STANDARDIZATION: A PRIMER

Ken Krechmer
krechmer@csrstds.com
http://www.isology.com

ABSTRACT

Recognition is growing of the importance of including standardization in an academic education. Standardization committees create a defined order applied to a specific application, e.g., a safety standard, a measurement standard, a telephone jack, a WiFi signal, a quality standard, a process standard, lumber size. This standardization activity is certainly necessary, but theoretically the details of any standard are largely arbitrary, which reduces any academic interest in standardization. This widespread view is simplistic and needs to change. Creating and maintaining a standard has significant technical and economic effects, even when the details of the standard are arbitrary. Teaching this basic theory of standards and its impact is missing from the existing academic curriculum. This primer develops and presents this theory with a focus on current issues related to interoperation.

Keywords—Standardization, interface standard, history of technology, standardization and innovation, standards and intellectual property rights

1. INTRODUCTION

The standardization of products, services and requirements, such as safety, is universal. Yet there is a major disconnect between the universal need for standardization and the low academic interest in standardization. This paper identifies that this disconnect occurs because, in theory, the specifics of any standard are arbitrary, except for physical constraints. From this perspective, common in the academic and technical community, standardization appears to be based on a committee's preferences and therefore not of academic interest. This incorrect analysis is behind the lack of interest in teaching about standardization in academic courses. The purpose of this standardization primer is to present a theory of standardization, called isology, which explains why and how standardization impacts the design, manufacturer, use and commercial profit generation of every product or service; and why standardization becomes more significant as technology evolves into complex systems.

The development of excellent academic course material on how standardization is accomplished and used is proceeding world-wide [1]. What is lacking is a theory of standardization [2]. A widely accepted theory that offers insight into the field is required before isology will be acceptable in academia. The standardization discipline "will never truly establish itself as an academic discipline in its own right until those that profess the subject demonstrate that it is capable of developing, and has developed, its own theoretical foundations" [3]. The following sections develop isology and identify its significance in different academic fields.

2. STANDARDIZATION THEORY

The history of standardization is one way to study isology [4]. First, standardization was a divine right. The Pharaoh's forearm was the length of a cubit – a measurement standard. Then standardization was the right of a king. King Henry's foot was a measure of length. Next standardization became a means of taxation via the 'weigh house' where imported goods were measured and taxed using the local system of measurement. In 1670, the French Academy of Sciences proposed a minute portion of the circumference of the earth to be the standard for length [5]. In this system (which eventually became the metric system), volume and weight were defined relative to a fixed volume of water. The developing metric system represented a significant change in thinking, from standardization based on gods and kings, to standardization based upon a human perception of the physical world. The rise of physically defined standards is one facet of the Renaissance, the evolution from a god-centered to a human-centered world.

In 1663, in England, the Royal Society was chartered by the King "for the Improvement of Natural Knowledge" [6]. The Royal Society, a collection of technical experts working to define technology under a charter from the government, is an early formal standardization organization. One aspect of the Royal Society's work was to define measurement technology. As measurement technology became more rigorous, multiple measurements were combined to define the similarity between objects or processes. Such sets of measurements become similarity standards and specifications for dead eyes, wire, oil, bolts, nuts, railroad standards, automobile standards, clothing sizes, etc.

With the industrial revolution, these definitions of similarity were necessary to define manufactured products, often first as government requirements or company specifications. Beginning in the 1800s, countries began to create and fund their own standardization organizations. By the late 1800s, standardization organizations with membership consisting of commercial organizations and government representatives developed to create standards for many manufactured products. By the 1950s, national standardization bodies had changed from mostly public membership (with members either a part of or controlled by a government, e.g., railroads and utilities) to mostly private membership. By the 1980s, consortia emerged which often focused on the need for software or system compatibility by defining interfaces.

The brief history above identifies three different classifications of standardization (*successions* in this paper): measurement, similarity and compatibility which emerged over time [7]. Each succession of standards provides the advantages of the previous successions and adds new advantages which increase the economic effects. Measurement standards (including currency) facilitate trade and taxation by making exchanges more consistent and repeatable. For these reasons measurement standards are often promulgated by a government.

Standardization of similarity (e.g., similar clothing sizes, lumber grades, time zones, or battery voltages) reduces variation and therefore reduces potential innovation [8]. Definitions of similarity are a facet of the industrial revolution as they define the result of repetitive processes (e.g., manufacturing). Similarity standardization reduces commercial costs (in production, operation and maintenance) which adds to the advantage of increased trade caused by the measurement standards used to define similarity [9].

The standardization of compatibility defines interfaces and protocols which increase variation and innovation [10]. Such interfaces include: wire and wireless interfaces, software APIs or user interfaces. Examples of compatibility standards and specifications: Bluetooth, WiFi, the cellular air interface, the Universal Serial Bus (USB 2.0), and Windows™ APIs. In each case, large new markets (respectively: wireless headsets, wireless LAN, smart phones, memory cards, PC application software) have emerged from the creation of these compatibility standards/specifications. Compatibility standardization creates interoperation, which in any communications system augments the cost reduction effect of similarity standardization and the increased trade effect of measurement standardization.

While similarity and compatibility standardization have very different effects, similarity and compatibility are technically intertwined. In all cases, when the similarity of each of two interrelated entities is standardized (e.g., a cell phone and base station), a compatible relationship (an interface) between the two interrelated entities is also defined (the same protocols connect both) [11].

When standardization studies do not differentiate between the different successions of standards, the results are confusing. The additive economic effects from each succession of standardization impact various commercial organizations very differently. Manufacturers (e.g., pharmaceutical companies) and most inventors have very different concerns from interface providers (e.g., Google or Microsoft) often called information and communications technology (ICT) providers. As example, the pharmaceutical industry is very supportive of intellectual property rights (IPR) because this industry is concerned about competitors copying proprietary drugs or processes (i.e., controlling similarity) [12]. The ICT industry is concerned about excessive patent litigation and IPR acquisition costs over patents which apply to the interfaces they develop or use (i.e., controlling compatibility).

3. BALANCING PRIVATE GAIN AND PUBLIC VALUE

Private gain refers to gain that a standardization process may confer on private parties based on copyright (rights to the documents that describe the standard), patent rights (rights to a technology that the standard uses or requires), or backwards compatibility (where the standard provides interworking with an existing proprietary product or service). The legal means to control these private gains is called intellectual property rights (IPR).

Public standardization value is created by what economists describe as self-reinforcing effects. Simply stated, the more a standard is employed, the more advantageous it is for all users or implementers (the public) to use it. A standard for the measurement of weight grows in acceptance as it is used in more transactions. Another example, the first telephone user finds no value, as there is no one to call, but as each additional telephone user is added and capable of calling the others, the value of having a telephone increases for all with telephone access. Since this advantage accrues to all users of the weight standard or telephone interface, it represents a public value. Looking at the economic effects of asserted IPR which controls similarity or compatibility: a patent on a specific design of a telephone set (similarity) may create a private value to the patent holder, if the specific design is desirable. But a patent which applies to a telephone interface (defined by a compatibility standard) will create a royalty cost to every telephone user and/or implementer.

Isology identifies why IPR issues unbalance more and more compatibility standardization activities [13]. Patents are used to allow an inventor to profit from their inventions by precluding competition from similar (i.e., copied) products. However, when IPR is applied to both sides of a standardized interface, created not by invention, but standardization agreement, such an application of IPR represents a significant increase in the IPR holder's private gain unforeseen as the use of IPR developed from the 15th century.

Since a compatible interface has very powerful self-reinforcing effects when interworking is required, it may become widely utilized. Some proprietary examples: Microsoft APIs, Intel x86 interfaces and IBM SNA proprietary networks were very important to the great success of these companies. These examples identify that control of market standardized interfaces enable very significant private gains.

When two companies try to include conflicting proprietary technology in a future compatibility standard, commercial conflicts ("standards wars") can occur. One solution to such conflicts is to prevent or avoid any occurrence of private property in a standard. There are some who believe that a standard should only address public value, not private gain (e.g., W3C). This is misguided. Taking this path removes private (commercial) incentive from the creation of standards. There is extensive economic history and theory indicating that removing private incentive from any market is ultimately disadvantageous to all who participate in the market (communism is the overarching example).

It is challenging to find a reasonable balance where both public value and private gain may be served. Establishing and maintaining a balance between private gain (e.g., market control and royalties) and the public's need for available, economical interworking may be the most difficult task facing modern standardization committees.

4. ESTABLISHING ORDER

Table 1 provides the definitions of the different terms for order as they are used in isology. Establishing order, a much broader term than standardization, may describe social requirements, customs and laws, or technical (quantified requirements) order. This paper addresses only technical order. Table 1 identifies the different ways technical order is established and identified.

F.A. Hayek identifies that any order develops in two ways: *kosmos* (self-generating) and *taxis* (created by humans) [14]. Table 1 identifies that much standardization is *taxis*. But *kosmos* standardization, established in the marketplace, may emerge from a successful commercial specification. *Kosmos* standardization occurs after the fact. Where trade is not restrained by regulation, the market recognizes when order exists, independent of whether a standardization process was *kosmos* or *taxis*.

5. THE DIMENSIONS OF COMPATIBILITY STANDARDIZATION

Isology identifies that the standardization of measurement and similarity have evolved in the past and related issues (e.g., public and private partnerships, the need for consensus, broad stakeholder representation) have been worked out in the past. The remainder of this paper focuses on the standardization required for the information age – compatibility standardization. Here significant issues have not yet been resolved, mostly because they have not been fully understood. Technical standards for compatibility are developed in a range of organizations: government regulations for telephone jacks, government mandated ITU Recommendations for DSL and cable interfaces, independent standardization organization such as IEEE for Ethernet or IETF for Internet RFCs (request for comments, what the IETF names its standards), to consortium standardization for commercial goals, as example the 3GPP consortium for cellular systems.

5.1. Which standardization organization

World-wide, government-funded compatibility standardization is common. Likely this is based on the successful history of government measurement standardization and on the impact any standard has on trade. However, the US government has a laissez faire approach to standardization, letting commercial interests fund and dominate US standardization and US participation in international standardization organizations. Since commercial interests are often different among competitors in an industry, the US approach to standardization has resulted in the fragmentation of standardization activities, where multiple different standards for the same or similar technologies/applications may occur and compete in the marketplace. One example of this fragmentation was in the development of mobile cellular standards in the 1990s. Three different 2G cellular

Table 1. Technical order

<table>
<tr><th>Established by</th><th colspan="2">How order occurs</th><th>Term for order</th></tr>
<tr><td>Physical laws</td><td colspan="2">Inherent</td><td>Nature</td></tr>
<tr><td>Convention</td><td colspan="2">Kosmos</td><td>Reference</td></tr>
<tr><td colspan="4">Standardization</td></tr>
<tr><td>Private entity</td><td>Commercial</td><td rowspan="4">Taxis</td><td>Specification</td></tr>
<tr><td>Government</td><td>Required</td><td>Regulation</td></tr>
<tr><td>Formal stds. body</td><td>Consensus</td><td>De jure standard</td></tr>
<tr><td>Consortium</td><td>Consensus?</td><td>Standard</td></tr>
<tr><td>Market</td><td colspan="2">Kosmos</td><td>De facto standard</td></tr>
</table>

standards were considered in the US: TDMA, CDMA and GSM and both TDMA and CDMA were approved. In Europe, the cellular standards did not fragment and GSM became the de jure standard. While fragmented standardization has caused problems related to measurement and similarity standards, it can offer significant advantages in future standards successions. The potential advantages of fragmentation of compatibility standardization are discussed in section 6, below.

5.2. Who participates in a standardization process

The creation, implementation or use of a standard represents different processes of creating order by different groups, regardless of the succession of standardization addressed. The creators, implementers or users of standards focus on different aspects of standardization. These different views help to understand how the term "standardization" is applied.

1. A standardization committee creates a standard.
2. A commercial organization may call to its own implementation a standard.
3. An end user organization may refer to their company's decision to use specific hardware or software as standardization.

In 2, an implementation of the commercial organization is a specification or, if market accepted, a de facto standard. Microsoft, as only one example, frequently refers to their products as standards. As an example of 3, an end-user organization may state, "We have standardized on Microsoft applications for all company documents." Such an end-user organization only participates in the implementation-of-the-use-of-the-standard, not in the standardization creation process.

5.3. When standardization is started

Using the terms de facto and de jure to identify a standard, while common, does cause confusion, as the terms relate to the timing of the standardization process not the standard produced. When considering compatibility standardization it is necessary to relate the standardization to the time when a product or service emerges in its market [15]. See Fig. 1.

Anticipatory standardization defines future implementations where a standard is needed *before* a product or service can go to market. This is often necessary for physical layer communications. Anticipatory standards are generally of most interest to creators and implementers, those with a direct interest in developing a new standard for an emerging market. The implementers may be interested in creating an anticipatory standard to increase the potential market size, include a controlled technology in the standard, or prevent a competitor from controlling an emerging market. Anticipatory standardization occurred with telephone modems, cellular systems and optical fiber systems.

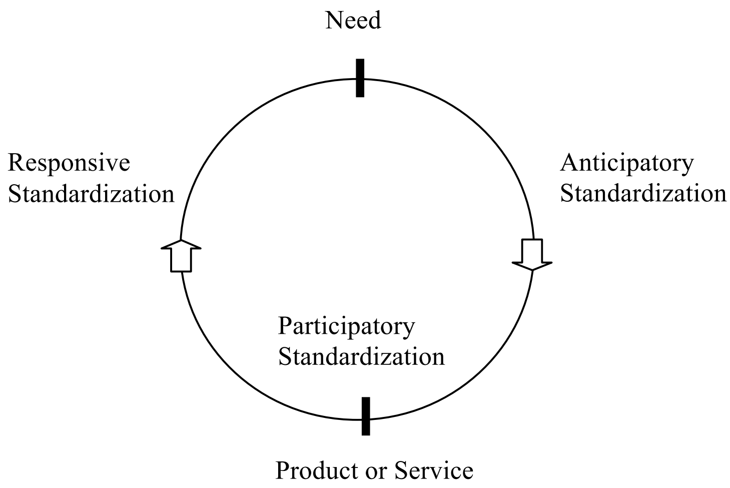

Figure 1. Relating the standardization process to the existence of a product or service.

Participatory standardization occurs during the development of implementations. The IETF calls their standards Request For Comments, because they want participation *during* the development of the implementation. In fact, the IETF requires two usable implementations of an RFC prior to approving it. This would be near impossible for a physical layer compatibility standard before the approval of what the standard includes. Participatory standards (Internet gateway protocols, naming requirements, domain name formats, file transfer protocols, etc.) are of interest to implementers and/or users of implementations of these standards.

Responsive standardization codifies the implementation of existing compatibility specifications. That is, an implementation is formally standardized *after* it has been widely accepted. Responsive standardization is of most interest to users as responsive standardization may protect the user's existing investment (e.g., Microsoft's Open Office XML OOXML). Responsive standardization is also of value to the implementers who have a proprietary interest in the specific technology being standardized. As example, IBM's SDLC (synchronous data link control - a layer two communications protocol) became ISO HDLC (high-level data link control).

Responsive standardization, the practice of standardizing an existing widespread implementation, is one indication of the importance of standards to society. When a responsive standard is defined, somewhat irrespective of which standardization organization first standardized it, the user and the implementer both feel that their investment in the use and implementation of the standard is more secure. As any standard is less subject to change (compared to a company specification, for example), the risk of obsolescence or incompatibility for the user or implementer decreases (but not to zero, which is sometimes assumed).

Once a standard is made, multiple sources of the implementation are more likely to exist, which may decrease the user's risk and cost when committing to products that implement the standard.

The de jure standardization of existing implementations can represent a windfall to the organization that controls a proprietary existing implementation. For this reason, commercial organizations may desire responsive standards based on their own implementations whenever possible. A company with a proprietary existing implementation is rewarded in several ways:

- When their intellectual property is included in the de jure standard, other companies must pay them royalties to use that IP.
- Their own products remain compatible (including user familiarity) with new products based on the de jure standard, while their competitors' products may not. This offers users an incentive to purchase their products instead of the competitors.'

Anticipatory standardization is focused on the lower OSI layers (X.200) and therefore has physical constraints. The IETF pioneered participatory standardization and was very successful initially as it was standardizing in a way that had not been possible before. Responsive standardization is focused on approving existing products and is therefore more political. Responsive technical standardization is increasing and increasingly political (as technology impacts more people). The work in ICANN (Internet Corporation for Assigned Names and Numbers) that deals with the usage of existing words and phrases (responsive standardization) as part of universal resource locators (urls) has been very political. This is not surprising when the world-wide use of .xxx or .sex urls is debated.

6. STANDARDIZATION IS AN EVOLUTIONARY PROCESS

The beginnings of the theory of isology is the recognition that standardization is one aspect of an evolutionary system. Biological evolutionary systems do not succeed by optimizing efficiency. In biological systems, survival is all that is required. Most biological systems are not simple. Biological systems function to increase the likelihood of survival by minimizing risk, rather than minimizing the total energy used (being efficient). In the evolutionary system we are familiar with, the most complex, diverse and inefficient species — humans — are the most successful.

For an engineer, the "best" standard requires the minimum resources (to design, operate and use) and allows maximum performance. Engineers, trained to create the most efficient and simple designs, consider standards that are fixed or with limited options to be the most efficient standard and often argue in a standardization process against adding technical complexity (increases design costs). This is quite different from biological systems which evolve with amazing complexity. Comparing biological development with compatibility standardization indicates that alternative approaches to compatibility standardization are worth considering.

When one design focuses on optimizing certain aspects and another design focuses on optimizing other aspects, conflicts in a compatibility standardization process arise. These conflicts are more significant in compatibility standardization as the rewards the self-reinforcing effects create are greater and the potential for greater rewards makes compromise less likely (e.g., VHS vs. Beta TV recording or Blu-ray vs. HD DVD). The conflicts over compatibility standardization can create a "standards war" [16]. In the 2G cellular standardization, CDMA designers optimized for maximum calls per cell site while the TDMA and GSM designers optimized for the simplest backward compatibility. Because of this conflict of goals there was no way to compromise and eventually all three technologies were included (multi-mode operation) in cellular systems.

The successions of standards are markers in the evolution of technology and the standardization process evolves to meet the needs of each new succession. Each standard succession (e.g., measurement, similarity and compatibility) requires a different standardization approach to establish and maintain the balance between public value and private gain that a standard represents. Fragmented measurement standards are usually undesirable as they reduce trade. Fragmented similarity standards are inefficient but may be acceptable. When independent markets are large and separate, multiple standards for the same requirement may exist (e.g., AC plugs in different regions of the world). Fragmented compatibility standardization and the resulting multi-mode standards is acceptable if interoperability is not reduced. As example, an automatic mechanism exists to select compatible audio and video codecs (algorithms for coding and compressing audio and video) already is used in video and audio conferencing standards.

Even in the cellular standards, now including LTE-A, different standards proposals are combined into a final standard so that each proposal becomes a mode within the completed standard. While this is not energy efficient or simple, it may be "standardization efficient." That is, with more supporters, the new multi-mode standard is more likely to be supported in the world-wide market.

Recognizing standardization as an evolutionary process, when programmable processors and very low cost memory are available, different technologies/implementations (e.g., audio and video codecs) can compete in the marketplace rather than in the standardization committee. This alternative approach to the single mode for each requirement supports multiple modes for the same requirement or even multiple standards with an automatic means to select among the alternatives. Supporting such an alternative approach greatly reduces the risks: The risk to society of standardizing what later turns out to be a less desirable technology, the risk to a company (or country) of not having their proprietary technology accepted by a standards committee, the risk of IPR (and related royalties) emerging after the standard is approved and the risk of market dominance by a single vendor. In each case if one mode or even standard becomes undesirable, there are alternative modes so long as an automatic peer-to-peer means of mode selection exists. For complete interoperability this automatic mode selection must be defined by adaptability standards, the next succession of standards [17].

7. APPLYING THE THEORY

Table 2 summarizes the way the three different groups (creators, implementers and users) may evaluate five compatibility standardization approaches. The complexity and variation of the design and implementation increases in the higher numbered approaches. This range of variation can only be achieved where it is practical. The upper layers of the OSI model coupled with implementations that allow for change (via programmable processors and changeable memory) favor increased variation, while lower OSI layers and/or less changeable systems favor the fixed approaches.

The use of XML supports more flexible systems (master-slave), but XML does not allow an innovative implementer to gain an economic advantage. Such advantage is only possible when a peer-to-peer negotiation is supported across an interface. Such negotiation allows multi-mode (or multi-standard) operation which can balance the desires for private gain by applying market forces [18].

There are situations where a single compatibility standard may be most desirable:

- When physical construction prevents any change.
- When changing modes may cause system problems.
- When there is no opposition to a single standard.

There are also situations where adaptable standards are most desirable:

- When programmable processors and changeable memory are available.
- When the standard applies to higher layer functionality.
- When there are conflicting views on how to implement the standard.
- Where there is IPR associated with implementing or using the standard.

Standardization practices appropriate for one succession of standards applied to another can cause unforeseen problems. Applying IPR, designed to control similarity and intended to prevent copying, to the compatibility of interfaces adds a cost to these interfaces borne by every user of that interface. It is neither necessary nor desirable for a standardization committee to select the commercial winners and losers as no single compatible operating mode will be "best" for all stakeholders over time. Ubiquitous programmable processors and low cost changeable memory have created a new standardization succession — adaptability standardization. No longer are commercial organizations rewarded with profits only for the products or services they offer.

Table 2. The different effects from different standardization approaches.

*	Approach	Creators	Implementers	Users
1	Single standard	Most efficient	Most risk and most reward (creates winners and losers)	Acceptable if IPR costs are acceptable
2	Single standard with extensions or options automatically selected	Added complexity	Less risk & less reward (still creates winners and losers)	Acceptable if IPR costs are acceptable
3	Multiple standards without automatic means to select between them	Poor standards - reduced interworking	Negative	Not acceptable
4	Mechanism to identify and select among multiple modes (e.g., XML)	State of the art	Low risk and low reward	Acceptable in master/slave systems, does not work peer-to-peer
5	Adaptive mechanism to identify, negotiate and select among multiple modes or standards	New technical approach	Some risk, possible reward	Acceptable as IPR costs are set by the market

*The approaches (rows) are shown from the simplest (1) to the most complex (5).

Commercial organizations that control compatible interfaces have found a major new source of profit and/or control of their markets. But this new cost should be controlled by market forces. Adaptability mechanisms support a way forward. Previous successions of standardization have taken hundreds of years to be commercialized. As standardization rightfully becomes a discipline of its own, the commercialization of adaptability standardization will evolve more rapidly.

8. TEACHING ISOLOGY

Teaching isology must have at least two phases. First, the subject should be introduced into existing courses, especially technical courses. A big gap in existing standardization education is the lack of discussion of standardization theory in any technical courses. Likely this occurs due to the feeling that standards are arbitrary and therefore standardization is an after thought. Few physics courses address the significance of standards for mass, time and space to the understanding of all physical phenomena. Second, there needs to be higher level courses specifically addressing isology.

Standards are perceived much like air, necessary but not noticed, in academia today. Even trade and technical courses aimed at implementing Internet standards do not address why such standards make the Internet possible. It is in such trade and technical classes that a recognition of why standards exist should be first presented. With such introductions to standardization, it is reasonable to expect an increased interest in higher level, specific courses on standardization.

Training current and future teachers and professors of technical courses to recognize the importance of standards to their students will take time. To accelerate the process, these teachers should be among the first to learn about standardization. Web-based courses promoted to existing teachers of technical curriculum would be helpful. One such course was developed by four Asian and two European universities, and offered by the Helmut Schmidt University Hamburg, Germany (http://www.standardization.de/_sites/_e-lehre/standardisierung_en.htm).

Isology provides the basis for an academic education in standards and standardization. Existing courses in many fields, especially technical fields, will benefit from understanding and integrating isology. When isology is taught, then an academic education in standardization will be more appealing and effective.

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