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Expected Human Resource Development for Standardization Activities as an International Standardization Strategy (4)

Balanced Standardization

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<**Summary**> In modern societies, formal standardization is one means to help balance the commercial desire for profit with the public desire for open standards. How does/should a standardization committee balance the importance of private gain to motivate the creation of the new and improved with the importance of open standards to expand markets and define open interfaces for future extensions? This paper presents a broad historical view of standardization and describes how different successions of standards have been balanced in quite different ways. A technical approach to balance compatibility standardization and standards is identified along with successful examples of its implementation.

1. Standards are Fundamental

"The adoption of standards marks an important stage in the passage from a scientific novelty to a commercial product."[1] Technical standardization has been successfully accomplished in every technical area including: every possible measurement type, screw threads, interfaces to public telephone networks, Internet protocols and software interfaces.

Economics identifies that a standard creates both private and public effects.[2] A specification, e.g., Intel x86 microcomputer interfaces, allows a commercial organization to completely control the specification. A public standard suggests that commercial organizations do not completely control the standard. As example, the metre length is controlled by governments.[3] But more and more, widely used standards, established in public standardization committees, are controlled by patents held by commercial organizations.[4), 5)] And patents are not the only way that commercial organizations exert control over standardization processes and the public standards created.

Balancing the interest of the public with the interests of private developers when developing and defining a standard is increasing difficult because standards have greater impact as the use of technology increases. Therefore more stakeholders participate in the standardization process and more interests need to be accommodated. This paper starts with a historical perspective on standards and identifies how different classes (successions) of standards have different needs for public accessibility (openness) and require different approaches to balance commercial gain. From this vantage, new approaches to balance current and future classes of standards are proposed.

This paper is an expansion and updating of a previously published paper.*

2. The Successions of Standards

Since humans emerged four different ages of human civilization have been identified: hunter-gatherers, agrarian, industrial and information.[6] In each age the technologies necessary to sustain it were discovered or invented. The term *succession of standards* refers to the standards that are first applied in each technology age (e.g., agriculture, manufacturing and information systems[7]). In this manner the succession of standards for all symbols emerges first; then the succession of standards for all measurements emerges; then the succession of standards for similarity emerges; etc. In the following ages, the now on-going standardization of the same succession continues to provide necessary standards. That is, new measurement standards emerge in the industrial age. The impact of each standards succession is most apparent, and contentious, during its introductory age. After the introductory age the basic concepts are more widely accepted and the on-going standardization in future successions is less contentious.

Table 1 adds to the four ages of civilization a fifth, the post-information age. In each succession of standards, the self-reinforcing mechanisms, which can create increased economic returns, are additive: measurement standards evidence coordination effects; similarity standards evidence both coordination and scaling/learning effects, compatibility standards evidence coordination, scaling/learning and network effects, etc. Therefore standards in each succeeding standards succession have greater economic impact.

* K. Krechmer: "The Entrepreneur and Standards." International Standardization as a Strategic Tool; Commended Papers from the IEC Centenary Challenge 2006, pp. 143-154. Geneva, Switzerland: International Electrotechnical Commission.

Table 1 Standards successions

		Age				
		Hunter Gatherer (before 3000 BC)	Agrarian (3000 BC−1750 AD)	Industrial (1750−1950)	Information (1950−2000)	Post-Information (after 2000)
1	Standards succession	Symbols	Measurement	Similarity	Compatibility	Adaptability
2	Common standards	Primitive language and digits	Length, weight and coinage	Products and services	Interfaces	Negotiation
3	Increased openness (public good)	More people communicate	Agriculture is more productive	Increase volume of product or service	More systems interwork	Increase backward and forward compatibility
4	Increased private gain	Control more people	Allow land ownership	Patent ownership	Patents on interfaces	Increase technology growth
5	Economic self-reinforcing effect	Trade	Coordination	Scaling and learning	Network	Interface (gateway)

Four trends are identified across the standards successions that appear in Table 1:

- Row 1&2—increasing complexity of technical standards.
- Row 3—increasing complexity of public accessibility (openness).
- Row 4—the expansion of private gain supported by new standards successions.
- Row 5—increasing economic impact of standards due to the additive nature of self-reinforcing effects.

These four trends identify why it has become more difficult to find a balance between the private gain and public good a standard should enable. This paper examines the standardization processes in each age and identifies how these trends have developed and what is/can be done to improve the balance of current standardization and standards.

3. Hunter-Gatherer Age

The first succession of standards, symbol standards, emerged as humans developed the common symbols of an early language. An early form of symbol standards was clay tokens to represent different commodities used in the Near East at a time when the first plants were planted for food and animals were being domesticated (10000 BC). Such tokens were found in the graves of high officials, indicating the importance of these symbol standards. Written numbers, possibly the first technical standards, emerged in Uruk (3000 BC) in Mesopotamia.[8)]

Today the symbols comprising the Hindu-Arabic numbers (1, 2, 3, etc.) are the most commonly used technical standard in the world. Even though each culture that evolved independently created its own number system, the desire to trade eventually led to a common number system across the world. This demonstrates how an economic self-reinforcing effect (trading) over a very long period consolidated the many different early digit symbols into one world-wide number system.

4. Agrarian Age

Measurement standards, the second succession of standards, were a significant factor in the development of agrarian civilizations. "Nomadic tribes have no need for land measurements. Division of the lands of a primitive people does not become a necessity until society has reached the level of settled agricultural development."[9)]

Measurement standards provide the weights and measures used for planting, cultivation and collecting taxes, thus assisting in the rise of Babylon and Egypt. By 3000 BC, the definitions of measurement standards were kept by an authority, such as a pharaoh or temple.[10)] In economic terms, widely utilized measurement standards create coordinating effects which serve to make transactions easier. By 2250 BC, currency, another economic measurement, enabled more complex transactions and further expanded trade.[11)]

Sellers, even just a vendor of produce, have long recognized that measurement standards reduce their advantage by increasing price competition.[12)] Measurement standards offer value to the public, better knowledge of what they are purchasing, but little value to the seller. Without value to the seller or manufacturer, the deployment of common measurement standards has been a slow process. Over a very long period the coordination effects of common measurement standards assisted trade, causing local measurement standards to merge into regional standards and eventually into the International System of Units (SI) measurement system.[13)]

Symbol and measurement standardization was accomplished by local leaders or governments. But, after the French and American revolutions, a change in how standards were developed and maintained emerged. At the beginning of the industrial revolution standardization began to be accomplished not by governments but by standardization committees in England and France.

In England, the Royal Society began meeting in 1660. King

Charles III granted the Royal Society a charter in 1663. As a result of the efforts of the Royal Society, the scientific (fact-based) description and publication of what had previously been craft emerged.[14] The Royal Society's publications on measurement instruments defined the then-current measurement technology.[15] The structure of the Royal Society established a powerful concept—that a balance between public interests (the King's charter) and private interests (of the members) could standardize technology.[16] With the advent of measurement instruments, rigorous measurement standards became practical. A similar organization to the Royal Society was established in France in 1666. By 1799 (after the French revolution), the then named "l'Institut national des sciences et des arts" established the technical basis of the metric system, a fact-based standard measurement system.[17]

5. Industrial Age

5.1 Similarity standards

"The rise of the machine industry, which we associate with the Industrial Revolution (1760–1830), was made possible, technically, by the existence of a vast number of standards…."[18] Similarity standards, the third succession of standards, developed during the industrial revolution to define the results of repetitive manufacturing processes. Similarity standards, including process standards, safety standards and quality definitions, define the minimum admissible attributes. While the litre measurement standard defines the units to measure the volume of a bottle, similarity standards define how similar in size, shape or materials one bottle is to the next (ISO 9058). Similarity standards, like measurement standards, increase price competition, potentially reducing private gain (profits). However, similarity standards also offer advantages of scale and learning which can improve efficiency in manufacturing, distribution and use.

The importance of similar parts was first identified for the rapid repair of guns after a battle. Thomas Jefferson paid a visit to the French gunsmith Le Blanc in 1785 and reported on the value of similar gun parts to the US Congress [ref. 19, p. 437]. In the early 1800s, similar parts were possible only among the guns from the same manufacturer. Maintaining similar parts gave the buyer a strong reason to make follow-on purchases from the original manufacturer, thereby limiting secondary competition and potentially increasing the entrepreneur's profits. Examples of proprietary products in this period that precluded secondary competition: guns, train track gauges,[20] fire hydrant flanges,[21] and nuts and bolts [ref. 19, p. 433]. The importance to the public of interchangeability (a precursor to compatibility) among multiple manufacturers' products was eventually recognized for all these products.

Many times the authorities stepped in to require similarity standards, as example, for train track gauges in England and America, or the USA War Industries Board during World War I which dramatically reduced the variation among similar consumer goods.[22] With government direction, manufacturers focused on the advantages of scaling/learning effects enhanced by similarity standards. The manufacturer could gain in production (scaling) efficiencies, the distribution chain could gain in handling and promotion (scaling) efficiencies, the end users could gain in operation and maintenance (learning) efficiencies, and the public also gained by the increased likelihood of competition. Manufacturers and developers have learned to recognize the advantages of similarity standards, but they still want to control their markets and increase their profits.

The market control that the manufacturer may lose by public standardization may be compensated with patent royalty fees. A patent's value to the manufacturer (private gain) may be a royalty fee per unit sold by licensees. The value to the public (public good) of the coordination and scaling/learning economic effects associated with similar products includes the lower production, distribution and use costs per unit. In the simplest case, as long as the royalty fee is less than the reduction in production, distribution and use costs, the public good is served by patents controlling similar products. This explains how similarity standards with patents as incentives for the manufacturer provide a better balance of private gain and public good than measurement standards.

5.2 Open standardization

When similarity standardization is accomplished by public committees rather than by governments, new requirements for standardization are needed. The author has previously identified 10 requirements for open standardization.[23] The following five relate to the standardization process.

1) Openness—all stakeholders may participate in the standardization process.
2) Consensus—all interests are discussed and agreement found, no domination.
3) Due process—balloting and an appeals process may be used to find resolution.
4) Open change—all changes to an existing standard are proposed and agreed in the standardization organization. This rule is nearly the reverse of open source agreements and is the most significant difference between open standards and open source.
5) Open documents—all may access standardization committee documents, drafts and completed standards.

The first three rules are widely accepted by standardization committees. The latter two rules are not widely accepted.

6. Information Age

Compatibility standards, the fourth succession of standards, emerge when two independent similarity standards are no longer technically sufficient to define an interface. A plug and a socket, each defined by different similarity standards, may or may not be compatible. The relationship between the plug and socket, whether compatible or incompatible, is defined by an interface standard, which identifies how each plug and socket similarity standard relates to the other. A compatibility standard defines a compatible interface.

6.1 Similarity and compatibility

The relationship between similarity and compatibility needs some clarification. Standardization of similarity (e.g., similar clothing sizes, lumber grades, time zones or battery voltage) reduces variation and therefore reduces potential innovation. However, the standardization of compatibility increases variation and innovation.[24] As example: compatibility standards and specifications include: WiFi, the cellular air interface, the Universal Serial Bus (USB 2.0), and Windows™ Applications Program Interfaces (APIs). In each case, large new markets (wireless LAN, smart phones, memory cards, PC software) have emerged from the creation of these compatibility standards/ specifications.

Compatibility standardization defines interfaces and protocols which increase innovation and invention. Similarity standardization defines specific properties of a product or service which forestall innovation, but decrease the costs of production, operation and maintenance. While similarity and compatibility standardization have completely different effects, similarity and compatibility are functionally tightly intertwined. In all cases, when the similarity of each of two interrelated entities (e.g., a cell phone and base station) is standardized, a compatible relationship between the two standardized entities is also defined (e.g., the same protocols connect both).[25]

6.2 Interfaces

A defined interface standard is necessary for public connection to a telephone network, a computer operating system, the internet or a cellular network. Defining a complex interface requires defining the physical and multi-layered protocol interfaces. The Open System Interconnect (OSI) standard ISO 7498 describes seven possible layers of technical standards for an interface. The definitions of all the layers required for a specific interface are the compatibility standards of that interface.

Compatible interfaces are necessary for a communications market to develop beyond a manufacturer's initial customer base.[26] Compatibility is of little value unless there are a reasonable number of products or services to be compatible with. As a network's number of connections (interfaces) increase, the value of a network to a user increases. In economic terms this is termed a network effect. The network effect identifies that the value of each network connection grows faster than the number of connections.[27] Network effects draw users to the larger network and away from smaller competing networks, eventually creating lock-in. Lock-in, a winner-take-all effect, gives the manufacturer or developer who controls an interface, control of the market(s) that interface enables.[28] The possibility of achieving lock-in motivates manufacturers and developers to patent interfaces or be first to the market in the hope of controlling the market that an interface defines. Where a single manufacturer or developer cannot control an interface market, a consortium of them may attempt to develop, promote and control interfaces that are potentially valuable.[29]

The value of patents on compatible interfaces, for the organization that controls such patents, may be much greater than the value of patents controlling similarity. Lock-in enables the manufacturers and developers who profit from controlled interfaces to reap greater rewards.[30] Microsoft (PC software interfaces) and Intel (x86 micro-processor interfaces) are examples of the enormous value created when an interface locks in a large market.

Controlling interfaces can greatly increase private gain but may decrease public good. In response to attempts to control important interfaces, different interfaces often emerge: US Federal Communications Commission Part 68 rules (1983) created new public interfaces to AT&T's controlled telephone network, Ethernet (IEEE 802.3) was an alternative to IBM's patented token ring networks (IEEE 802.5), the Chinese have developed TD-SCDMA cellular technology to compete with, patented 3G cellular technology. While examples in the three previous successions of standards suggest that a single standard for a single requirement benefits the public by facilitating trade, these examples of compatible interfaces suggest that attempts to require a single controlled interface, even if formally standardized, may complicate trade. This appears to be caused by the winner-take-all aspect of compatibility standards.

One indication of the winner-take-all aspect is a "standards war." As example, consider the video disk format war (a compatibility war): Blu-Ray or HD-DVD.[31] This standards war occurred when competing implementers with different technical solutions to the interface between the disk and the disk player refused to agree on one technical solution to be included in a fixed compatibility standard. This delayed the mass market for video disk players.

A standards war represents a standardization process breakdown, as standardization should be a balanced process. Standards wars occur because the economic stakes are very high. The more users who are compatible with one format, the more desirable (and profitable) that format becomes for specific manufacturers and developers.

There are also political examples to support multiple standards for the same function (termed multi-mode operation): The Chinese government's push for their own communications technology in Chinese communications systems.[32] As one example, China did not participate in the development of 2G cellular standards, therefore Chinese companies had little intellectual property relating to the next generation 3G cellular standards. To address this economic problem, China chose to standardize an additional 3G compatibility standard (TD-SCDMA) and support the use of this technology in China.[33] Then cross licensing of the TD-SCDMA technology with technology from other companies allows the Chinese companies to minimize royalty payments to other companies for use of the 3G patents.

The disadvantage is that each multi-mode cell phone system has one more cellular technology (and associated development costs). When cell phones were not programmable, requiring another standard would have been near impossible. And a trade war with China could have resulted. Now, with programmable cell phones, an additional standard seems a less disruptive way to resolve such a problem. While multi-mode 3G cellular is not adaptive, it does show how multi-mode operation can mitigate IPR issues.

The private gain possible when patents are applied to compatibility standards may be too much. The combination of coordination, scaling, network and interface effects is too enticing to manufacturers and developers; this seems to be the root of the intransigency of competing companies in interface standardization discussions (e.g., the standards war between the Blu-ray Disk and HD-DVD video disk formats). Fortunately, the evolution of technology presents new way to resolve this.

6.3 Open standards

Compatibility standardization requires further requirements to create open standards (different than open standardization). The following four requirements are important for the public benefit, but have yet to be required by most standardization organizations.

6) One world—same standard for the same function, worldwide. Given the user advantages offered by network effects, world wide compatibility becomes more important.
7) Open IPR—low or no charge for IPR necessary to implement the basic compatibility standard. IPR on interfaces increases the potential for lock-in which is anti-competitive.
8) Open access—objective conformance mechanisms for implementation testing and user evaluation. Compatibility conformance requires more complex testing than similarity conformance.
9) On-going support—standards are supported until user interest ceases. It is near impossible to change very large communications networks at once, so once interfaces are standardized, backward compatibility must be maintained for very long periods.

7. Solutions for the Post-Information Age

If the equipment/software providing an interface is programmable and changeable, such as cellular phones, tablets or personal computers, then multiple different software versions may be supported on the same equipment (e.g., Mozilla and Microsoft Internet Explorer browsers on the same computer). Users could select between the different software or use a converter when they know what to change to achieve compatibility. When users are not aware of what to do to achieve compatibility, which is most often the case, an automatic means to select among multiple different software, protocols or interfaces is needed. Such a means is termed adaptability.

The post-information age is beginning to use adaptable systems. Adaptable systems occur when autonomous elements of a network can identify, negotiate and select among different software capabilities to implement the most desired. All three functions, identification, negotiation and selection, must exist for a system to be adaptable. When systems —including their interfaces— are micro-processor based with low cost read-write memory, they can be adaptable if adaptability standards are defined. Different forms of adaptability standards already exist and are quite successful.

The most widely used adaptable systems currently are based on etiquettes.[34] An etiquette is a communications protocol that connects between nodes to implement application-specific adaptable systems. Much like an etiquette between humans, etiquette protocols only address how to communicate. Examples include: The International Telecommunications Union (ITU) T.30 (an etiquette) has maintained compatibility between Group 3 facsimile machines for about thirty years; ITU Digital Subscriber Line (DSL) standards which use G.994.1 (an etiquette) to support forward and backward compatibility among the different types of DSL transceivers; In the Internet Engineering Task Force RFC 3261, Session Initiation Protocol (an etiquette), is used to negotiate multimedia communications including Voice over Internet Protocol (VoIP).

Other approaches include meta languages such as Standard Generalized Markup Language (SGML, ISO 8879) and its derivatives including Extensible Markup Language (XML). Such meta languages currently provide only a means to identify relationships, leaving negotiation and selection to other processes.

Ricoh, a Japanese facsimile machine manufacturer, offers an example of the balance possible between public good and private gain using adaptable protocols. Starting in the 1980s, Ricoh offered over time different proprietary higher data rate G3 facsimile capabilities to its corporate customers. Each higher data rate facsimile enhancement was proprietary and available only between Ricoh facsimile machines. Several years after each Ricoh proprietary higher speed product was introduced, a higher speed enhancement similar to what Ricoh offered was standardized in G3 facsimile at which point Ricoh would introduce an even higher data rate. The T.30 etiquette standard defined for G3 facsimile machines supported compatibility with both Ricoh proprietary features and the G3 standards. This ability to support desirable proprietary features while maintaining compatibility with the G3 facsimile standard contributed to Ricoh's position as the largest corporate facsimile supplier for many years. By the way, this is author's personal knowledge from participating in G3 facsimile standardization.

Proprietary functions are identified across public adaptable interfaces using a legally controllable identifier (e.g., a trademark) that is transferred between the communicating ends. Only when each end presents the specific identifier is the proprietary function supported. In this manner a commercial company could offer public software interfaces to network servers and personal computer applications, yet offer proprietary operation of specific capabilities that the commercial company wishes to control, similar to the Ricoh example.

The use of adaptability standards allows developers to charge for their proprietary technology used via public standardized interfaces. If the proprietary technology is valuable, implementers or users will have reason to pay for its use. Many different mechanisms are possible to compensate the entrepreneur: charge for downloads, per implementation fees, usage fees, periodic maintenance/support fees, or simply the sales advantages of offering improved performance.

The last (of the 10) requirements may be the most important for openness:

10) Open interfaces—support migration (backward compatibility) and allow proprietary advantage, but standardized interfaces are not hidden or controlled. Open interfaces are adaptable.

8. Adaptability Standards Offer a New Balance

The development of adaptability standards, defined in public standardization committees, is necessary to create open interface standards. There is also a need to review some standardization policies. The standardization committees' reasonable and non-discriminatory (RAND) intellectual property policies have worked well for similarity standards but are not sufficient for compatibility standards. Public standardization committees need to require adaptability standards for new compatible interfaces (e.g., LTE, 4G, WiFi, WiMax). Any controlled technology in public compatibility standards should be adaptable, unless the controlled technology clearly offers greater public good than private gain. Adaptability standards allow the market to find the balance, where the public good is at least equal to the private gain.

As technologies develop, new waves of human civilization emerge. In each wave of civilization the balance between the private gain of a few and the needs of society is achieved differently. The information age is built on the technologies that create information systems. The expanding standardization of these technologies is a hallmark of the information age. However, proprietary control of information technology standards is changing the balance between private gain and public good. Post-information age standards offer new ways to achieve commercial advantage yet support open standards.

References

1) J. E. Holmstrom: Records and Research in Engineering and Industrial Science, Second edition, London: Chapman and Hall, p. 65 (1947).
2) C. P. Kindleberger: Standards as public, collective and private goods, Kyklos, Vol. 36, No. 3, pp. 377–396 (1983).
3) Metre Convention (n.d.). Retrieved from, http://www.bipm.fr/en/convention/
4) A. Updegrove: The Essential Guide to Standards, Chapter 4, Intellectual Property Rights And Standard Setting, http://www.consortiuminfo.org/essentialguide/intellectual.php
5) T. Simcoe, M. Rysman: Measuring the performance of standards setting organizations, Fig. 1 The increase in total IPR disclosures, International Standardization as a Strategic Tool, IEC Centenary Challenge, p. 91 (2006).
6) A. Toffler: The Third Wave, New York: Bantam Books (1980).
7) P. A. David: Some new standards for the economics of standardization in the information age, P. Dasgupta, P. Stoneman (Eds.), Economic Policy and Technological Performance, Cambridge, England: Cambridge University Press (1987).
8) J. Burke, R. Ornstein: The Axemaker's Gift, New York: Tarcher/Putnam, pp. 29–45 (1997).
9) A. W. Richeson: English Land Measuring to 1800, Cambridge, MA: The Society for the History of Technology and The MIT Press, p. 1 (1966).
10) F. G. Skinner: Measures and weights, C. Singer, E. J. Holmyard, A. R. Hall (Eds.), A History of Technology, Vol. 1, p. 774, London: Oxford University Press (1954).
11) A. E. Berriman: Historical Metrology, London: J. M. Dent & Sons Ltd., p. 102 (1953).
12) C. Shapiro, H. R. Varian: Information Rules, Boston, MA: Harvard Business School Press, p. 231 (1999).
13) IEC SI zone (2006). Retrieved from, http://www.iec.ch/zone/si/
14) A. R. J. P. Ubbelohde: The Beginnings of the Change from Craft Mystery to Science as a Basis for Technology, chapter 23, History of Technology, Vol. IV, London: Oxford University Press (1958).

15) T. Sprat: The History of the Royal Society of London for the Improving of Natural Knowledge, London (1667).
16) R. Friedel: A Culture of Improvement, Technology and the Western Millennium, Cambridge, MA: The MIT Press, p. 397 (2007).
17) H. A. Klein: The World of Measurements, New York: Simon and Schuster, p. 108-115 (1974).
18) Industrial Standardization, New York: National Industrial Conference Board (1929).
19) K. R. Gilbert: Machine-tools, In C. Singer, E. J. Holmyard (Eds.), A History of Technology, Volume IV: The Industrial Revolution (1750-1850), New York: Oxford University Press (1958).
20) D. Puffert: Tracks Across Continents, Paths Through History, The University of Chicago Press (2009).
21) R. C. Cochrane: Measures for Progress, Washington DC: National Bureau of Standards, US Department of Commerce, pp. 84-86 (1966).
22) D. Hemenway: Industrywide Voluntary Product Standards, Cambridge, MA.: Ballinger Publishing, p. 22 (1975).
23) K. Krechmer: "Open Standards: A Call for Action", Invited Paper at the first ITU Kaleidoscope Conference, Geneve, Switzerland May 12, (2008) and published in IEEE Communications Magazine, Vol. 47, No. 5 (2009).
24) K. Krechmer: The Entrepreneur and Standards, International Standardization as a Strategic Tool: Commended Papers from the IEC Centenary Challenge 2006, pp. 143-154 (2006). This paper defines similarity and compatibility standards successions.
25) K. Krechmer: The Mathematical Basis of Standards, Proceedings of the Standards and Innovation in Information Technology (SIIT) Conference, Geneva, Switzerland (2005).
26) M. L. Katz, C. Shapiro: Network externalities, competition and compatibility, The American Economic Review, Vol. 75, No. 3 (1985).
27) B. Briscoe, A. Odlyzko, B. Tilly: "Metcalfe's law is wrong", IEEE Spectrum, NA, Vol. 43, No. 7, pp. 34-39 (2006). Retrieved from, http://www.spectrum.ieee.org/jul06/4109
28) W. B. Arthur: Self-reinforcing mechanisms in economics. In P. W. Anderson, K. J. Arrow, D. Pines (Eds.), The Economy as An Evolving Complex System, Santa Fe Institute studies in the science of complexity, pp. 9-31. Reading, MA: Addison-Wesley Publishing Co. (1988).
29) A. Updegrove: Consortia and the role of the government in standards setting. In B. Kahin, J. Abbate (Eds.), Standards Policy for Information Infrastructure, Cambridge, MA: The MIT Press (1995).
30) S. M. Bensen, J. Farrell: "Choosing how to compete: strategies and tactics in standardization", The Journal of Economic Perspectives, Vol. 8, No. 2 (1994).
31) http://www.engadget.com/2005/09/19/blu-ray-vs-hd-dvd-state-of-the-s-union-s-division/
32) P. Qu, C. Polley: "The new standard-bearer", IEEE Spectrum, NA, Vol. 42, No. 12, pp. 49-52 (2005). Available at, http://www.spectrum.ieee.org/dec05/2361
33) J. Stewart, X. Shen, C. Wang, I. Graham: "From 3G to 4G: standards and the development of mobile broadband in China", Technology Analysis & Strategic Management, Vol. 23, Issue 7, pp. 773-788 (2011).
34) K. Krechmer: "The fundamental nature of standards: technical perspective", IEEE Communications Magazine, Vol. 38, No. 6, pp. 70-80 (2000). Also available at, http://www.csrstds.com/fundtec.html

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