strong adherence to democratic governance for representative administration of the SDO
	Funding	FU	Adequate funding and income generation by the SDO for long-term operation and stability
	Certification Program	CP	Ability of the SDO to administer programs to test conformance to the specification to ensure interoperable implementations
	Rules & Procedures	RP	Availability and adherence to fair, transparent and uniformly applied sets of rules and procedures
	Operational Efficiency	OE	Overall efficiency of the SDO, its speed of execution, timely promotion of standards and other considerations
	Technical/Marketing Focus	FO	Primary focus of the SDO – technical/technology development, marketing or other

	Member Contributions	MC	Ability of SDO members to contribute technologies during the definition/development of standards
	Partnerships	PA	Ability and experience of the SDO in forming partnerships with other SDOs to promote standards
	Enrollment Policies	EP	Flexibility of the SDO in accepting new members to participate in standards development
Legal	Incorporation	IN	Legal status of the SDO as a recognized for-profit or non-profit entity with and elected Board of Directors and Officers
	Antitrust Enforcement	AN	Adherence of the SDO to antitrust monitoring and timely action when violations are detected
	IP Disclosure Requirements	ID	IP disclosure requirements and related policies of the SDO that will identify essential patents reading on the standard
	IPR Licensing	IL	IP license availability consistent with the IPR policies of the SDO on reasonable and non-discriminatory terms
	Government Regulations	GR	Government mandated regulations that bear on the work product of the SDO such as restrictions or other limitations

6.3 Model Quantification

In this phase of research, the model is scored with the judgment of the experts using the equation shown in Figure 14:

$$ST = \sum_{i=1}^{I} P_i \sum_{j=1}^{J} C_j \sum_{k=1}^{K} O_k$$

Symbol	Explanation
ST	Aggregate score of the decision to standardize a technology (sums to unity)
P_i	Relative contribution of the i^{th} Perspective to the decision
C_j	Relative contribution of the j^{th} Criterion to the decision
O_k	Relative contribution of the k^{th} Outcome to the decision
I	Total nodes at the Perspectives level of the hierarchy (4 in this model)
J	Total nodes at the Criteria level of the hierarchy (28 in this model)
K	Total nodes at the Outcomes level of the hierarchy (4 in this model)

Figure 14 - Aggregate score equation and symbol definition.

The experts on Panels 2a and 3a were asked to complete I.5 (Model Quantification Instrument – Criteria). The result is shown in Figure 15 below:

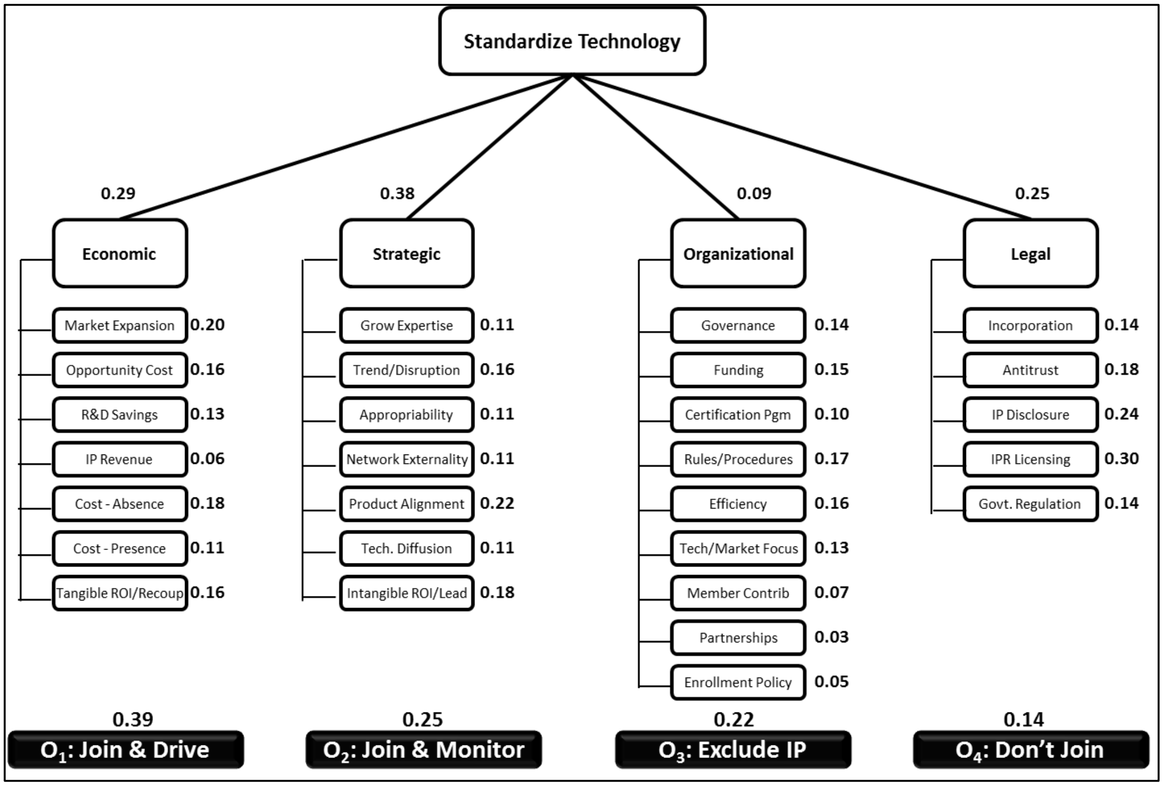

Figure 15 - Quantified model (General).

The experts rated the strategic perspective highest among the 4 ESOL perspectives with a score of 38% and rated the organizational perspective lowest with a score of only 9%.

Among the criteria, Product Alignment (PA) is rated highest by the experts under the strategic perspective.

The decision outcome preferred by the experts is O_1 with a score of 39% with O_4 rated lowest at 14%.

The experts on Panels 3a and 3b were asked to complete I.6 (Model Quantification Instrument – Outcomes). The result is shown in Figure 16 below:

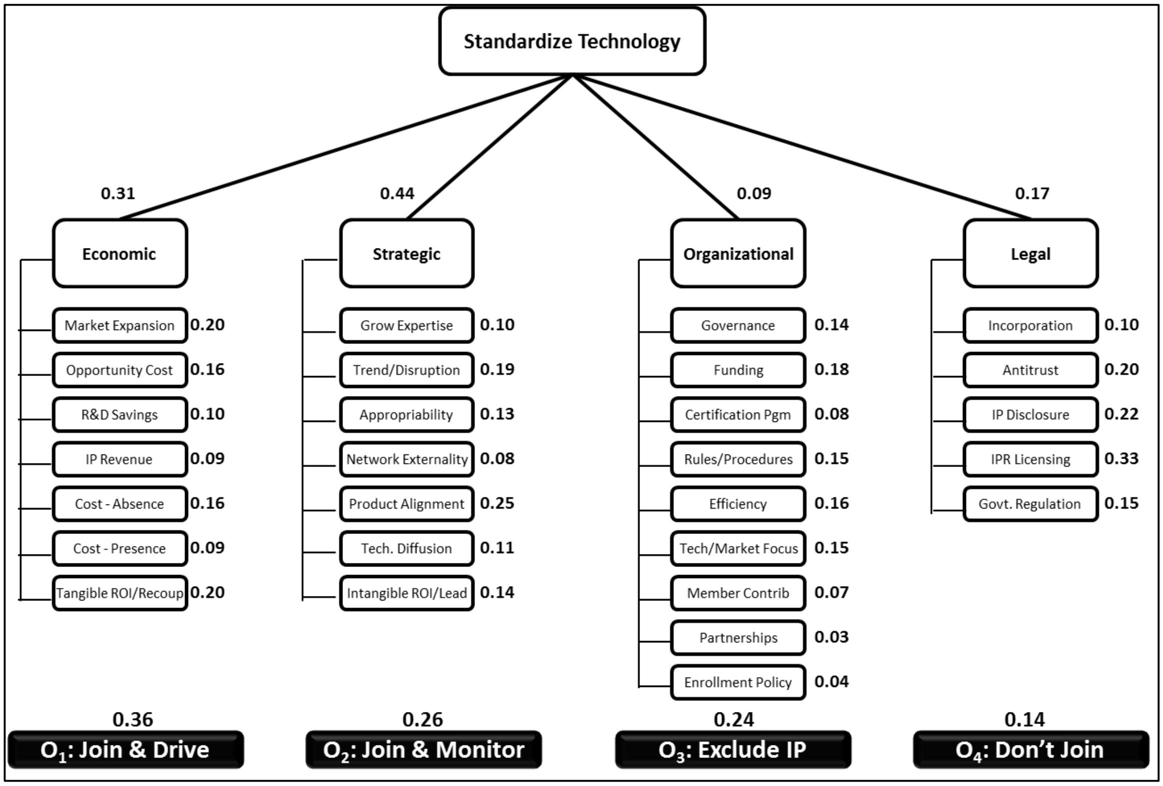

Figure 16 - Quantified model (USB).

In the case of the USB model too the experts rated the strategic perspective highest among the 4 ESOL perspectives with a score of 44% and rated the organizational perspective lowest with a score of only 9%. This is consistent with the General model.

Among the criteria, Product Alignment (PA) is rated highest by the experts, which is consistent with the General model.

The decision outcome preferred by the experts is O_1 with a score of 36% with O_4 rated lowest at 14%. This, too, is consistent with the results obtained in the General model.

Chapter 7: Analysis of Results

As mentioned, the use of expert judgments involves subjectivity among the input sources. To ensure an effective use of subjective data in a quantitative decision model, the data must be checked for inconsistencies, disagreements and sensitivities.

A simple method to check for sensitivity of decision alternatives with respect to the criteria follows a "what-if" scenario wherein weight assignments are incrementally altered one at a time while holding all others constant, to determine if that incremental change induces a different outcome or result.[253] These perturbations are performed systematically over the entire matrix of criteria and alternatives. Where sensitivities are found to alter the initial model result, further analysis can be performed to determine the relationship and dependence of the factors involved in the change.

In my analysis I will systematically vary the weights of perspective and criteria nodes to assess the sensitivity and robustness of the model.

7.1 Model Scores

In reviewing the results for both the General and USB models there are some inconsistencies that need to be mitigated but the disagreement scores are generally below the expected threshold. These results are discussed below.

7.1.1 Inconsistency Scores

Most of the experts' data was consistent but there were some experts that exhibited inconsistencies. Table 18 below depicts the expert inconsistency scores:

Table 18 - Inconsistency scores for all panels.

Phase	Panel	Panelist	Model	Inconsistency
2	2a	Expert02	General	0.16
2	2b	Expert02	USB	0.18
2	2b	Expert03	USB	0.22
3	2a	Expert15	General	0.14
3	2a	Expert27	General	0.16
3	2a	Expert15	General	0.24
3	2a	Expert16	General	0.17
3	2a	Expert27	General	0.11
3	2a	Expert29	General	0.14
3	2b	Expert03	USB	0.17
3	2a	Expert14	General	0.15
4	3b	Expert05	USB	0.18
4	3b	Expert06	USB	0.15

The data from these inconsistent experts were removed from both the General and USB models which caused slight modifications to the weight computations of the perspectives, criteria and outcomes elements at each layer of the model hierarchy. None of these changes, however, had any material impact on the priority or ranking of the various elements, nor did they have any impact on the decision outcome. The removal of inconsistent data from the model improves its overall robustness and increases confidence in the derived results.

The revised side-by-side scores for both the General and USB models are shown in Figure 17 below, with the numbers on the right (in blue color) representing the General model and the numbers on the left (in red color) representing the USB model:

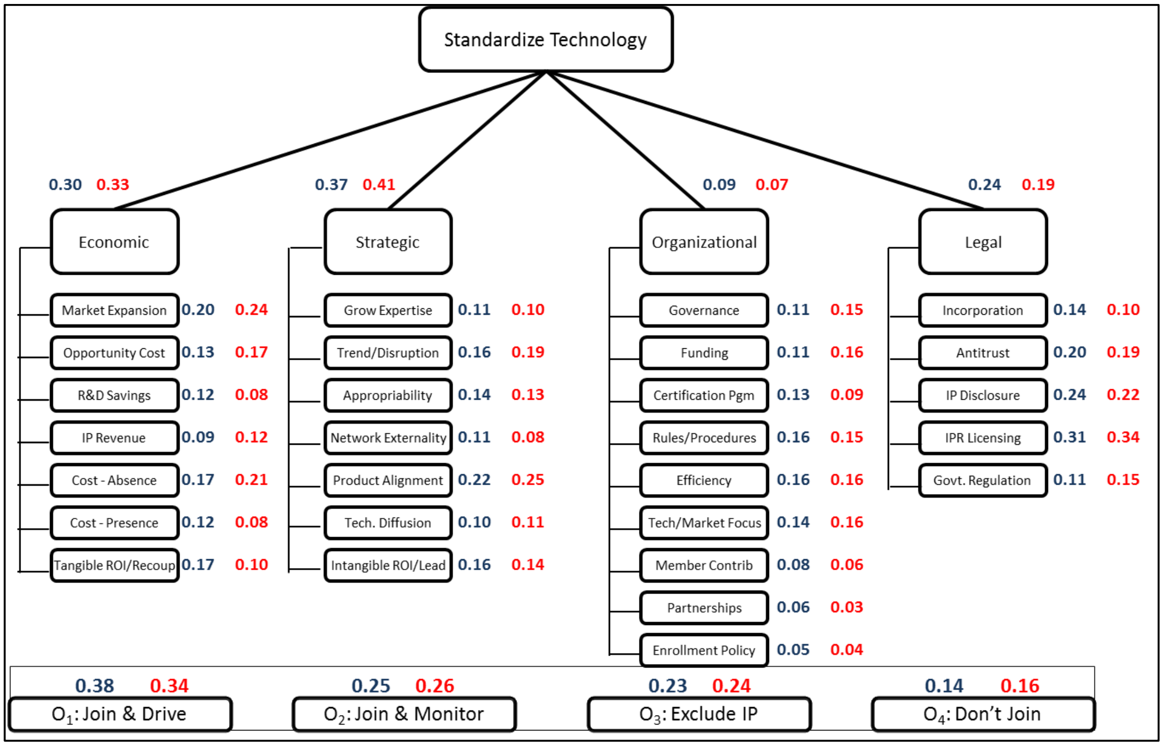

Figure 17 - Final model scores without inconsistencies.

7.1.2 Disagreement Scores

Table 19 below shows the panel disagreement scores:

Table 19 - Disagreement scores for all panels.

Hierarchy Layer	Model	Disagreement	Explanation
Perspectives	General	0.12	Expert13 (SW engineer) and Expert25 (IP attorney) disagree
	USB	0.04	Below threshold
Criteria – Economic	General	0.09	Below threshold
	USB	0.08	Below threshold
Criteria – Strategic	General	0.06	Below threshold
	USB	0.06	Below threshold
Criteria – Organizational	General	0.03	Below threshold
	USB	0.05	Below threshold
Criteria - Legal	General	0.08	Below threshold
	USB	0.07	Below threshold
Outcomes	General	0.09	Below threshold
	USB	0.10	At threshold

Except for one score noted above, the disagreement scores do not pose a problem as they are all at or below the accepted threshold. The exception in this case is not significant since the score is fairly low and the reason for the disagreement can be fathomed from a closer look at the expert's job functions and thus their varying experiences and priorities. Specifically, Expert13, a software engineer, and Expert25, an attorney, provided data that were significantly at odds with that from the other experts. These disagreements are expected when the panel is sufficiently large and diverse. A disagreement score of 0.12, however, although above the acceptable threshold of 0.10, is not sufficiently large to have a material impact on the overall quality of the results.

7.1.3 Key Scores and Findings Summarized

From the final model scores shown in Figure 17 above, it is clear that:

1. Both models highlight strategy as the primary perspective. Effectively, technology standardization is a strategic decision for most ICT firms.
2. Both models confirm Market Expansion (ME) as the most important economic factor in pursuing technology standards. In other words, ICT firms view standardization as an enabler to grow their availability and access to core and adjacent markets.
3. Both models confirm Product Alignment (PA) as the most important strategic factor in pursuing technology standards. This is evidence that ICT firms are interested to align their product roadmaps with the content and entry of technology standards.
4. Both models confirm IPR Licensing (IL) as the most important legal factor in pursuing technology standards. The availability of licenses and the IPR policies of the SDO rank high for most ICT firms.
5. Both models point to the similar decision outcome: O_1. In effect, ICT firms prefer to join the SDO in question and drive the standard effort to reap the various benefits that accrue from engagement at this level of involvement and influence.

In the sections that follow, results from each layer of the hierarchy will be further analyzed and discussed.

7.1.4 ESOL Perspectives

For the ESOL perspectives, strategic is rated highest by both panels, followed by economic, legal and organizational. The weight of the organizational perspective has changed little between the two panels and is deemed to be an insignificant factor in the decision to standardize technologies. Panel 2a rated the legal perspective 21% higher.

This may be due to the less litigious environment in the ICT industry when USB was being standardized in the early 1990s; in more recent times IP-related legal entanglements have multiplied. Panel 2a rated the strategic perspective 11% lower. This may be partly offsetting the increase in the importance of the legal aspects of standardization, resulting in a relative tradeoff in priorities. There is negligible difference in the relative weight placed on the economic perspective between the panels.

7.1.5 Economic Criteria

For the economic criteria, Market Expansion (ME) is consistently rated highest by both panels. Indeed, the standardization of USB increased market opportunities for its early proponents as shown by Gawer and Cusumano (2002). Opportunity Cost (OC) is rated 30% higher by the experts on Panel 2b. R&D Savings (RD) is rated 33% higher in importance by experts in Panel 2a over their peers in Panel 2b. Panel 2b experts rated IP Revenues (IP) higher by 33%, emphasizing the opportunities in harvesting USB IP at its introduction. Panel 2b judged Cost of Absence (CA) higher by about 24%. Panel 2a rated Cost of Presence (CP) higher by about 33%, reflecting the growing costs in attending SDOs. Panel 2a rated Tangible ROI (TR) 41% higher, reflecting expectations of economic gains and recoupment of investments through technology standardization.

7.1.6 Strategic Criteria

For the strategic criteria, Product Alignment (PA) is rated higher than other criteria by both panels. Panel 2b rated Trends/Disruptions (TD) higher by 19%, confirming its importance at the time of USB adoption. Network Externality (NE) is rated higher by Panel 2a by 27%, reflecting the importance of ecosystems in standardization. Experts on Panel 2a rated Intangible ROI/Leadership (IR) higher by about 13%, suggesting that ICT firms expect to establish leadership in the ecosystem through standardization. This finding was also observed by Gawer and Cusumano (2002).

7.1.7 Organizational Criteria

For the organizational criteria, Rules/Procedures (RP) & Organizational Efficiency (OE) are rated highest by both panels consistently. There are negligible differences in the panels' ranking of Enrollment Policy (EP) of the SDO. Panel 2b rated Governance (GO) and Funding (FU) higher by over 30%, reflecting the need for a smooth functioning SDO. Panel 2a rated Certification Program (CP) higher by 30%, suggesting the growing importance of product interoperability in the ecosystem. Panel 2b rated organizational Focus (FO) higher by 14%, suggesting the importance of proper marketing to position USB technology in the market. Panel 2a rated Partnerships (PA) higher by 50%, showing a strong preference for SDO collaboration.

7.1.8 Legal Criteria

For the legal criteria, both panels rated IPR Licensing (IL) as the highest consideration, followed by IP Disclosure (ID) and Antitrust (AN). This is in keeping with expectations since a major component of technology standardization is the availability of licenses to IP held by others in the ecosystem, the need for *a priori* disclosure of essential IP and the SDO enforcement of its antitrust policies. Panel 2a rated Incorporation (IN) higher by 28%. This suggest that in more recent times SDOs seek to take advantage of the benefits inherent in better organization, transparent/democratic governance and more favorable tax treatments provided under the law (such as 501(c)(6)). Panel 2b rated Government Regulation (GR) higher by roughly 36%.

7.1.9 Composite Outcome Scores

For the global outcome scores, the highest decision alternative from the preferences of both panels is O_1 (Join & Drive Standard). Both panels rated O_2 (Join & Monitor Standard) as the next highest preference. Both panels exhibited consistency in the choice of O_3 (Join & Exclude IP) in that this alternative was the third-most preferred outcome. O_4 (Do Not Join) was the least favorite outcome of both panels. Panel 3a showed a nearly 18% higher preference for O_1 while Panel 3b showed a nearly 12% higher preference for the same outcome.

7.2 Key Decision Factors

As was observed, both panels rated the strategic perspective as the highest consideration in this decision. Also, both rated Product Alignment (PA) as the highest decision criterion, constituting nearly 8% and 10% of the total decision score in the General and USB models, respectively.

The computed eigenvalues show that the top 5 criteria differ slightly between the two panels. In the General model the other top factors in order of priority are IPR Licensing (IL), Market Expansion (ME), Trends/Disruptions (TD) and Intangible ROI/Leadership (IR), while in the USB model the other top factors in order of priority are

Market Expansion (ME), Trends/Disruptions (TD), Cost of Absence (CA) and IPR Licensing (IL). Further analysis of these findings will be discussed in the next chapter.

7.3 Model Sensitivity

Using the aforementioned “what-if” scenarios, extreme weights are assigned at the perspective layer of the hierarchy to determine the sensitivity of the General and USB models to such perturbations. Three different profiles are used as follows:

Profile 1: for each perspective in turn, assign a 70% weight while holding the other perspectives at a uniformly low weight of 10%.

Profile 2: eliminate the organizational perspective and its criteria since they do not appear to be significant, re-normalize the weights for the other perspectives and repeat the method described in Profile 1 with weights of 80% and 10%, respectively.

Profile 3: eliminate the organizational perspective and its criteria since they do not appear to be significant, re-normalize the weights for the other perspectives and repeat the method described in Profile 1 with weights of 98% and 1%, respectively.

With the removal of the organizational perspective and the re-normalization of the weights at the perspectives layer of the hierarchy and the criteria contributions to the outcomes layer of the hierarchy, each of these “what-if” profiles was applied to determine the model’s overall sensitivity to extreme perturbations. The results are shown in Table 20.

The Baseline scores are the weights of the four outcomes when there are no perturbations. The scores in the E, S, O, and L columns depict the change in outcome scores when each of the profiles is applied, with the higher weight being applied to the identified perspective in that column.

Table 20 - Sensitivity scores for both models.

Profile	Model	Outcome	Baseline	E	S	O	L
Profile 1 70%	General	O_1	38	36	42	39	31
		O_2	25	24	27	22	23
		O_3	23	24	21	23	25
		O_4	14	16	10	16	21
Profile 1 70%	USB	O_1	34	34	36	36	31
		O_2	26	24	28	23	24
		O_3	24	24	24	24	25
		O_4	16	18	12	17	20
Profile 2 80%	General	O_1	37	35	42	NA	30
		O_2	26	25	28	NA	23
		O_3	23	24	21	NA	25
		O_4	14	16	9	NA	22
Profile 2 80%	USB	O_1	34	33	35	NA	30
		O_2	26	24	29	NA	25
		O_3	24	25	24	NA	24
		O_4	16	18	12	NA	21
Profile 3 98%	General	O_1	37	34	45	NA	28
		O_2	26	25	28	NA	22
		O_3	23	25	20	NA	25
		O_4	14	16	7	NA	25
Profile 3 98%	USB	O_1	34	34	36	NA	31
		O_2	26	24	28	NA	24
		O_3	24	24	24	NA	25
		O_4	16	18	12	NA	20

There are some changes in the weight distributions among the outcomes but in all instances O_1 leads the decision. The most perturbation is observed when the legal perspective is arbitrarily weighted high as in Profile 3. When this is done, the composite scores for the decision alternatives begin to level out as can be seen for the General model. A similar phenomenon is observed in the USB model, which was weakly emergent when the organizational perspective was included in the model.

Chapter 8: Discussion of Findings

From the results documented in chapters 6 and 7 it can be seen that the overall finding of this research points to the increasing importance of strategic decision-making in determining whether or not to join a standards development activity. Both the General model and the USB model substantiate this finding. In both cases, the economic and legal perspectives lag behind the strategic perspective in importance.

The global scores of all criteria in the General model appear in Figure 18 below:

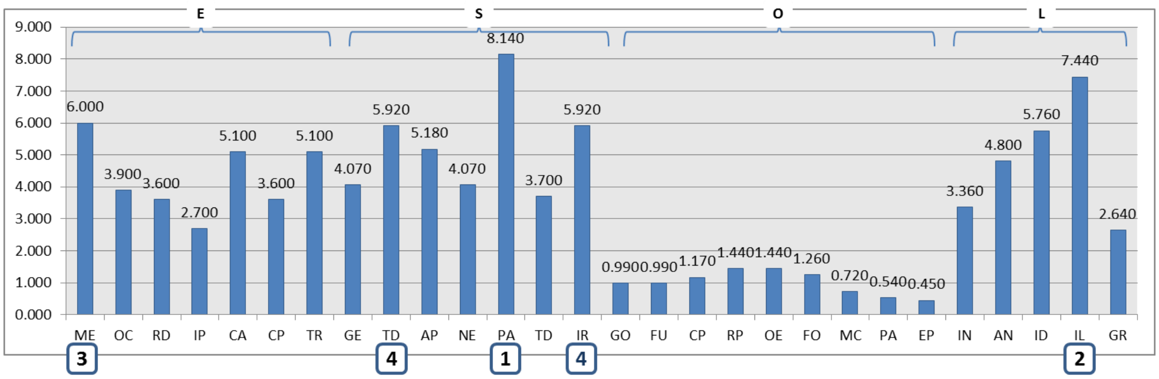

Figure 18 - Global criteria scores for the General model.

The global scores of all criteria in the USB model appear in Figure 19 below:

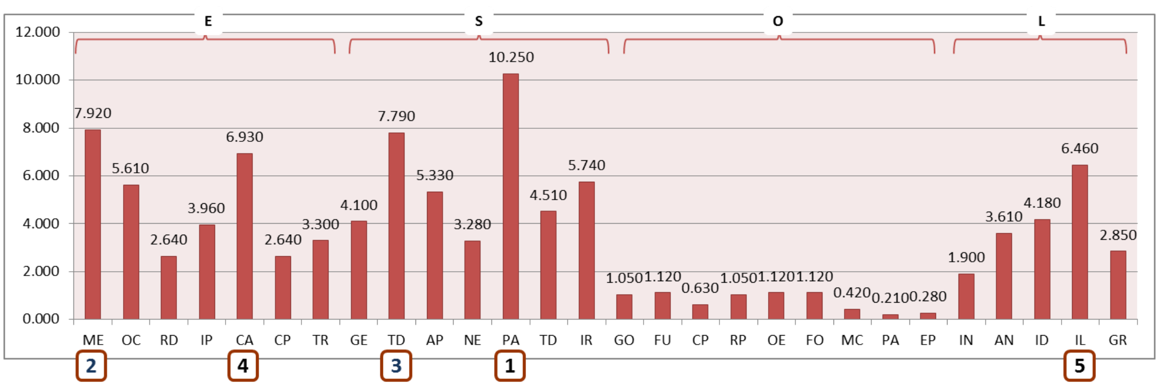

Figure 19 - Global criteria scores for the USB model.

8.1 Key Findings

Both models confirm Product Alignment (PA) as the top criterion informing the decision to participate in technology standardization. In the General model, this criterion accounts for over 8% of the total decision score. In the USB model, this number is even higher, accounting for over 10% of the total decision score. The experts believe that aligning the firm's corporate strategy and product roadmap to the emerging standard is the highest consideration in the decision to join standards development.

IPR Licensing (IL), Market Expansion (ME), Trends/Disruptions (TD) and Intangible ROI/Leadership (IR) are ranked right behind Product Alignment in the General model, whereas Market Expansion (ME), Trends/Disruptions (TD), Cost of Absence (CA) and IPR Licensing (IL) appear in that order in the USB model.

In the General model, three of the top five considerations are strategic, one is legal and one is economic, whereas in the USB model, two of the top five considerations are strategic, two are economic and one is legal, in that order. All the organizational criteria are rated at the bottom of the pile for both models.

IPR Licensing (IL) is the second highest priority in the General model, whereas it is the fifth highest priority in the USB model. Market Expansion (ME) is the third highest priority in the General model, whereas it is the second highest priority in the USB model. Trends/Disruptions (TD) is the fourth highest priority in the General model, whereas it is the third highest priority in the USB model. Finally, Intangible ROI/Leadership (IR) is the fifth highest priority in the General model but it does not make the top five in the USB model, whereas Cost of Absence (CA) is the fourth highest priority in the USB model but it does not make the top five in the General model.

Both models agree in weighing the O_1 (Join & Drive Standard) decision outcome highest, although with variable weights amongst the two models. This finding favors the active participation in, and contributions to, SDOs as confirmed by Gawer (2000).

In the USB model, the economic perspective shows a measurable distance between it and legal considerations. This is a reflection of the fact that in the 1990s the ICT industry was less litigious, and there were fewer "IP wars" then as opposed to now.

The model developed here has been shown to be robust and insensitive to extreme perturbations in the data. Even with radical weight redistribution, the models do not yield a different decision outcome, although the weight differences narrow in some cases. Further, almost all disagreements within the panels are well below the conventional threshold and all data from experts exhibiting inconsistency in their judgment quantifications have been eliminated from the computation of eigenvalues.

8.2 Research Contributions

My research has enriched scholarship in technology management, specifically in the area of standardization, in a number of ways as summarized in Table 21 below:

Table 21 - Research contributions.

Contribution	Type
Holistic ESOL framework and robust MCDA model that can be used by managers to assess the key determinants of the decision to participate in technology standardization (i.e. join SDO)	Praxis
Taxonomy and insights on the variances between the IPR policies of different SDOs in the ICT industry, and their influence on the diffusion and adoption of technological innovations	Praxis
Identification of the most and least important determinants in the decision to standardize a technology, and verified by the application of the USB case as the basis for comparison/contrast	Praxis
Path-dependent "best practices" as a non-tautological strategy to minimize resource allocation and maximize competitive advantage within the Transaction Cost paradigm and related theories of the firm	Theory

8.2.1 Contributions to Praxis

First, the definition and application of the ESOL framework facilitates the contextualization of technology standards within the economic, strategic, organizational and legal perspectives. Such a multi-perspective structure, heretofore absent from scholarship in this field, allows managers to adopt a more balanced and all-inclusive approach in formulating the decision to join a given SDO, and to place emphasis where it matters most for achieving the firm's imperatives and objectives. Specifically, the ESOL framework can be used to disaggregate and assess the chief factors that are germane to the firm in its decision-making processes and structures with regard to the standardization of innovative technologies. The significance of this contribution is confirmed through feedback received from the experts who are directly involved in the development of technology standards.

Next, my development of a robust, MCDA model to assist managers in ICT firms in determining whether or not to participate in technology standards development fills a major gap identified in praxis and confirmed by experts in the field. My proposed model identifies and ranks the most and least important determinants in the decision to standardize a technology. The import of this contribution is corroborated through the application of the USB case and borne out by the response of the experts to my findings.

Finally, to smooth the progress of the diffusion and adoption of technological innovations through standards I have expatiated the implications of the varying intellectual property rights management of SDOs. In deciding to participate in technology standards development the firm may be obliged to offer license to its IP portfolio that read on the standard to other members of the SDO. In effect, the firm could coincidentally counteract some or all of the advantages derived from the exclusive privilege of exercising the protected knowledge and methods inherent in its intellectual assets such as patents. Knowledge about and transparency in IPR policy definition and enforcement impacts the decision to join or to not join the SDO as has been shown.

8.2.2 Contributions to Theory

My research contributes to the extant Production Cost theory in considerable ways. It is evident that the firm's internal resources and assets, including IP, potentially play a significant part in its prospects and motivations to participate in technology standardization. It is equally evident that the firm's long-term competitiveness and growth prospects influence its decision to join a standards developing organization.

Consider the theory of Core Competence. It has been posited that core capabilities constitute a "wellspring of new business development" when extended to adjacent market opportunities, and that they can positively impact a firm's growth potential by "exploiting economies of scope."[254] [255] This viewpoint is buttressed by the seminal works of many scholars, particularly those that have theoretical underpinnings in the Resource-Based View (RBV) of the firm, and shed light on the firm's distinctive competencies and heterogeneous capabilities. [256] [257] [258] [259] [260] [261] [262] Proponents of RBV argue that firms that possess valuable, rare, inimitable and non-substitutable resources are positioned for sustained competitiveness. The necessary conditions for such an advantage include superior resources, *ex post* limits to competition, imperfect resource mobility and *ex ante* limits to competition.[263] However, within the classical economic Structure-Conduct-Performance (SCP) paradigm, RBV is regarded as an evolutionary economic concept with only limited applicability, especially given the inevitable temporal changes in the routines and capabilities of the firm within a dynamic industry or ecosystem.[264] Moreover, as knowledge about the value of assets and their combinational significance is broadly disseminated, those assets, over time, tend to migrate to firms that value them most.[265]

With the exception of "strategic needs and social opportunities" in the formation of industry-wide alliances, the body of research cited above is largely silent on managerial strategies, in particular where it may be germane to the standardization of innovative technologies.[266] My research highlights the importance of path-dependent "best practices" as a non-tautological strategy that can deliver advantage to the firm for long-term competitiveness through participation in the development of technology standards within the ICT industry. This allows the firm to optimize its resources and its investments. Whether other strategies are necessary or sufficient to inform the firm's decision is indeterminate and remains fertile ground for future scholarly endeavor.

Chapter 9: Limitations and Future Research

There are a few limitations that can be overcome in future scholarship. There are also a number of interesting by-products of this treatise that deserve further probing and study.

9.1 Limitations

First, the application of the USB case entails biases in the memory of experts and historical learning. Consider that the USB technology was first conceived in the early 1990s. This limitation was overcome to some extent through comparison and contrast with the General model.

Second, the proposed General model has been developed and quantified with panelists with expertise in interconnect technology development within the ICT industry. Although this segment of technological innovation is crucial in the development of a number of indispensable products and has been the intense focus of standardization for many decades, yet the panel experts can be viewed as sequestered from other areas of non-ICT standardization efforts. While this is a minor limitation, yet it can be overcome through the inclusion of experts in the fields of expertise in the ICT industry, as well as other technical disciplines. The upside of this limitation is that the panelists are fully affiliated with the goals of this study.

Third, the model has been quantified with experts that are mostly focused in *de facto* standards development. Again, this is not a significant limitation since it aligns with the stated purpose and focus of this study. This limitation too can be overcome by incorporating data from experts in *de jure* standards development.

Fourth, the use of pairwise comparisons, if not carefully analyzed, can be prone to a known problem referred to in scholarly research circles as the violation of the independence of irrelevant alternatives, through which a random removal of alternatives in the comparison matrix and subsequent re-computation may result in an illogical outcome, such as a previously low rated item trumping a higher one.[267]

Finally, the use of judgment quantification is representative of the personal worldviews of the participating experts. This limitation was partially overcome through mitigation of the Inconsistency and Disagreement scores.

9.2 Future Research

With respect to a research agenda for future scholarship, the exploration of additional perspectives, decision criteria and decision outcomes to augment the framework and the proposed General model developed in this treatise constitutes fertile ground and could be a worthwhile pursuit for extending or customizing this decision framework to a broader array of applications.

Next, the extension, application and analysis of the General model developed in this research to other innovations in the ICT industry or to other fields, such as service industries, could prove insightful and beneficial to future scholars in the field of technology management.

An interesting byproduct of this research highlights the need to probe into uniform IP valuation methodologies which have thus far eluded professionals in the field. IP valuation is important for setting licensing fees, determining transaction support, vetting of merger and acquisition targets, forming of strategic alliances, quantifying damages for infringement law suits, complying with accounting and regulatory requirements, ascertaining attorney malpractice awards, shaping intercompany transactions, defining collateral-based financing limits and many other applications.[268] An increasing body of recent research points to a deficiency in IP valuation methodology. This deficiency is systemic and is based on experiential knowledge that vastly inconsistent results are obtained from some of the prevalent methods in use today.[269] He identifies several methods in order of sophistication: cost, market, income, discounted cash flow, risk, and so on, and admits that none of these methods is universally applicable owing to several limitations, one of which is the lack of a suitable technique for estimating the variables used in the valuation methods.

In the ICT industry firms decide to form consortia or alliances that have direct bearing on their IP portfolios. Proper valuation of IP contributions form the basis on which these alliances can come together and function for the benefit of the industry. Damage analysis for lawsuits involving the infringement of IP is convoluted and does not always resolve to a fee-simple amount. In such cases, uniform IP valuation provides clarity, removes uncertainty and facilitates the equitable application of the law. In most accounting and regulatory environments, precise valuations are needed for entry into balance sheets and other financial statements.

Further, Initial Public Offering (IPO) documents usually highlight the importance of the IP held by the firm but the absence of a credible valuation methodology can introduce risk and uncertainty in these IPO transactions. Moreover, in cases where attorneys fail to obtain IP rights for their clients, valuations are necessary to determine any losses for *post facto* recoupment. In most markets, various regulatory and tax authorities require precise valuation of IP to determine whether the transfer of IP among related parties must be further scrutinized for antitrust or other violations. Finally, in certain situations IP can be a dominant asset when it is used as collateral to obtain financing by a firm. Proper valuation is crucial in ensuring a successful outcome for the firm. Aside from aiding in all of the aforementioned commercial and legal areas, my research contributions will fill a void in the current academic literature by integrating a decision support framework with an empirically-developed IP valuation model.

The development and application of a robust quantitative model for the objective valuation of patents and other intangible intellectual assets would be welcomed by most ICT firms. Ancillary research in IP portfolio valuation may touch on a number of related topics such as optimal licensing terms to balance innovation with IP investment recoupment, the relationship between the innovation strategies of the firm and the IPR policies of standards development organizations, and so on.

Investigating these and related issues constitute a formidable agenda to extend scholarship in technology standardization.

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Appendix A: Data Collection Instruments

Instrument I.1 Subject Recruitment Letter

Dear [participant] [date]

I am Ramin Neshati, a Ph.D. candidate in the Engineering and Technology Management department of the Maseeh College of Engineering and Computer Science at Portland State University. My dissertation is titled "Participation in Technology Standards Development: A Decision Model for the Information and Communications Technology Industry." My proposed research is significant in that it will yield a decision-support framework to guide technology managers in determining whether or not to join in technology standards development.

If you volunteer to provide data for this proposed research, you will be asked to review, sign and return the attached Informed Consent Letter which describes mutual expectations for confidentiality and privacy. Please note that there are no risks to you should you choose to participate, and your identity and responses will be held in strict confidence. You may withdraw at any time without cause, compulsion or repercussion. Participation involves returning the attached survey instrument. There may be additional surveys to refine the various elements of the decision-support model.

Your participation will help in the development and validation of a decision-support framework. The significance of this proposed research is potentially enormous as it bears on Intellectual Property (IP) portfolios and licensing obligations of firms that operate in the Information and Communications Technology industry. Your input will enrich the knowledge base and impact the practice of technology standardization for years to come.

You may reach me at rn@pdx.edu for any matter pertaining to this proposed research.

Sincerely,

Ramin Neshati

Attachments: 1-Informed Consent Letter, 2-Model Development Instrument.

Instrument I.2 Informed Consent Letter

Dear [participant] [date]

Thank you for agreeing to participate in my proposed dissertation research titled "Participation in Technology Standards Development: A Decision Model for the Information and Communications Technology Industry." The outcome of this proposed research will be a decision framework to assist technology managers in the ICT industry, such as you, to decide whether or not to standardize technological innovations.

Please be aware that you are not being asked, nor are you required, to disclose any information that is confidential or sensitive to your firm or person. You will be asked to indicate your preference on a set of decision criteria by providing quantified judgments in a pairwise matrix of choices pertaining to technology standardization. All information you provide will be maintained in strict confidence and your identity will not be disclosed without your permission. You may withdraw from this research at any time without cause and will not be subjected to any negative repercussions or loss of confidentiality.

Should you have any questions about your participation in this proposed research, please feel free to contact the Portland State University Human Subjects Research Review Committee, Office of Research Strategic Partnerships, 1600 SW Fourth Ave., Suite 620, Portland, OR 97201, 503-725-3423. As always, you may contact me at rn@pdx.edu for any technical questions related to the proposed research.

Please sign, date and return this note to indicate your understanding and agreement to participate in this proposed research. You may e-mail it to rn@pdx.edu.

Sincerely,

Ramin Neshati

____

Name (optional)

____

Signature (required)

____

Date (required)

Instrument I.3 Model Development Instrument

Phase 1 – Model Development Instrument

The extant academic literature on technology management highlights four distinct perspectives which managers consider when making decisions on technology standardization. These perspectives are: Economic, Strategic, Organizational and Legal (ESOL). Are there other perspectives that should be considered in this context? If so, please indicate:____

Using a total of 100 points, please express your judgment about the relative importance of the following paired items (e.g. Economic – Strategic). If the first item is 3 times more important than the second, distribute 75 points to the former and 25 points to the latter. Do not assign 0 points at any time. If you judge that one item has no importance in comparison to its pair, assign 1 and 99, respectively. Please rate the following pairs:

Compare	Preference		Compare
Economic			Strategic
Economic			Organizational
Economic			Legal
Strategic			Organizational
Strategic			Legal
Organizational			Legal

The Economic perspective is comprised of the following factors: cost of participation in technology standardization, and return on investment in technology standardization. Are there other factors that should be considered? If so, please indicate:____

The Strategic perspective is comprised of the following factors: alignment to corporate objectives, scope of the standards effort, network externalities (i.e. ecosystem support), and appropriability (i.e. ease of adoption). Are there other factors that should be considered? If so, please indicate:____

The Organizational perspective is comprised of the following factors: membership enrollment policy of the standards defining body (i.e. open, by-invitation, etc.), and geographic range of the membership (i.e. global, confined to a region, etc.). Are there other factors that should be considered? If so, please indicate:____

____

The Legal perspective is comprised of the following factors: IPR policy, and IP disclosure requirement. Are there other factors that should be considered? If so, please indicate:____

Thank you for participating in this phase of data collection. The decision-support model I am developing is based on the Analytic Hierarchy Process (AHP). I will follow-up on the updated decision model using your (and other) data and will be asking for further judgment quantifications on the revised model definition at each level of the decision hierarchy.

Sincerely,

Ramin Neshati

Instrument I.4 Model Validation Instrument

Dear [participant] [date]

Thank you for participating in this important research effort; your input has been most useful. The attached data collection instrument pertains to Phase 2 of my dissertation research: model validation. The instructions are embedded in the attached instrument. I appreciate your time and attention.

Please print, complete, scan & e-mail your response to rn@pdx.edu by/before 10/19/12!

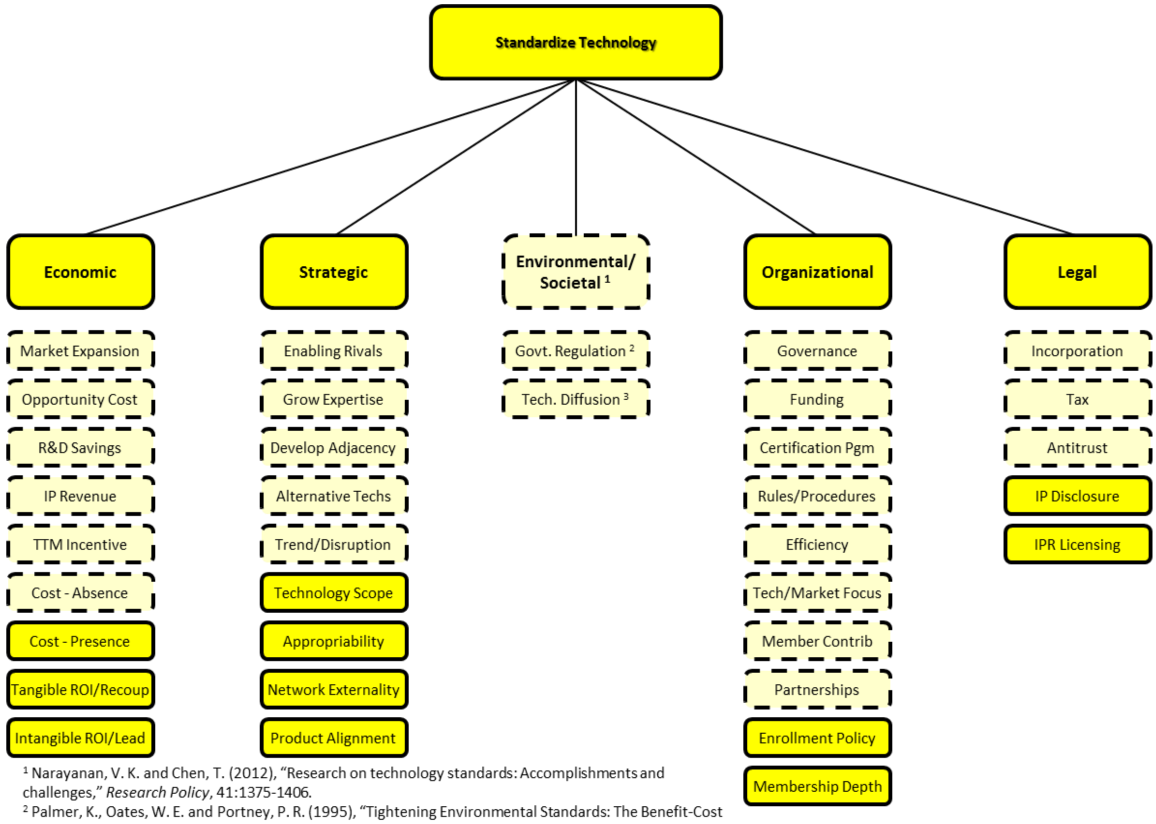
Sincerely,

Ramin Neshati

Attachments: 1-Model Validation Instrument.

Phase 2 – Model Validation Instrument (estimated completion time: 15 minutes)

Thank you for participating in Phase 1 of this research effort. Your input, and those of others, has been incorporated into my model. Based on recent academic literature and your inputs, I have revised the preliminary AHP model on technology standardization in the ICT industry as shown below. Elements in solid (yellow) boxes are from the original model, elements in dashed boxes are additions from your inputs.



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In Phase 2 you are asked to validate the revised model via a series of simple checklists. If you concur with the *presence* of the element, mark the "Agree" column for that entry; if you oppose the *presence* of the element, mark the "Disagree" column for that entry. Note: I am NOT asking for your input on the computed weights, only the model elements.

Please print, complete, scan & e-mail your response to rn@pdx.edu by/before 10/19/12!

Please express your [dis]agreement on the model's Perspectives in the checklist below:

Perspectives	Agree☑	Disagree☒
Economic		
Strategic		
Organizational		
Legal		
Environmental/Societal		

Please express your [dis]agreement on the Economic criteria in the checklist below:

Economic Criteria	Agree☑	Disagree☒
Market Expansion (growth of TAM)		
Opportunity Cost (other use of resources)		
R&D Savings (savings through learning w/ min invest.)		
IP Revenue (income from licensing)		
TTM Incentive (fast product intro)		
Cost – Absence (loss from non-participation)		
Cost – Presence (expenses for participation, giveaways)		
Tangible ROI (investment recoupment)		
Intangible ROI (leadership, etc.)		

Please express your [dis]agreement on the Strategic criteria in the checklist below:

Strategic Criteria	Agree☑	Disagree☒
Enabling Rivals (rivals gain at no cost)		
Grow Expertise (build tech/market savvy)		
Develop Adjacency (new skills/tech/…)		
Alternative Technologies (invent around)		
Trend/Disruption (avoid surprise)		
Technology Scope (delimit scope for predictability)		
Appropriability (ease of adoption)		
Network Externality (ecosystem support)		
Product Alignment (BU alignment with market)		

Please express your [dis]agreement on the Organizational criteria in the checklist below:

Organizational Criteria	Agree☑	Disagree☒
Governance (BoD, officers, elections, committees, etc.)		
Funding (income, expenses, grants, etc.)		
Certification Program (logo, compliance testing, etc.)		
Rules/Procedures (operating structure)		
Efficiency (responsive to market needs)		
Technology/Market Focus (develop-only, promote, …)		
Member Contribution (ease of participation)		
Partnerships (collaborations, liaisons, …)		
Enrollment Policy (member recruitment, geo reach, …)		
Membership Depth (limited, complete, …)		

Please express your [dis]agreement on the Legal criteria in the checklist below:

Legal Criteria	Agree☑	Disagree☒
Incorporation (legal status of the SDO)		
Tax (tax treatment of the SDO)		
Antitrust (policies of the SDO)		
IP Disclosure (disclosure rules/requirements)		
IPR Licensing (model used by the SDO)		

Please express your [dis]agreement on the Environmental criteria in the checklist below:

Environmental Criteria	Agree☑	Disagree☒
Government Regulation (e.g. “green,” social, …)		
Technology Diffusion (policies, barriers, etc.)		

Thank you for participating in the model validation phase of my research. I will follow-up with the revised, validated model using your (and others’) input and will ask for additional pairwise judgment quantifications at the criteria and sub-criteria levels of the hierarchy.

Sincerely,

Ramin Neshati

Instrument I.5 Model Quantification Instrument - Criteria

Dear [participant] [date]

Thank you for participating in this important research effort; I have incorporated your input, as well as those of other participants, in the validated decision model. In this the 3rd phase of data collection, I am looking for your quantified judgment on the importance of various criteria in the decision model when compared in a pairwise manner. The instructions are embedded in the attached document.

Please complete and send your response to rn@pdx.edu by/before 11/16/2012!

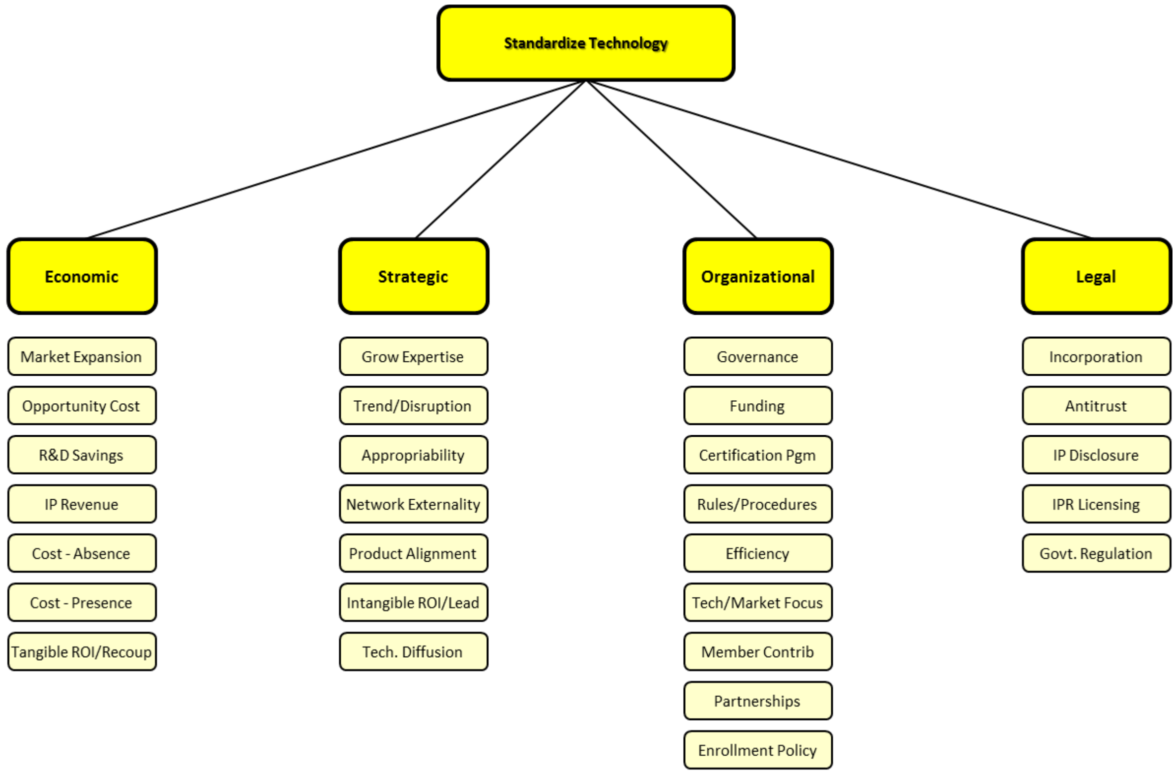
Sincerely,

Ramin Neshati

Attachments: 1-Criteria Judgment Quantification Instrument.

Phase 3 – Model Quantification Instrument (estimated completion time: 30 min)

Thank you for participating in my research on technology standardization in the ICT industry. Based on your input I have refined the decision model as shown below:



Some elements that existed in the prior model were removed on the strength of the preferential inconsistency among respondents. Specifically, elements with less than 2/3rd collective agreement of the respondents were dropped from further consideration.

In Phase 3, you are asked to quantitatively rate the decision criteria. Using a total of 100 points, please express your judgment about the relative importance of the paired items in the following four tables. For example, if the first item is 3 times more important than its pair, distribute 75 points to the former and 25 points to the latter. Do not assign 0 at any time. If you judge that one item has no importance in comparison to its pair, assign 1 and 99 points, respectively. I have included a glossary at the end of this document for your reference. Please e-mail the completed questionnaire to rn@pdx.edu. Should it facilitate your response, I can send the Word version of this document upon request. Thank you.

Please rate the following Economic criteria. Scores must sum to 100 in each row.

Economic Criteria	Preference Score		Economic Criteria
Market Expansion			Opportunity Cost
Market Expansion			R&D Savings
Market Expansion			IP Revenue
Market Expansion			Cost of Absence
Market Expansion			Cost of Presence
Market Expansion			Tangible ROI/Recoupment
Opportunity Cost			R&D Savings
Opportunity Cost			IP Revenue
Opportunity Cost			Cost of Absence
Opportunity Cost			Cost of Presence
Opportunity Cost			Tangible ROI/Recoupment
R&D Savings			IP Revenue
R&D Savings			Cost of Absence
R&D Savings			Cost of Presence
R&D Savings			Tangible ROI/Recoupment
IP Revenue			Cost of Absence
IP Revenue			Cost of Presence
IP Revenue			Tangible ROI/Recoupment
Cost of Absence			Cost of Presence
Cost of Absence			Tangible ROI/Recoupment
Cost of Presence			Tangible ROI/Recoupment

Please rate the following Strategic criteria. Scores must sum to 100 in each row.

Strategic Criteria	Preference Score		Strategic Criteria
Grow Expertise			Trends/Disruptions
Grow Expertise			Appropriability
Grow Expertise			Network Externality
Grow Expertise			Product Alignment
Grow Expertise			Intangible ROI/Leadership
Grow Expertise			Technology Diffusion
Trends/Disruptions			Appropriability
Trends/Disruptions			Network Externality
Trends/Disruptions			Product Alignment
Trends/Disruptions			Intangible ROI/Leadership
Trends/Disruptions			Technology Diffusion
Appropriability			Network Externality
Appropriability			Product Alignment
Appropriability			Intangible ROI/Leadership
Appropriability			Technology Diffusion
Network Externality			Product Alignment
Network Externality			Intangible ROI/Leadership
Network Externality			Technology Diffusion
Product Alignment			Intangible ROI/Leadership
Product Alignment			Technology Diffusion
Intangible ROI/Leadership			Technology Diffusion

Please rate the following Organizational criteria. Scores must sum to 100 in each row.

Organizational Criteria	Preference Score		Organizational Criteria
Governance			Funding
Governance			Certification Program
Governance			Rules/Procedures
Governance			Organizational Efficiency
Governance			Focus (Tech/Market)
Governance			Member Contributions
Governance			Partnerships
Governance			Enrollment Policies
Funding			Certification Program
Funding			Rules/Procedures
Funding			Organizational Efficiency
Funding			Focus (Tech/Market)
Funding			Member Contributions
Funding			Partnerships
Funding			Enrollment Policies
Certification Program			Rules/Procedures
Certification Program			Organizational Efficiency
Certification Program			Focus (Tech/Market)
Certification Program			Member Contributions
Certification Program			Partnerships
Certification Program			Enrollment Policies
Rules/Procedures			Organizational Efficiency
Rules/Procedures			Focus (Tech/Market)
Rules/Procedures			Member Contributions
Rules/Procedures			Partnerships
Rules/Procedures			Enrollment Policies
Organizational Efficiency			Focus (Tech/Market)
Organizational Efficiency			Member Contributions
Organizational Efficiency			Partnerships
Organizational Efficiency			Enrollment Policies
Focus (Tech/Market)			Member Contributions
Focus (Tech/Market)			Partnerships
Focus (Tech/Market)			Enrollment Policies
Member Contributions			Partnerships
Member Contributions			Enrollment Policies
Partnerships			Enrollment Policies

Please rate the following Legal criteria. Scores must sum to 100 in each row.

Legal Criteria	Preference Score		Legal Criteria
Incorporation			Antitrust Policy
Incorporation			IP Disclosure Requirement
Incorporation			IPR Licensing Model
Incorporation			Government Regulation
Antitrust Policy			IP Disclosure Requirement
Antitrust Policy			IPR Licensing Model
Antitrust Policy			Government Regulation
IP Disclosure Requirement			IPR Licensing Model
IP Disclosure Requirement			Government Regulation
IPR Licensing Model			Government Regulation

Instrument I.6 Model Quantification Instrument - Outcomes

Dear [participant] [date]

Thank you for participating in this important research effort. In this the 4th and last phase of data collection, I am looking for your quantified judgment on the importance of various decision alternatives when compared in a pairwise manner against the criteria. The instructions are embedded in the attached document.

Please complete and send your response to rn@pdx.edu by/before 5/31/2013!

Sincerely,

Ramin Neshati

Attachments: 1-Alternatives Judgment Quantification Instrument.

Phase 4 – Model Quantification Instrument (estimated completion time: 30 min)

Thank you for participating in my research on technology standardization in the ICT industry.

In Phase 4, you are asked to quantitatively rate the decision alternatives. Using a total of 100 points, please express your judgment about the relative importance of the paired items in the following tables. For example, if the first item is 3 times more important than its pair, distribute 75 points to the former and 25 points to the latter. Do not assign 0 at any time. If you judge that one item has no importance in comparison to its pair, assign 1 and 99 points, respectively. I have included a glossary at the end of this document for your reference. Please e-mail the completed questionnaire to rn@pdx.edu. Should it facilitate your response, I can send the Word version of this document upon request. Thank you.

Economic Criteria																								
ME					OC					RD					IR					CA				
O1			O2		O1			O2		O1			O2		O1			O2		O1			O2	
O1			O3		O1			O3		O1			O3		O1			O3		O1			O3	
O1			O4		O1			O4		O1			O4		O1			O4		O1			O4	
O2			O3		O2			O3		O2			O3		O2			O3		O2			O3	
O2			O4		O2			O4		O2			O4		O2			O4		O2			O4	
O3			O4		O3			O4		O3			O4		O3			O4		O3			O4	
CP					TR																			
O1			O2		O1			O2																
O1			O3		O1			O3																
O1			O4		O1			O4																
O2			O3		O2			O3																
O2			O4		O2			O4																
O3			O4		O3			O4																

Strategic Criteria																							
GE					TD					AP					NE					PA			
O1			O2		O1			O2		O1			O2		O1			O2		O1			O2
O1			O3		O1			O3		O1			O3		O1			O3		O1			O3
O1			O4		O1			O4		O1			O4		O1			O4		O1			O4
O2			O3		O2			O3		O2			O3		O2			O3		O2			O3
O2			O4		O2			O4		O2			O4		O2			O4		O2			O4
O3			O4		O3			O4		O3			O4		O3			O4		O3			O4

IR					DT				
O1			O2		O1			O2	
O1			O3		O1			O3	
O1			O4		O1			O4	
O2			O3		O2			O3	
O2			O4		O2			O4	
O3			O4		O3			O4	

Organizational Criteria																							
GO					FU					CP					RP					OE			
O1			O2		O1			O2		O1			O2		O1			O2		O1			O2
O1			O3		O1			O3		O1			O3		O1			O3		O1			O3
O1			O4		O1			O4		O1			O4		O1			O4		O1			O4
O2			O3		O2			O3		O2			O3		O2			O3		O2			O3
O2			O4		O2			O4		O2			O4		O2			O4		O2			O4
O3			O4		O3			O4		O3			O4		O3			O4		O3			O4
FO					MC					PA					EP								
O1			O2		O1			O2		O1			O2		O1			O2					
O1			O3		O1			O3		O1			O3		O1			O3					
O1			O4		O1			O4		O1			O4		O1			O4					
O2			O3		O2			O3		O2			O3		O2			O3					
O2			O4		O2			O4		O2			O4		O2			O4					
O3			O4		O3			O4		O3			O4		O3			O4					

Legal Criteria																							
IN					AN					ID					IL					GR			
O1			O2		O1			O2		O1			O2		O1			O2		O1			O2
O1			O3		O1			O3		O1			O3		O1			O3		O1			O3
O1			O4		O1			O4		O1			O4		O1			O4		O1			O4
O2			O3		O2			O3		O2			O3		O2			O3		O2			O3
O2			O4		O2			O4		O2			O4		O2			O4		O2			O4
O3			O4		O3			O4		O3			O4		O3			O4		O3			O4

Appendix B: Expert Panel Data

General Model																													
	Economic						0.30	Strategic						0.37	Organizational								0.09	Legal				0.24	
	ME	OC	RD	IP	CA	CP	TR	GE	TD	AP	NE	PA	IR	DT	GO	FU	CP	RP	OE	FO	MC	PA	EP	IN	AN	ID	IL	GR	
	0.20	0.13	0.12	0.09	0.17	0.12	0.17	0.11	0.16	0.14	0.11	0.22	0.10	0.16	0.11	0.11	0.13	0.16	0.16	0.14	0.08	0.06	0.05	0.14	0.20	0.24	0.31	0.11	
O1	0.52	0.31	0.18	0.30	0.17	0.35	0.52	0.41	0.29	0.41	0.37	0.43	0.68	0.65	0.44	0.43	0.27	0.40	0.44	0.39	0.43	0.47	0.29	0.26	0.27	0.23	0.31	0.29	
O2	0.22	0.19	0.37	0.14	0.28	0.29	0.22	0.33	0.40	0.34	0.33	0.25	0.18	0.18	0.19	0.24	0.30	0.20	0.21	0.19	0.18	0.17	0.19	0.26	0.17	0.27	0.21	0.20	
O3	0.23	0.29	0.26	0.38	0.23	0.21	0.19	0.21	0.24	0.20	0.22	0.25	0.12	0.13	0.23	0.22	0.27	0.20	0.22	0.26	0.22	0.28	0.23	0.26	0.23	0.27	0.24	0.28	
O4	0.03	0.21	0.19	0.18	0.32	0.15	0.07	0.05	0.07	0.05	0.08	0.07	0.02	0.04	0.14	0.11	0.16	0.20	0.13	0.16	0.17	0.08	0.29	0.22	0.33	0.23	0.24	0.23	
	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
O1	0.0312	0.0120	0.0064	0.0081	0.0086	0.0126	0.0265	0.0166	0.0171	0.0212	0.0150	0.0350	0.0251	0.0384	0.0043	0.0042	0.0031	0.0057	0.0063	0.0049	0.0031	0.0025	0.0013	0.0087	0.0129	0.0132	0.0230	0.0076	0.376
O2	0.0132	0.0074	0.0133	0.0037	0.0142	0.0104	0.0112	0.0134	0.0236	0.0176	0.0134	0.0203	0.0066	0.0106	0.0018	0.0023	0.0035	0.0028	0.0030	0.0023	0.0013	0.0009	0.0008	0.0087	0.0081	0.0155	0.0156	0.0052	0.252
O3	0.0138	0.0113	0.0093	0.0102	0.0117	0.0075	0.0096	0.0085	0.0142	0.0103	0.0089	0.0203	0.0044	0.0077	0.0022	0.0021	0.0031	0.0028	0.0031	0.0032	0.0015	0.0015	0.0010	0.0087	0.0110	0.0155	0.0178	0.0073	0.230
O4	0.0018	0.0081	0.0068	0.0048	0.0163	0.0054	0.0035	0.0020	0.0041	0.0025	0.0032	0.0057	0.0007	0.0023	0.0013	0.0010	0.0018	0.0028	0.0018	0.0020	0.0012	0.0004	0.0013	0.0073	0.0158	0.0132	0.0178	0.0060	0.142
	6.00	3.90	3.60	2.70	5.10	3.60	5.10	4.07	5.92	5.18	4.07	8.14	3.70	5.92	0.99	0.99	1.17	1.44	1.44	1.26	0.72	0.54	0.45	3.36	4.80	5.76	7.44	2.64	1.000

USB Model																													
	Economic						0.33	Strategic						0.41	Organizational								0.07	Legal				0.19	
	ME	OC	RD	IP	CA	CP	TR	GE	TD	AP	NE	PA	IR	DT	GO	FU	CP	RP	OE	FO	MC	PA	EP	IN	AN	ID	IL	GR	
	0.24	0.17	0.08	0.12	0.21	0.08	0.10	0.10	0.19	0.13	0.08	0.25	0.11	0.14	0.15	0.16	0.09	0.15	0.16	0.16	0.06	0.03	0.04	0.10	0.19	0.22	0.34	0.15	
O1	0.57	0.20	0.20	0.40	0.22	0.23	0.40	0.28	0.23	0.28	0.28	0.38	0.62	0.52	0.36	0.41	0.27	0.33	0.39	0.41	0.42	0.41	0.26	0.28	0.28	0.24	0.34	0.25	
O2	0.19	0.15	0.39	0.17	0.30	0.29	0.25	0.36	0.39	0.30	0.37	0.28	0.18	0.24	0.22	0.24	0.31	0.22	0.24	0.19	0.17	0.22	0.23	0.28	0.19	0.29	0.21	0.25	
O3	0.20	0.23	0.27	0.29	0.28	0.23	0.25	0.29	0.29	0.22	0.28	0.23	0.15	0.19	0.24	0.23	0.27	0.22	0.25	0.23	0.19	0.27	0.25	0.27	0.23	0.29	0.23	0.30	
O4	0.04	0.42	0.14	0.14	0.20	0.25	0.10	0.07	0.09	0.20	0.07	0.11	0.05	0.05	0.18	0.12	0.15	0.23	0.12	0.17	0.22	0.10	0.26	0.17	0.30	0.18	0.22	0.20	
	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
O1	0.0451	0.0112	0.0052	0.0158	0.0152	0.0060	0.0132	0.0114	0.0179	0.0149	0.0091	0.0389	0.0279	0.0298	0.0037	0.0045	0.0017	0.0034	0.0043	0.0045	0.0017	0.0008	0.0007	0.0053	0.0101	0.0100	0.0219	0.0071	0.343
O2	0.0150	0.0084	0.0103	0.0067	0.0207	0.0076	0.0082	0.0147	0.0303	0.0159	0.0121	0.0287	0.0081	0.0137	0.0023	0.0026	0.0019	0.0023	0.0026	0.0021	0.0007	0.0004	0.0006	0.0053	0.0068	0.0121	0.0135	0.0071	0.262
O3	0.0158	0.0129	0.0071	0.0114	0.0194	0.0060	0.0082	0.0118	0.0225	0.0117	0.0091	0.0235	0.0067	0.0109	0.0025	0.0025	0.0017	0.0023	0.0028	0.0025	0.0008	0.0005	0.0007	0.0051	0.0083	0.0121	0.0148	0.0085	0.243
O4	0.0031	0.0235	0.0037	0.0055	0.0138	0.0066	0.0033	0.0028	0.0070	0.0106	0.0023	0.0112	0.0022	0.0028	0.0018	0.0013	0.0009	0.0024	0.0013	0.0019	0.0009	0.0002	0.0007	0.0032	0.0108	0.0075	0.0142	0.0057	0.152
	7.92	5.61	2.64	3.96	6.93	2.64	3.30	4.10	7.79	5.33	3.28	10.25	4.51	5.74	1.05	1.12	0.63	1.05	1.12	1.12	0.42	0.21	0.28	1.90	3.61	4.18	6.46	2.85	1.000