WORKING PAPERS

EAST-WEST CENTER WORKING PAPERS

Economics Series

No. 117, April 2011

A Brief History of Standards and Standardization Organizations: A Chinese Perspective

Wang Ping

EAST-WEST CENTER
COLLABORATION • EXPERTISE • LEADERSHIP
SINCE 1960

The East-West Center promotes better relations and understanding among the people and nations of the United States, Asia, and the Pacific through cooperative study, research, and dialogue. Established by the U.S. Congress in 1960, the Center serves as a resource for information and analysis on critical issues of common concern, bringing people together to exchange views, build expertise, and develop policy options.

The Center's 21-acre Honolulu campus, adjacent to the University of Hawai'i at Mānoa, is located midway between Asia and the U.S. mainland and features research, residential, and international conference facilities. The Center's Washington, D.C., office focuses on preparing the United States for an era of growing Asia Pacific prominence.

The Center is an independent, public, nonprofit organization with funding from the U.S. government, and additional support provided by private agencies, individuals, foundations, corporations, and governments in the region.

East-West Center Working Papers are circulated for comment and to inform interested colleagues about work in progress at the Center.

For more information about the Center or to order publications, contact:

Publication Sales Office
East-West Center
1601 East-West Road
Honolulu, Hawai'i 96848-1601

Telephone: 808.944.7145
Facsimile: 808.944.7376
Email: EWCBooks@EastWestCenter.org
Website: EastWestCenter.org

EAST-WEST CENTER WORKING PAPERS

Economics Series

No. 117, April 2011

A Brief History of Standards and Standardization Organizations: A Chinese Perspective

Wang Ping

Wang Ping is the deputy chief engineer and principal researcher of China National Institute of Standardization (CNIS). He was educated in radio science and automation engineering and worked in an enterprise of the Railway Ministry of China. Since 1989, he has been working on standardization, involved in China's standardization strategy and International Standardization Organization (ISO) activities.

This working paper is based on the author's research with help and cooperation from Dr. Dieter Ernst, senior fellow at the East-West Center.

A Brief History of Standards and Standardization Organizations: A Chinese Perspective

Wang Ping

Bionote: Wang Ping is the Deputy Chief Engineer and Principle Researcher of CNIS. He was educated in radio science and automation engineering and worked in an enterprise of the Railway Ministry of China. Since 1989, he has been working on standardization, involved in China's standardization strategy and ISO activities.

Abstract: This paper reviews the history of standardization, from firm-level standardization at the early Industrial Revolution, to private standardization organizations and voluntary standards in the market economy, and national or international standardization organizations that emerged as a result of industrialization and international trade as well as their national or international standards. The paper examines the driving forces, principles and methodologies of standardization and addresses the position and role of technical standards and standardization organizations in the context of market economies. The author argues that standardization enables optimizing resource allocation in market economies and that standardization is the root cause of Adam Smith's "invisible hand". The paper proposes a strong relationship between innovative technologies and standards in the ICT industry and demonstrates that ICT standards are of strategic significance and have a great effect on the industry.

Key Words: standard, standardization, industrialization, market economy, WTO/TBT

Acknowledgments:

I would like firstly to acknowledge very helpful and important suggestions from Dr. Dieter Ernst, Senior Fellow at the East-West Center in Honolulu. This paper has benefited greatly from discussions with him. Secondly, I also would like to acknowledge copy and style editing support by Diana Lu, Project Assistant at the East-West Center.

1. Introduction

Since the advent of 21st century, the Chinese economy has grown at a high rate so that its competitiveness has always increased. According to *Global Competitiveness Report 2010 – 2011* published by the World Economic Forum –WEF, China ranks the 27th on the list. China has been a member of WTO for 10 years, during which it met many technical barriers involving international trade and challenges from standard-related conflicts in Chinese market, from *Positive List System* upon agricultural products in Japan and *RoHS* in Europe, through

WAPI as a bargaining counter during negotiation between governments, to market segmentation in China by Chinese *TD-SCDMA* and overseas standards. All these things suggest that technical standards play an increasingly important role in international trade. During the period under *The Ninth Five-year Plan*, the Ministry of Science and Technology (MOST) included standardization as one of three strategies for technological development. The National Development and Reform Commission (NDRC) has also included national standardization as an important policy for less emission and energy saving.

This author published an article titled *The Property and Status of Standardization Organizations in the View of Historical Development* [i] in 2005, which proposed ideas arising from research on *Opportunities and Challenges upon Chinese Technical Standards*, a task assigned by the MOST. It examined the nature and position of standards and standardization organizations in the context of a market economy and justified the examination as necessary for development of standardization theory and reform in the standardization system in China. In May 2008, this author published an article titled *Standardization Historical Overview*[ii] in *China Standardization* of English version, which gave a primary summary of and examined historical events in the standardization community. This article repeats the subject matter because this author has developed new ideas from further examination and hopes this article will shake up the discussion in the standardization community.

2. A few concepts

As far as the definitions of standard and standardization are concerned, everyone in the standards community in China is familiar with the one made by ISO, which is also used by GB/T20000.1, a national standard in China. As defined by ISO, standards refer to "documents, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context". This definition is accompanied with a note, which read: "standards should be based on the consolidated results of science, technology and experience, and aimed at the promotion of optimum community benefits". As such, standardization refers to activities of establishing, with regard to actual or potential problems, provisions for common and repeated use, aimed at the achievement of the optimum degree of order in a given context (GB/T20000.1). [iii]

The above mentioned definitions however are made in a narrow sense and only in terms of standardization among standardization organizations. It is obvious that they do not completely accommodate in-company standardization.

In 2006 IEC held the conference *IEC Centenary Challenge 2006* and published the symposia titled *International Standardization as a Strategic Tool* in celebration of the 100th anniversary. The introduction in the first few pages reads: "Successful societies have flourished by their ability to trade effectively. Trade has always been supported by perceptions of value based on standards of function, quality and performance. These

‘standards’ can be explicit or implicit, and formal or informal. Whatever the ‘business context’, whenever a transaction takes place there is always a question of ‘what are the standards of function, quality and performance being offered?’’’[iv]

This statement reveals a truth that standards may be defined in a broad sense. They may be not only developed and published by standardization organizations but also are made implicitly and informally. In fact the term standard is used for indicating the concept of “bases and rules for measuring” in human activities in different fields.

Sometimes people discuss what criteria should be used for deciding a case; sometimes they resort to so-called moral standards in support of specific codes of conduct. The historical evolution of these codes or standards varies from country to country because of differences in culture, civilization and values and so do their contents.

In a broad sense, therefore, we can define standards as accepted bases or rules derived from economic and social activities for measuring things and standardization as a process that people establish rules consciously and unconsciously. Alternatively, standardization can be defined as an activity that people develop bases or rules for measuring things and thus codes of conducts by establishing regularity from disorder.

Diversity and regularity are among the important propositions that have long been addressed in the philosophical community. Standardization appears as the embodiment of these two propositions in the history of human society. Surveying human history, we are impressed by the efforts of human beings to seek regularity from diversity. Some regulated activities have evolved into accepted rules and later standards that people abide by.

A specific type of standardization that plays a very important role in the history of human society has arisen from technological applications and industrialization as science and technology have progressed, especially by companies and standardization organizations that emerged after the Industrial Revolution. Companies make standardization serve their business and product strategies, doing in-company standardization for better quality products and higher productivity and participation in standardization by standardization organizations at different levels for their own benefits. Standardization in a standardization organization is a process that stakeholders are invited to develop a standard by consensus for a specific purpose. Modern standardization arises from industrialization and is driven by desire for higher productivity and efficient resource allocation. This is precisely the focus of this article.

Both standard and standardization are important treasures for human society, playing a role in all fields in modern society. One often cannot feel the standards all around but will ask question how a standard was developed if issues arise. Both of these have become the unique infrastructure for economic and social development and function as a platform for technological innovation and industrial development.

3. Early Industrial Revolution and In-company Standardization

3.1 In-company standardization in the early Industrial Revolution marked the advent of modern standardization

The steam engine invented by James Watt in 1782 marks the advent of the Industrial Revolution. The mode of low level production in the form of manual workshop was developing into mechanized production. "Almost 40 percent of male work force at the age of more than 20 had been employed in trade and manufacturing field in UK by the middle eighteenth century. Technological innovation by workers allowed production process to be standardized and streamlined so that a new mode of production was emerging as a factory production and a brand new chain was formed among technologies, production and market as well as productivity considerately increased.[v]" remarked by CCTV in a document titled *The Power of Companies*.

Mass production boosted labor division and produced streamlining in a company. It was no longer necessary for a factory to employ as well-skilled masters as those needed in a manual workshop. Production expansion required cheap labors who had been farmers urgently to do simple job in factories. This should be attributed to in-company standardization. The standardization of manufacturing devices, raw materials, workplace, operating actions, etc. allowed new workers to be competent to their job immediately after simple training. The originator of management science Frederick Winslow Taylor authored *The Principles of Scientific Management* on the basis of practices in factories. Taylorism became popular with manufacturers soon as the Industrial Revolution progressed and finally evolved into the mode of production Americans are now proud of – streamlined automobile production in the Ford Motor Company.

In the late eighteenth century when the USA was founded, the government was in urgent need of a large sum of ammunition. Authorized by the Fifth Parliament, Vice President Thomas Jefferson concluded with Eli Whitney (1765 - 1825), a mechanical engineer and employer, a contract in 1798, under which ten thousand rifles should be delivered to the government within two years. As required by the government, these rifles should be identical with those Charleville invented in France in 1763. Because the government recognized that the parts of rifles should be interchangeable because of war, Whitney set up requirements for interchangeability. He managed to simulate the prototype rifle provided by the government in parts. Because the parts were standardized so that they could be interchangeable, and they could be easily assembled into rifles, the final products.[vi] Though according to data from Yale University it is controversial that Whitney is the first person to manufacture parts on the principle of interchangeability, his innovation was really revolutionary in the USA. Specialization and standardization of parts in the course of manufacturing allowed for mass production and thus higher productivity, which laid the foundation for streamlined production later. Whitney is accordingly well known as the father of standardization.[vii]

In-company standardization began with uniform dimension and interchangeability of parts and afterward continued with essential forms of standardization such as unification, simplification and modularization in product design, processes and manufacturing. Since the advent of the IT society, interoperability, a new form of standardization, has been proposed in ICT field.

Though inventions triggered the Industrial Revolution, it was the emergence of companies that allowed the revolution to boom. The nature of seeking maximum profits drove companies to commercialize technical innovations and ultimately benefit human beings. Modern standardization was directly related to companies from the beginning. Need for capacity expansion, higher profit and quality and innovation provided companies the impetus to standardization. Capacity expansion called for labor division and specialization. Specialization and need for higher productivity boosted standardization of in-company management and products as well as corresponding technologies.

Modern standardization appeared as a management tool in support of corporate operation in order, keeping companies from underperforming, low productivity, impairment of in product quality, resource waste and increase in cost. As the smallest unit for resource allocation in the context of market economy, companies must ensure profitable operation. Any act in breach of standards is prohibited. In-company standardization serves the purpose of R&D and marketing strategy.

In-company standardization is the first step to the externalization of standard development. Standards that workers are implementing are not made by themselves but by quality engineers or industrial engineers[viii]. Well-skilled masters are not necessary for mass production any longer. It is also unnecessary for workers to know the meaning of their job. They seem to be no more than a screw in the industrial machine when repeating assigned actions on their posts.

Sometimes it is difficult to distinguish technologies from standards in a company because standards are locked technologies. The process that a company transforms technological innovation into a product is to lock the technologies. All technical documents (including drawings) signed by a CTO (technical director) can be called, in a sense, standard documents to be implemented for manufacturing purpose. These documents may be developed in the form of technical drawings and/or technical documents, which however are not called standards by the company.

3.2 Historically technical innovation and standardization were interweaved together

The period around the nineteenth century witnessed the bloom of technical innovation, when great sums of mechanical and electrical inventions were emerging. In 1775, John Wilkinson, a blacksmith in the USA, invented a boring machine. In 1797, H. Henry Mauslay of England built a screw-cutting engine lathe. In 1834, Jacobi of Germany invented a DC motor. In 1879, Thomas Alva Edison invented an incandescent lamp. In

1870, Gramme of Belgium invented a DC generator. In 1880, an Italian physical scientist Alessandro Volta built the first battery in the world. By then, the world entered into an electrified era which was totally different from before.

In 1800, Henry Maudslay (1771 - 1831), a mechanical engineer in England, was well-known as the father of lathe, who held an important position in the history of lathe and contributed significantly to the evolvement of lathe. His contribution to standardization, by inventing a screw-cutting engine lathe, marked the advent of the standardization of screw size[ix], the applications of interchangeability principle to both bolts and nuts, the advances of interchangeability and generality with parts, and the foundation of screw standards. Before his invention, both bolts and nuts had to be made one by one separately.

In 1841, Sir J. Whitworth (1803 - 1887), an engineer in England, proposed a screw standard to include a fixed screw at an angle of 55 degree with a standard pitch for a given diameter. A number of railway companies in England first adopted this standard. Afterwards, it was so widely accepted that it eventually was adopted as the screw system in England, called Whitworth Screw Thread.[x] After being consolidated into inch screw thread, it was even further adopted in the USA, UK and Canada.[xi]

Lord Kelvin William Thomson (1824 - 1907), a physical scientist in Scotland, proposed the concept of absolute temperature in 1848. As one of the founders of thermodynamics in 1851, he discovered the second law of thermodynamics. He devoted his afterlife to physics especially electricity. As the leader of BSI Electricity Committee, he introduced a set of measurement units for electricity, which were later adopted all over the world.[xii]

Historical overview indicates clearly that technical innovation has been interrelated with standardization. Talented inventors and scientists have contributed to standardization and thus are remembered by later generations.

3.3 Military and national defense needs gave an impetus to the defense industry and industrial standardization

Demands for weapons and equipments such as aircrafts, tanks, vehicles, and the spare parts thereof, both in terms of time and quantity, during the First and Second World Wars were much higher than those during the peacetimes. These demands imposed requests for more massive productions and higher productivities upon the military manufacturers. To supply sufficient weapons and equipments efficiently, they had to implement the streamlined production practice. Wars, therefore, were important impetuses to the industrial standardization. The story of Whitney made rifles was a perfect example.

Charles Renard (1847 - 1905), a military engineer of France, led the design of manned airship in the aeronautic department after the Franco-Prussian War（1870/7）. He proposed the system of preferred numbers, which has been widely used since. It used geometrical progression for the insertion values in between 1 and 10

($10^{n/5}$ or $10^{n/10}$). With this approach, the French army reduced the types of ropes for balloons from 425 to 17, which considerably decreased their cost and improved their efficiency.[xiii] Preferred numbers were later included in ISO 3. They represented a form of standardization, namely simplification. An example of the application of these preferred numbers standard is a series of dimensions or physical quantities included in a number of mathematical charts in the engineering manuals, such as screw dimensions, surface roughness, diameter of cylinder and oil pressure. We can also see the application of the preferred numbers standard to capacitance and resistance values in the electronic field. Though it is easy to speak of simplification as one of principles for standardization, it could not be realized without bold innovation.

3.4 Standardization issues among companies and Taylor's *The Principles of Scientific Management*

According to Frederick W. Taylor (1856-1915), the founder of classical management science, in-company standards were classified into management, operation, man-hour, and tools and devices. In his well-known work *The Principles of Scientific Management*, he described his standardization experiments in the factory and his findings as management principles in a factory , which included standardization of operation, tools, machines, raw materials and workplace , [xiv]. One could find from his description that he refined "scientific laws" from worker's labor and accordingly established standards that workers had to follow for maximum productivity. "It is only through enforced standardization of methods, enforced adoption of the best implements and working conditions, and enforced cooperation that this faster work can be assured. And the duty of enforcing the adoption of standards and enforcing this cooperation rests with management alone.[xv]," said Taylor. Many persons viewed streamlined production in Ford Motor Company as a mode of production of American style or of Taylorism. It is clear that this mode of production calls for standardization of high level.

As time passed by, companies no longer called the rules for management, operation and finance as standards as they were viewed as business management systems and methods. In this author's opinion, they are closely related to the evolvement of management science. Three statements were accepted as the financial language for any companies all over the world, and they were indeed de facto financial standards. We also find that companies are paying less attention to management, operation and financial standards than to product design, manufacturing and service standards, which are classified into the technical ones.

4. The Emergence and Development of the Private Standardization Organizations

4.1 Production specialization among companies and trade expansions made private standardization organizations emerge.

During the second half of the nineteenth century, the second Industrial Revolution accelerated the industrialization across Europe and the USA, which resulted in abrupt capacity expansions. Products were so sophisticated that a single company could not complete all designing and manufacturing efforts, which inevitably resulted in specialization and production division among companies. Companies in the industrial chain, whether upstream or downstream, were naturally bounded as a group for common interests. The nature of making profits and market competition forced a company to obtain more market shares as its first goal. Employers paid more attention to returns and hoped that their technical innovations would yield more profits. But excessive attention to technical innovation could diversify product families to an improper extend causing technical non-coordination, incompatibility among products, un-interchangeability among spare parts and excessive and dispersed product series. Market competition could contribute to disorder in technical terms, which inevitably causes both economic and social underperformance. They can not be solved only by the companies through free market competitions under the invisible hand.

Adam Smith published *The Wealth of Nation* in England in 1776, which assured people that there would be no troubles if thousands of operators were allowed to compete fully in the market as these individual transactions would naturally allocate the resources in an efficient way.[xvi] The Nobel economics winner Ronald H. Coase proposed the theory of transaction cost in 1937, which viewed the companies as a tool of saving transaction cost in the market.[xvii] Using a competitive market model, economists explained that price and market competition would help increase the productivity, allocate resources efficiently and satisfy consumers' needs maximally.

These economists neglected the above mentioned fact, however, that allowing numerous companies to pursue their own shares of interest would not improve their overall benefit as a pie in the market. Without convincing reasons for the causal relationship between the disorderly market competition and the entire benefit for all companies, they use the invisible hand to justify for themselves individually. As a result, resource allocation is down graded to a black box issue. What they neglect are actually **the** standards and standardization that play important roles in economical development.

In 1895, Harry J. Skelton (1867~1934), an iron and steel dealer of England, complained of difficulty in purchasing steel girders in a letter to *The Times*: "…, architects and engineers generally specify such unnecessarily diverse types of sectional material or given work that anything like economical and continuous manufacture becomes impossible. In this country no two professional men are agreed upon the size and weight of a

girder to employ for given work." In 1900, he reaffirmed the complaint at BITA and proposed to standardize the cross section of rolled steel girders.[xviii]

It should be noted that this proposal was not made by an engineer but a merchant, which means that standardization is not driven by technologies but by trade relations among the companies. Skelton recognized that inefficient market due to non-coordination among companies had a negative effect on the entire benefit for a number of companies and called for standardization organizations accordingly. It did have an important effect on the emergence of standardization organizations. In 1901, ESC, the former BSI, was founded, was partly credited by Englishmen to Skelton.

What happened subsequently was that standardization did contribute to an orderly market and the efficient resource allocations and that standards became the basis for both the technological and industrial innovations. Private standardization organizations appeared to be a mechanism for economic regulation and resource allocation. They allowed companies throughout an industrial chain to coordinate for unification, simplification and interchangeability in technical terms, to lead an industrial eco-system with companies' orderly operation, and to improve the overall efficiency for the whole industry. The ISO's recent attempt on the analysis of economic benefit of standards indicated the same fact.[xix]

4.2 Private standardization organizations are the variants of private associations

Early standardization across the companies was actually organized by private associations, e.g.:

- ICE in 1818
- IMechE in 1847
- ASME in 1881
- AIEE, the former IEEE, in 1883; and
- VDE in 1893

These associations were founded to summon experts in specific fields for certain technical solutions. Standardization needs in a specific industry pushed these associations to deal with the subject. Members of such organizations came together to coordinate their common interests, develop standards with technical contents and abide together.

Of course, private standardization organizations were founded later, e.g. ASTM in 1898 and IEEE-SA affiliated with IEEE. Apparently, IEEE-SA does not look differently from IEEE; however IEEE-SA is a relatively independent standardization organization. A board of directors for standardization was set up for IEEE in 1963, and IEEE-SA was set up in 1998. IEEE-SA has established a stringent management system and procedure for standardization.

The standards setting in both the associations and private standardization organizations followed the

principles of openness, transparence and consensus. Standards developed by them were classified as the voluntary ones and also called consensus ones. Companies adopted these standards at their discretions are not obliged to implement them. If two parties agreed on a standard for their manufacturing or business, they could make it binding by referring it in their agreements. Voluntary standards became compulsory upon their inclusion in the agreements. [xx]

Direct relation among companies may be safeguarded by agreements. However, all kinds of standards also play their roles accordingly. Professor Jin Bei[1] addressed it as "standards are the product of clubs", which mostly indicated the nature of standardization organizations. According to Professor Xue Lan,[2] "standards are products representing public interest", which clearly identified the stakeholders of standard development-- i.e. standards are not products representing the interests of individual companies. In terms of standardization procedures, standards are technical agreements that representatives from the companies and other stakeholders agree upon through negotiation and compromise.

Of course, technical coordination between two companies can be achieved by agreements. However, in case of multiple issues need to be coordinated, relying on agreements could cause flooded technical contents, prohibitive costs and market underperformance. This is exactly the reason why companies are willing to participate in standard development as members of standardization organizations. Voluntary standards appear to be a solution for non-coordination of technical issues among companies to a great extent and the subsequent uneconomical market performance.

Standard development conducted by the private standardization organizations was the second step to the externalization of standard development. Some standards that companies had to implement were developed by external organizations. The appearance of private standardization organizations that went with the externalization of standard setting was a kind of evolution and progress of civilization. Companies therefore implemented not only their own standards but also those developed by standardization organizations at different levels, including trade societies and national and international standardization organizations (Figure 1). Nevertheless, because maximum profit is the priority for each company under the market economy, they made their decisions regarding a specific standard based on their business strategies.

[1] Profession Jin Bei, president of Industrial Economics Research Institute of Chinese Academy of Social Sciences

[2] Professor Xu Lan, president of Public Management College of Tsinghua University

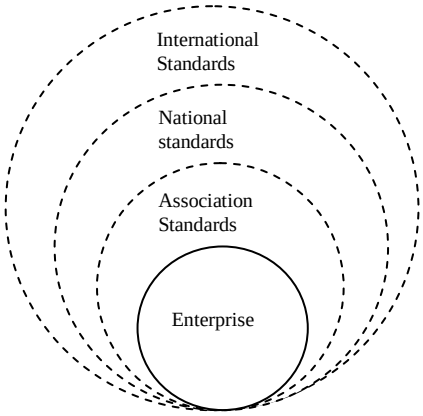

Figure 1. Externalization of standards used by a company

Private standardization organizations under a market economy inevitably face challenges specifically to the market. They have to publish market-oriented standards timely. Because they are non-profit organizations, they have to cover their costs through provision of standards and services (such as trainings). Organizations that have no cohesive force to their industries will be inevitably eliminated because of their failure in wining trust from companies. Private standardization organizations must make efforts on delivering market-oriented standards by attracting and retaining companies as their members and maintaining procedures for ensuring standard developing in an open, transparent and consensus manner. They must keep their sensitivities to the new technologies and market changes with rules so that they set out on a standard project on demand. They must also make amendments to standards in question and withdraw those no longer meeting the industrial needs on time.

Private standardization organizations could be compared to a shell, with the core of the principles as openness, transparence and consensus. Their members came from various fields. Priorities and subject matters were not determined by certain individual or minority ones but by all members participating in the standard development (Figure 2). Every member was charged for its membership. They volunteered their services in the organizations, including serving as the chairman or vice chairman. All members regardless government officials or not are treated equally with the one vote per capita. Standardization organizations played a unique role of setting up rules of implementing the basic principles of openness, transparence and consensus in the standardization process, and the rules of updating and/or withdrawing outdated standards, as well as ensuring the rules being implemented properly. It was in this way that all stakeholders could be treated equally and the market-relevant standards were delivered.

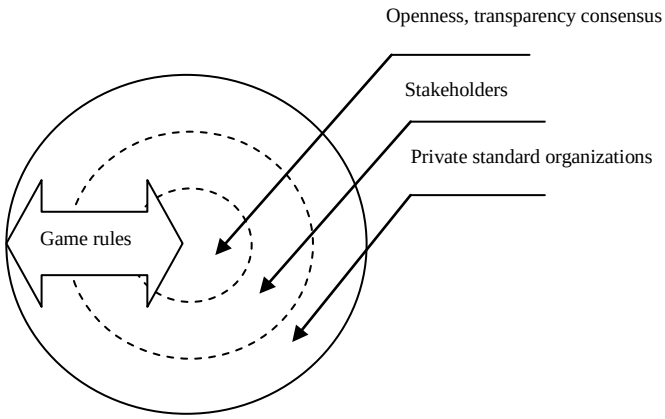

Figure 2 Standardization in private standardization organizations

In 1951, Van Dyck, the President of IRE, published an article complaining that the implementation of preferred numbers standard in the industry was not as good as expected because people always paid more attention to the short-term interests instead of the long-term ones.[xxi] It indicates that voluntary standards do not necessarily create a complete harmony for various interlaced industrial interests in a market economy. When the orderly industrial development conflicts with the individual interests, different employers might make different decisions. Standardization organizations provided a platform for stakeholders to agree upon special standards by compromises for their product innovation as their marketing strategies. This author believes that it is also a mechanism that market improves standard system by itself.

5. The Emergence and Development of National, International and Regional Standardization

5.1 National standardization organizations

Around the end of the nineteenth century, international trade expanded abruptly due to the transportation development. Because raw materials and spare parts varied from country to country, it was difficult to use them without follow-up alternation. This difficulty not only baffled trade expansion but also caused disputes among countries. These disputes, due to incompatibility among products in international trade, obviously brought up the needs of national and international standardizations, which drove countries to unify their standards and allocate resources across the borders efficiently. This was exactly the reason for the emergence of the national and international standardization organizations. The national standardization organizations founded in the early twentieth century are shown in Table 1.

Table 1 National standardization organizations founded in early twentieth century

	Organizations	Founded year	Country	Notes
1	Engineering Standard Committee (ESC), the predecessor of British Standard Institute (BSI)	1901	UK	
2	Deutsches Institut für Normung e.V. (DIN)	1917	Germany	
3	American National Standard Institute (ANSI)	1918	United States	
4	Commission Permanente de Standardisation, a predecessor of Association Francaise de Normalisation (AFNOR)	1918	France	AFNOR was founded in 1926
5	The Association belge de Standardisation (ABS) , a predecessor of Belgian Standards Institute (Belgisch Instituut voor Normalisatie/Institut belge de normalisation)	1919	Belgium	Belgian Standards Institute was created in 1945
6	Österreichische Normenausschuss für Industrie und Gewerbe (ONIG) [Austrian Standards Committee for Industry and Trade], a predecessor of "Österreichisches Normungsinstitut ON" [Austrian Standards Institute ON].	1920	Austria	The organization changed its name to "Österreichisches Normungsinstitut ON" in 1969.
7	Italian Organization for Standardization (UNI)	1921	Italy	
8	Swedish Standards Institut (SIS)	1922	Sweden	
9	Norwegian Standards Association (NSF)	1923	Norway	
10	State Committee of the Russian Federation for Standardization and Metrology (GOST R)	1925	Russia	
11	Japanese Industrial Standards Committee (JISC)	1929	Japan	
12	Industrial Standard Committee of China	1931	China	

National standardization organizations in developed countries mostly originated from the private standardization organizations and thus inherited private organization structures and operation practices accordingly (for exceptions, see hereinafter). They were non-profit (non-government) organizations developing standards on the principles of openness, transparence and consensus. The national standards they developed were the voluntary ones and they covered their costs by providing standard related services. Each country had only one national standardization organization according to the membership rule of the international standardization organizations, such as ISO and IEC, that only one national standardization organization was allowed to represent its country (see the next section). To be represented in any international standardization organizations, therefore, a country had to coordinate and designate one organization as its national standardization organization. ESC, the former BSI, was co-founded by four private organizations in 1901. It was the first national standardization organization in the world, which was a great pride of the British.

AESC, the former ANSI, was co-founded by five private organizations and the government in 1918.

National standardization organizations in Europe considerably differ from that one in the USA. Take an example of DIN, the Ministry of Economy of Germany reached an agreement with DIN in 1975 by accepting DIN as the unique national standardization organization of the country. Despite of its private and non-profit natures, DIN has been in a monopoly position for the national standardization in Germany. It served as an organizer to develop national standards and also as the representative of Germany to participate in standard development in international standardization organizations such as ISO, IEC and regional standardization organizations such as CEN and CENELEC. Several other countries in Europe adopted the same approach.

The US remains to be the most dispersed standardization system. Though ANSI represents the USA at ISO and IEC, it does not develop standards by itself but only serves as a coordinator for standardization activities. National standards are developed by standard development organizations (SDOs) such as ASTM, ASME and IEEE.

There are exceptions, including SCC of Canada and JISC of Japan, which were organized by their government. They were founded in this way for historical reasons. Nevertheless, these national standardization organizations had their own boards of directors or council; they also maintained their organization structures/charts and operating practices on the principles of openness, transparence and consensus to ensure developing the market-relevant/oriented national standards.

5.2 The International and regional standardization organizations

The establishments of International standardization organizations mostly were simultaneous with national ones which made it difficult to draw a clear time boundary between them. Their establishments were greatly influenced by the national modality in the world.

Founded as early as in June 1906 in London the IEC dealt with standardizations in the electronic and electric fields. Standardizations in other fields were mostly addressed by the ISA which was founded in 1926 with its initial focus on mechanical engineering. It closed down in 1942 due to its bad business performance

At the conference “internationally coordinated and unified industrial standards” in London in 1946, representatives from 25 countries made a decision on a new international organization. As a result, the ISO was formed in 1947[xxii] and China was one of the founders. The IEC was incorporated into the ISO in 1947 but they divorced in 1976. According to Willy Kuert, the former ISO should include the ISA and UNSCC.[xxiii]

The International Telecommunications Union (ITU) is another important organization as an academic and a standardization organization as well. The International Telegraph Union (ITU) was co-founded by 20 European countries in 1865, and was renamed as the International Telecommunications Union in 1932. It became part of the U.N. in 1947.[xxiv]

Another attention shall be paid to the emergence of the regional standardization organizations during the second half of the twentieth century, including the CEN founded in 1961, the CENELEC in 1973 and the ETSI in 1988. In addition, other organizations such as PASC ACCSQ of ASEAN were also founded (See Table 2) during this period.

Table 2 Regional standardization organizations founded during the second half of the twentieth century

	Organization	Founded Year	Region	Note
1	Comité Européen de Normalisation (CEN)	1961	Europe	
2	Comité Européen de Normalisation Electrotechnique (CENELEC)	1973	Europe	
3	European Telecommunications Standards Institute (ETSI)	1988	Europe	
4	ASEAN Consultative Committee for Standards and Quality (ACCSQ)		ASEAN Countries	
5	Pacific Area Standards Congress (PASC)		Pacific Area	
6	Arab Industrial Development and Mining Organization (AIDMO)		Arab Countries	
7	Pan American Standards Commission（COPANT)		Pan American	
8	African Regional Organization for Standardization (ARSO)		African Regional	
9	Euro Asian Council for Standardization, Metrology and Certification (EASC)		Euro Asian Regional	

The standardization system formed in the twentieth century was comprised of the private, national, regional and international standardizations. It reflected both the competition and cooperation among countries and regions in the context of economic globalization.

Historically, the establishments of both the ISO and IEC are based on private standardizations; therefore they both inherited the private practicing patterns. Both the ISO and IEC carried the characteristics of any non-government (private) and non-profit organizations; the international standards they developed/delivered were the voluntary ones. Their international standardization was conducted on the principles of openness, transparence and consensus. What different from the private organization was that the ISO and IEC lied to the membership rule in that only one national standardization organization was allowed to represent for its country. It meant that to be represented at ISO and IEC, a country had to coordinate and designate one organization as its national standardization organization in the international organizations. As aforementioned, this difference was due to the effect of country modalities in the world.

As global market expanded, demands for international standards were increasing. Both the ISO and IEC

took the postwar opportunities and made great achievements as reputable world standardization organizations. Meanwhile, international standards became a tool for global manufacturing and trade (procurement and marketing).

The ITU was somehow a different organization, in terms of structure/chart and operating practice, from ISO and IEC for historical reasons; however, it developed standards on the same principles of s openness, transparence and consensus. This article will not elaborate it more in details due to limited pages.

5.3 Standardization across the third world/developing countries

In general, the Industrial Revolution catalyzed the modern standardization developing from the west to the orient or from the developed countries to the developing ones. However, standardization across the third world was conducted by governments meaning that standardization organizations were organized and operated by the governments.

On March 1, 2005, the ISO/IEC published the *Standardizing Bodies Having Accepted the WTO TBT Code of Good Practice*[xxv], which indicated two different kinds of standardization organizations in the world. According to statistics, 80 of those were the central government agencies, while the other 70 organizations as the non-government ones. The result also indicated that most governmental standardization organizations are from the third world while those non-governmental ones are based in developed countries.

This distinction is due to the immature market economies, poor industrialization and incompetence of standardization in the third world. Affected by the international environment especially the WTO, however, government officials in the third world realized the importance of international standardization. So it is not a surprise to see the national standardizations organized by the governments in the third world. In the developing countries, government funding may first fuel standardization and then promotes the development of the industries and standardization. The lower productivity, the more necessary is for governments to preside over standardization during their early stages of economic development.

6. The WTO/TBT and the Economic Globalization

6.1 Challenges from the economic globalization and strategic standards for the ICT Industry

Late twentieth century witnessed the wave of economic globalization, which catalyzed the development of information technology. Both the microelectronic technology and Moore law contributing to chip innovation dramatically shortened the life cycles of products. It was obvious in the ICT field that existing technologies were replaced by the new generation ones for every eighteen months or shorter. It was hard for

the manufacturing community to tolerate traditional standardization organizations that spent five years or longer on developing a standard.

Meanwhile, the consortia standards emerged as well. Both the W3C and OASIS are examples of such consortia. Instead of maintaining the traditional procedures for standard development, consortiums develop and publish market-relevant/oriented standards by using advanced networking techniques and means, inviting experts for standard development and keeping updating the existing standards. Technologies included in such standards are mostly the communication protocol, network technique, data modeling and interface between software and hardware. These kinds of standards are not made available to the customers. Consortia standards succeeded in the ICT field. The emergence of consortia standards marked a more advanced phase of standardization diversification during the 21st century.

This put a great pressure upon the international standardization organizations. The ISO, IEC and the national standardization organizations were all trying to provide technical standards at a higher rate by improving their strategies and shortening times of standard development. For example, the ISO introduced the PAS and IWA in addition to IS, TR and TS. Short-cut procedure was maintained for PAS and IWA so that such draft standards could be adopted as ISO standards more quickly

Since the advent of the 21st century, some technical standards have become totally different from the traditional ones due to the ICT industry development. There are a majority of standards in the traditional fields, where each one just seem like a screw in a machine by playing a role on a single technical point without significant effects on their industries. Technical standards in the ICT field especially the interoperability standard, however, signified greatly to the industry in term of a strategy. This author believes that standards in the ICT field have a special nature which is closely related to firstly the technical innovation and secondly the relevant patents.

ICT Standards are characterized by compatibility and interoperability which are the extension of interchangeability among spare parts in the traditional standardization. As interchangeability in traditional standardization is generally simple, companies do not view interchangeable technologies as their competitiveness. Technologies included in interoperability standards are considerably different from the interchangeable ones. They are intrinsically the key technologies consisted of dozens or even hundreds or thousands of patents instead of a few. For example, Qualcomm has over 3,000 patents on CDMA.[xxvi] Any mobile operator can not implement the CDMA standard without being licensed for the CDMA-based technologies and patents.

This author names it **as the binding relationship** between standards and innovative technologies. Take network communication field, as an example. The communication protocols cannot be implemented without key technologies. The communication protocols are often in the standard forms and so cannot be separated from the key technologies. As a result, a binding relationship is formed between them (Figure 3). This special

relationship emerges only in the ICT field. The externalization of network and positive feedback justified by network economics enable the ICT standards to greatly influence the industry. These standards can be therefore called **strategic standards**. The GSM application in Europe is a clear evidence for this issue. In modern society, examples of interoperability standards with strategic significance include standards of mobile communication technologies (GSM and TD-SCDMA), network communication protocol, wireless network communication protocol (Wi-Fi), etc.

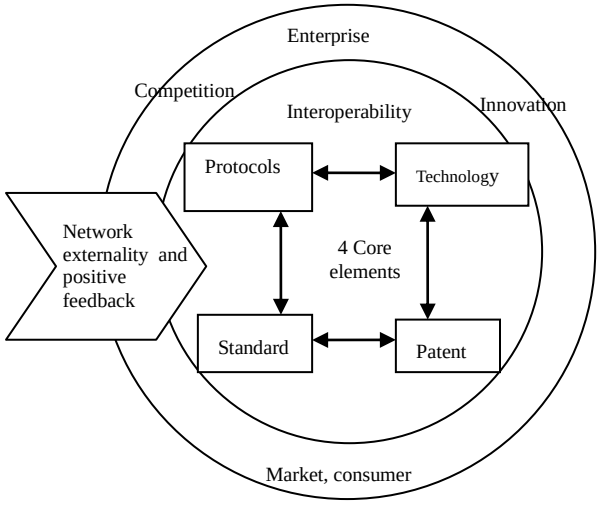

Figure 3: Binding relationship between the standards and technologies in ICT field

6.2 An important milestone in modern standardization history – the founding of the WTO

Founded in 1994, the WTO's aim is to promote international trade. GATT, the former WTO, was set up in 1947. The founding of the WTO has been recognized as the greatest milestone in modern standardization history. With the tariff barriers against international trade removed non-tariff barriers were used for baffling international trade, which pushed the WTO to accelerate the conclusion of TBT agreement. The descriptions of technical regulations, technical standards and conformance assessment, general rules and good practices for standardization were all refined in the TBT agreement. Every country was required to refer to the standards developed by international standardization organizations when developing its own technical regulations and standards. Technical regulations and standards became important rules for international trade. This strengthened the positions of the international standardization organizations both for standards development and for their roles in international affairs.[xxvii]

The fact that members of the WTO are governments and that government officials participate in negotiation at the WTO makes it possible for these officials being more aware of standardization and the importance of standardization in international trade. Whenever international affairs are addressed, one could

often hear government officials speaking of a truth, "standards is the common trade language globally"

The conclusion of the WTO/TBT demonstrated that governments need standards to deal with their national affairs and regulate market competitions, especially the standards on technical indicators or targets with legal enforcement basis for their national defense, healthcare, food safety and resource and environmental protection. In the very beginning, governments directly included these technical indicators or target into their technical regulations but with a big challenge of the quickly outdated existing technical regulations due to the increasing acceleration in technology advances. Amendments to the technical regulations were subject to complicated procedures through a long time. On the other hand, governments were not technical institutions and hence are not good at technical solutions.

The 1950s witnessed the EU efforts on a common market. As the EU members had their own technical regulations, technical standards and conformance assessment, technical barriers were used against each other in the common market. The EU therefore worked hard as a coordinator in order to establish the unified standards and technical regulations across Europe. In 1985, the EU approved *A New Approach of Technical Harmonisation and Standards*, which proposed the using of European voluntary standards in supporting technical regulations, i.e. private standardization organizations developing the voluntary standards while governments developing the technical regulations and the technical indicators or target in technical regulation with references to privately developed standards. The advantages of this practice were to distinguish the accountabilities between the governments and private organizations and to provide a solution to the challenge of the rigid legal systems in response to various technical developments. Inclusion of private voluntary standards in the technical regulations made it possible for the legal regulations to be valid longer with the voluntary standards updated accordingly to the technical development and market changes due to the technology and market sensitivities. Voluntary technical standards supported technical development as a platform in the market economy, while technical regulations played a role in regulating market by the governments. When there are no standards for market regulations developed by the standardization organizations, governments may consult with these private organizations to develop the standards in their own procedures. Reforms in the EU technical directives actually improved the existing directives by removing the unreasonable contents.

Most countries later reached a consensus that inclusion of voluntary standards developed by private standardization organizations in their technical regulations was a good solution to the rigidity of technical regulations in meeting market needs, saving government resources and improving social productivities.

Viewing this as an opportunity in Sep. 2007, the ISO/IEC published the *Using and Referencing ISO and IEC Standards for Technical Regulations*, which described the advantages of using or referencing the international standards for technical regulations, provided introduction to international standards and listed methods for using or referencing international standards. "The advantage of using the ISO and IEC standards in technical regulations is that they would not create unnecessary barriers to trade."

It is interesting that technical standard development has expanded bottom-up in the developed countries. In the very beginning, only the private companies paid attention to standards. Then the industrial associations developed their voluntary standards later. In the end, governments paid attention to standards too, referencing to the voluntary standards in their technical regulations. In contrast, standardization has expanded top-bottom in China. Government first paid attention to standards during the planned economy period when all standards were made mandatory. Since the economic reform, China's national standards have been made both on mandatory and voluntary bases because of the deregulations, and Chinese companies were permitted to develop their own standards. With China's market-oriented economic reforms in the past years, accepting industrial association standards has been proposed as an important subject in the future reforms in China.[xxviii]

7. The implication to the Standardization Reforms in the Developing Countries

The above discussion is significantly relevant to the standardization reform in China and other developing countries. Under the global economy, developing countries reform their standardization systems to gain the industry-specific competitive edges. They stimulate their own economic and industrial growths and facilitate their foreign trades by advancing standardization. There is, however, a great gap on industrialization between the developed and developing countries. For the latter ones, their companies are very inadequate in standardization. Developing countries fall far behind the developed ones in the overall standardization. Therefore, meeting this challenge of advancing their standardization both at a scale level and at a strategic level are the important tasks in front of the developing countries.

The 21st century witnessed the establishments of the ISO, IEC and national standardization organizations in key developed countries with their own standardization strategies. Under waves of these influences, the Chinese standardization institutions and authorities have great concerns on the standardization issue, especially after China became a member of WTO; participation in WTO/TBT made the Chinese officials be aware of the important role of standardization in international trade and therefore determine to implement its standardization strategy. This author here would like to briefly analyze and summarize China's implementation of standardization strategy and certain existing issues. China's standardization strategy is carried out by SAC and government agencies at every level. After years of efforts, China has made great progress in standardization with various technical standardization committees being matured and more companies' participating in standard development. China's standardization has been increasingly playing an important role in stimulating its industrial growth and innovation, supporting the urban and rural expansions and facilitating the Chinese experts in participation in international standardization activities. [xxix]

On the other hand, China's standardization system grew from its planned economy, being pursuant development. Government has been presiding over its overall standardization all along. There is a great gap on the standardization capability between the Chinese industries and the oversea counterparts; there are also a lot

of differences in the standardization system between them. With the above analysis and discussion, this author is looking for solutions to certain issues, including how to evaluate the standardization reforms in China and the ones in other developing countries by using the status and role of standardization organizations developed from market economies; and how to learn from the developed countries for solutions to the existing problems.

Since the 1980s, China has been learning from the developed countries in its standardization reform. It first gave up its practice of all compulsory standards in the planned economy and published the *Standardization Law* in 1988 which recognized the status and role of recommended/voluntary standards in the Chinese standardization system. China has actively participated in activities with international SDOs and built up cooperative relationships with SDOs in many countries. Influenced by the international SDOs and those in the developed countries, China's government standardization administration, the State Bureau of Quality and Technical Supervision in 1980s, has been making efforts to support the establishment of industry-specific technical committees for standardization in different fields. Members of these committees consist of experts from companies, academic institutes, universities and government agencies. Since then, consensus standards have been developed by these committees. The government standardization administration has developed guidelines for standardization in China by referring to the basic rules of the international SDOs (ISO/IEC's directives). The practice of standards development by the technical committees was included in *Standardization Law*[xxx] in 1988 and thus established as a standardization regulation.

The above analysis shows that modern standardization emerged in response to the needs of technical coordination in and among companies. The SDOs were non-profit and private institutions in the developed countries with the exceptions of national standardization organizations in Canada, Japan, Korea and other countries. In the developing/the third world countries, all SDOs were state-owned because of their faltering industries and poor abilities in standardization at the company level. Though the structure and expansion of a SDO's is closely related to its historical development, national culture and economic level in the individual country, a conclusion can be made on the basis of the above analysis that the standards developed by non-profit SDOs have the better character of market relevance. But in China, a large percentage of standards are by far developed by the government which made China's non-profit SDOs incomparable to the state-owned ones in term of standardization capability. Efforts should therefore be made to foster China's non-profit SDOs under the market economy in order to achieve vigorous standardization advancement.

It's been only 30 years since China initiated its economic reform in the 1980s and therefore its regulation system remains affected by the previous planned economic module. In the *Standardization Law* passed in 1988, the Chinese standards were classified at four levels as the national, industrial, local and enterprise standards. All standards except enterprise ones are developed by the government. This classification is likely to mislead people with a conclusion that standards developed by the industrial associations are not accepted legally, or in another word, Chinese industrial associations cannot develop their own standards. Though many in China's standardization community agree that associations should be permitted to develop their own standards under

China's market economic system, a quite large percentage of officials disagree. After the *Standardization Law* has been revised for nearly 10 years, however, today it is still impossible to anticipate when this issue will be addressed in the Law. There is still a long way to go to achieve a successful standardization reform in China.

Of course, the Chinese government is attempting to improve its standardization capability under market economy, e.g. government support to the CCSA and ChangFeng Open Standard Software Alliance. In 2006, six ministries and commissions including the Ministry of Science and Technology supported and promoted the set-up of industrial technology innovation strategic alliance, which resulted a number of industrial alliances emerging shortly after that have been playing an important role in China's voluntary standard development.

With its high economic growth in all these years, China still needs a long time to change its system and mentality for its policy making. Although the current version of the *Standardization Law* does not explicitly state whether it is legal for the industrial associations to develop standards, there should not be a problem if they develop standards under/in their own names. However, industrial associations or alliances actually are reluctant to develop the association or alliance standards in their own names. Take CCSA and IGRS as an example, they developed consensus standards by themselves and made a success. But still they request the government approval and publishing these standards as the national or industrial ones. This is because, under the Chinese cultural, the Chinese always consider documents issued by the government as the most authoritative ones. It therefore takes quite a long time for the non-profit organizations to develop standards in their own name.

Technical regulations and voluntary standards are different issues in China. Mandatory standards, developed by the government as technical regulations, are accepted and included into the notification lists to WTO. However, both mandatory and voluntary standards are by far developed under the same system in China. China's SAC and the standardization agencies under various ministries are in charge of organizing to develop both the mandatory and voluntary standards. Therefore, the technical committees have to develop both versions of standards. The Chinese legal community does not position the technical regulations including mandatory standards in existing legal system. This causes the Chinese officials and the public to be unable to distinguish the mandatory standards from the voluntary ones and vice versa or realized their different roles in administration and industrial development. It can be therefore concluded from the above discussion and analysis that identifying the social roles of the technical regulations (mandatory standards) and voluntary standards and referring the voluntary standards in the government-developed technical regulations are urgently necessary for an effective and efficient usage of various social resources.

8. Conclusions

(1) Standards in a broad sense: Standards refer to bases or rules derived from economic and social activities for measuring things.

(2) Demands for less skilled labors and labor division by the companies stimulated standardization in the early Industrial Revolution during the second half of the eighteenth century. This contributed to the massive productions and higher productivities. Company's standardization principles were unification, simplification, modularization and interchangeability among products. Companies used standardization to implement strategies on product and business issues and also to fuel technical innovation.

(3) In the mid nineteenth century, private standardization organizations emerged due to the industrial development, specialization and product division among companies as well as disputes arose from technically incompatible products in international trade. Private standardization organizations are non-profit organizations covering their costs by providing standard-related services. They develop voluntary standards on the principles of openness, transparence and consensus (also called consensus standards). One important duty of these standardization organizations is to ensure that these principles are fulfilled properly. Only standards developed in proper ways are likely to become market relevance standards. Companies implement voluntary standards at their discretion, which is exactly the reason why the private standardization system can be optimized by itself.

(4) As a legal entity with its goal of profit maximization, each among many enterprises on its own is unable to solve the problem of social inefficiency caused by lack of unity and incompatibility at the technical level. Voluntary standards, however, is the solution to this problem. As an invisible infrastructure for the industrial economy, standards serve as a coordinator for technical issues across the industrial chain. They contribute to the growth of the industrial economy, the efficient allocation of resources and the increase of social productivities. While technical standards' tremendous contributions to the market economy as an invisible hand have long been acknowledged /appreciated by the economists, standards' roles in unification, simplification, modularization and interchangeability across the industrial chains have been neglected by the economists.

(5) In the late nineteenth century and the early twentieth century, both national and international standardization organizations emerged due to the industrial and trade expansions across the countries. In the developed countries, national standardization organizations mostly originated from the private ones were the non-profit and non-government organizations; they delivered voluntary standards under the principles of openness, transparence and consensus. In the third world, most of the national standardization organizations were organized and operated by their governments due to their poor industrializations and incompetence in standardization. The hierarchy of standardization consisted of national, regional and international standardization were formed all over the world during the twentieth century.

(6) Since the advent of the 21st century, both the microelectronic technology and ICT industry have greatly challenged the standardization that both national and international standardization organizations should apply the incentives, short-cut procedure and more flexible methods for the standard development. Consortia standards diversify standardization. The binding relationship between ICT standards and technical innovation, along with the network externalization and positive feedback in ICT field, enables the ICT technical standards

to have a great effect on the industry.

(7) The WTO/TBT agreement has enhanced the position of international standards; governments have paid more attentions to standards than before. Governments' consensus is that adopting the voluntary standards delivered by the private standardization organizations in technical regulations is a good solution to the rigidity of technical regulations in meeting the market demand by saving the government resources and improving social productivities.

(8) Another insight of the standardization reform in the developing countries from the above review of standardization history is that the ownership of a SDO, private or state-owned, is closely related to the history and culture of an individual country. Especially to a developing country, government-organized standardization maybe a good approach to advance standardization due to its faltering industrialization and poor ability in standardization. Their standardization rules, however, are expected to meet the internationally accepted ones with the principle of openness, transparency and consensus. It is necessary to encourage private SDOs to develop standards ensuring the robust standardization which is the foundation of industrial innovation and development. In order to meet the WTO/TBT's essential rules, it is necessary to coordinate technical regulations and voluntary standards. Referencing voluntary standards in government-developed technical regulations is a practice of effectively taking advantage of social resources, which shall be supported legally.

Bibliography

[i] Wang Ping, *The property and status of standardization organizations in the view of historical development*, China Standardization, 2005 (6)

[ii] Wang Ping, *Standardization Historical Overview* , China Standardization, P27, 2008 (5)

[iii] Bai dianyi, *Drafting a Standard*, P1, P3，China Standard Press, 2009

[iv] IEC, *International Standardization as a Strategic Tool -- Commended Papers from the IEC Centenary Challenge 2006*, P7, Printed in Switzerland, ISBN 2-8318-8867-0

[v] Ren Anxue, *The Power of Companies*, P57, Shanxi Education Press, 2010.8

[vi] Benjamin A. Gorman，*Discover Eli Whitney* http://www.yale.edu/ynhti/curriculum/units/1979/3/79.03.03.x.html

[vii] ASTM, *A little History*, http://www.astm.org/NEWS/handbook.html

[viii] Constanze Clarke, *Forms and functions of standardisation in production systems of the automotive industry*, Dissertation, DDC Political science, Freie Universität Berlin http://www.diss.fu-berlin.de/diss/receive/FUDISS_thesis_000000001108

[ix] the Canadian Museum of Making, *Henry Maudslay* (1771 - 1831)，, http://www3.museumofmaking.org/dbtw-wpd/bios_maudslay.htm

[x] Answers.com: *Joseph Whitworth*, http://www.answers.com/topic/joseph-whitworth

[xi] Ye Belin, *Encyclopaedia of Quality, Standardization, Metrology*, P250, Encyclopaedia of China Publishing House, 2001

[xii] Answers.com: *William Thomson, Lord Kelvin* http://www.answers.com/topic/william-thomson-1st-baron-kelvin?cat=technology

[xiii] Sizes.Com, *Preferred Numbers*, http://www.sizes.com/numbers/preferred_numbers.htm

[xiv] Answers.com: *Frederick Winslow Taylor*, http://www.answers.com/topic/frederick-winslow-taylor

[xv] Frederick Winslow Taylor, *The Principles of Scientific Management* (1911), P64, Republished 2008 by Forgotten Books

[xvi] Ren Anxue, *The Power of Companies*, P57, Shanxi Education Press, 2010.8

[xvii] Ren Anxue, *The Power of Companies*, P21, Shanxi Education Press, 2010.8

[xviii] Robert C. McWilliam, David Taylor, *BSI: The First Hundred Years 1901-2001*, P18

[xix] ISO/IEC, *ISO/IEC Inventory of Studies on the Economic and Social Benefits of Standardization* http://www.standardsinfo.net/info/livelink/fetch/2000/14878/6301438/benefits/benefits_s1.html

[xx] Wang Ping, *The property and status of standardization organizations in the view of historical development*, China Standardization, 2005 (6)

[xxi] Van Dyck, *Preferred Numbers*, PROCEEDINGS OF THE I.R.E, P115, 1951 http://ieeexplore.ieee.org/Xplore/login.jsp?url=http%3A%2F%2Fieeexplore.ieee.org%2Fiel5%2F10933%2F35843%2F01701434.pdf%3Farnumber%3D1701434&authDecision=-203

[xxii] Questlaser.Com, *ISO History and Definitions*, www.questlaser.com/PDF_Files/**ISO**_Notes.pdf

[xxiii] Willy Kuert, *The founding of ISO*, http://www.iso.org/iso/founding.pdf

[xxiv] ITU.int, *ITU's History*, http://www.itu.int/en/history/overview/Pages/history.aspx

[xxv] ISO IEC, *WTO TBT Standards Code Directory -- Standardizing Bodies Having Accepted the WTO TBT Code of Good Practic*e, 2005-03-01

[xxvi] Hudong.com, *Qualcomm* http://www.hudong.com/wiki/%E7%BE%8E%E5%9B%BD%E9%AB%98%E9%80%9A%E5%85%AC%E5%8F%B8

[xxvii] Wang Ping, *Standardization Historical Overview* , China Standardization, P27, 2008 (5)

[xxviii] Wang Ping, *The property and status of standardization organizations in the view of historical development*, China Standardization, 2005 (6)

[xxix] Wang Ping, Wang Yiyi, John Hill, *Standardization Strategy of China – Achievements and Challenges, Economics Series*, No. 107, January 2010, West Center Working Paper,

[xxx] Standing Committee of the National People's Congress, *Standardization Law of the People's Republic of China*, 12-29-1988, http://www.lawinfochina.com/law/display.asp?id=1197