State of the Art on Semantic IS Standardization, Interoperability & Quality

Erwin Folmer

Jack Verhoosel

State of the Art on Semantic IS Standardization, Interoperability & Quality

Erwin Folmer
Jack Verhoosel

Colofon

Authors: Ir. Erwin Folmer (TNO, University of Twente, NOiV)
and Dr. ir. Jack Verhoosel (TNO)

Reviewers: Prof. Dr. Jos van Hillegersberg (University of Twente)
and Dr. ir. Paul Oude Luttighuis (Novay)

English edit: Jadzia Siemienski-Kleyn - PAK Business Services

Layout: Nicole Nijhuis - Gildeprint Drukkerijen
Printing: Gildeprint Drukkerijen, Enschede

Website: www.semanticstandards.org
Info: erwin.folmer@tno.nl

ISBN: 978-90-9026030-3
Copies: 1000

Photo page 94: Photos8.com
Photo page 140: Courtesy of EuroNCAP and TTAI

The printing of this book was financially supported by:

TNO innovation for life

NOiV

UNIVERSITY OF TWENTE.

CTIT

Contents

Preface

“Those who do not learn from history are doomed to repeat it”

(George Santayana)

The importance of standardization as a means to achieve interoperability is growing. Within this broad area, the topic of semantic information system (IS) standards and interoperability is relatively new and in the process of becoming a profession. Part of becoming a profession is education, which includes materials that can be used by practitioners and professionals. Recently some new, highly interesting work, BOMOS version 2[1], was published, and it shares common practices in day to day standardization work.

However, what is lacking is a theoretical foundation, i.e. the link between scientific knowledge and its accessibility to practitioners. Currently, there is a gap between standardization research and its use in practice. In our opinion, a state-of-the-art (SOTA) is a starting point to make scientific knowledge accessible. Our SOTA gives an overview of a vast amount of important research that has been carried out in the area of semantic IS standards, interoperability and quality. The goal of sharing the SOTA by means of this booklet is to make it easier to find and get hold of other interesting scientific work.

Obviously, we had to limit the scope of our SOTA. The selected scope is on semantic IS standards including relevant subjects like interoperability. The main reason for this scope is that a good state-of-the-art on semantic IS standards and interoperability is not available yet. We dedicated a chapter to the subject of quality, because we believe that more emphasis on quality is needed to achieve effective interoperability with standards.

Hopefully this booklet will assist you, the reader, in your work in the domain of standardization and interoperability. And simultaneously, we hope that by writing this booklet we have contributed to our goal of making standardization and interoperability a profession.

We thank TNO, University of Twente / CTIT and Netherlands Open in Connection, for sharing our ambition by giving financial support for the design and printing of this booklet. In particular we would like to thank Paul Oude Luttighuis and Jos van Hillegersberg for their continuous support for research in the area of semantic IS standards.

Happy reading,

Erwin Folmer
Jack Verhoosel

[1] For more information on BOMOS version 2 visit: www.semanticstandards.org or www.noiv.nl/bomos

Introduction & Research Approach

1

CHAPTER ONE

“The Internet? Is that thing still around?”

(Homer Simpson)

This study describes the state of the art research available on the topic of semantic IS standards and quality. It sets a foundation on which our and other research can contribute and make a knowledgeable contribution. The main research question is: what is the state of the art research on the quality of semantic IS standards. We have chosen to perform a broad state-of-the-art, including topics like the economics and adoption of standards. Based on this state-of-the-art we are able to define concepts for further studies, including standard, standard organization, interoperability, quality and success of standards.

Our research approach starts with selected studies from a structured literature review which is sure to capture the most relevant studies (Folmer, Berends, Oude Luttighuis, & Van Hillegersberg, 2009). As research is not limited to what is available in top journals, we used the keywords without limiting ourselves to top journals and conducted a Google search to also include other relevant work. Other important resources are several PhD scholars that have included a state of the art in their thesis (Löwer, 2005; Rukanova, 2005; Van Wessel, 2008; Wapakabulo Thomas, 2010).

The results have been enormous. This might have been expected, because since 1980 the number of articles on computer standards has doubled (Cargill, 1989).

This state-of-the-art document begins with Chapter 2, a general introduction about the standards domain which is followed by interoperability, the goal of standardization (Chapter 3). For additional background there is a side step with a description of the economics of standardization (Chapter 4). Reaching the core of the research objective, Chapter 5 is a specialisation within the standards domain: the semantic information system (IS) standards. Two other side steps are made regarding the development & adoption of semantic IS standards (Chapter 6), as well as the trends within the standards domain (Chapter 7). Chapter 8 presents the other side of core research, i.e. the quality domain.

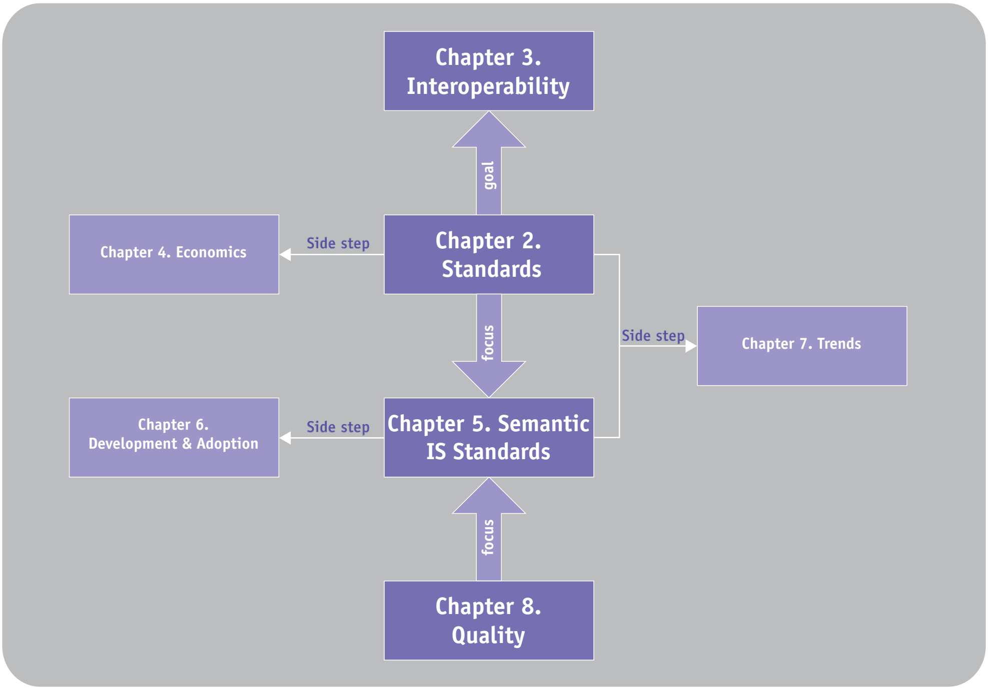
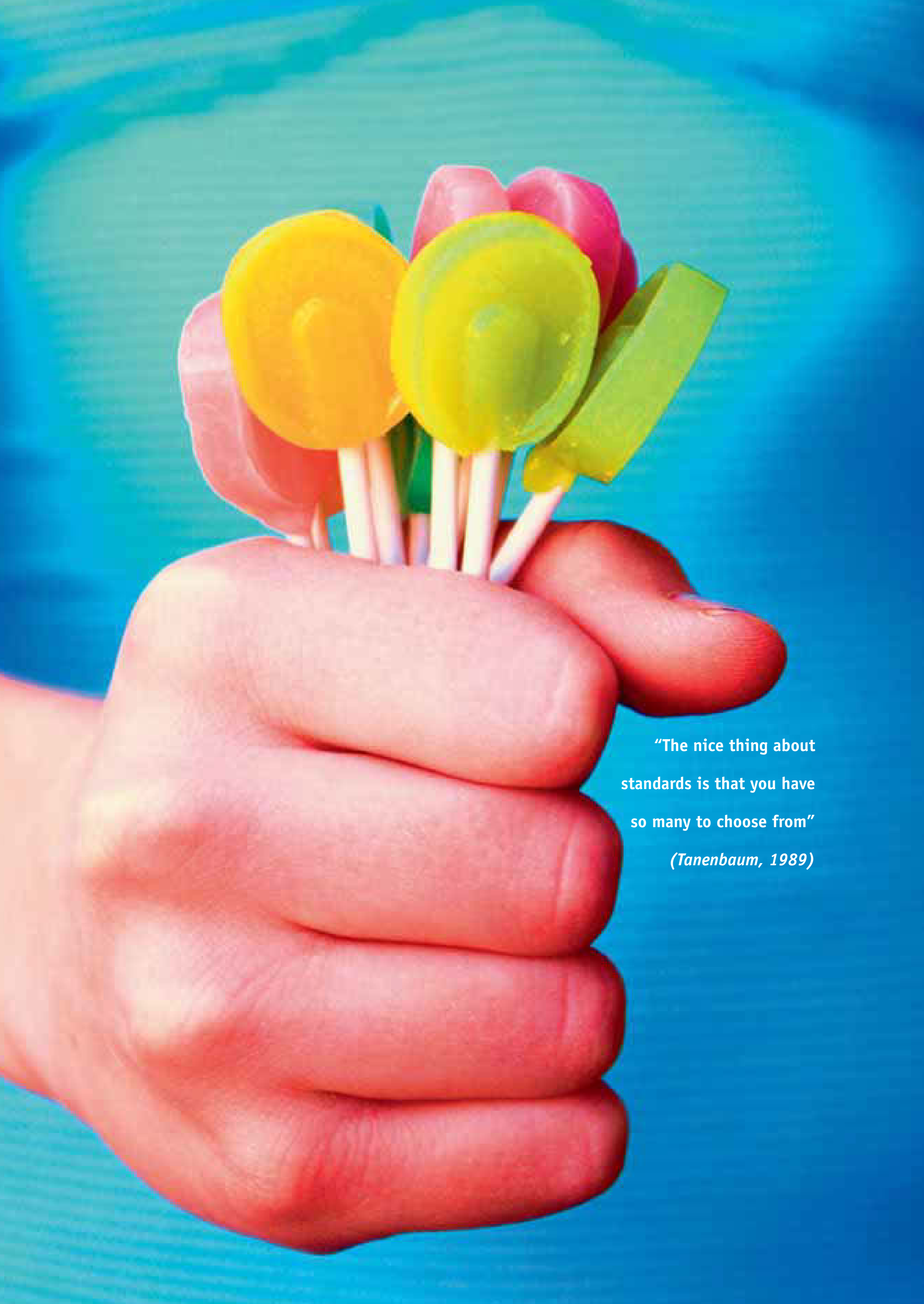


Figure 1 – Chapter structure

The Standards Domain

2

CHAPTER TWO



"The nice thing about standards is that you have so many to choose from"

(Tanenbaum, 1989)

"Standards, like the poor, have always been with us" (Cargill, 1989; Cargill & Bolin, 2007). Many studies describe examples from recent and past times. Simons and De Vries (2002) include an extended list from McDonalds 'Hamburger', creditcards, lightbulbs, petrol, paper formats upto screw threads, voltage, etc. Spivak and Brenner (2001) go even further back in time with examples starting from 3000 BC, but also include dramatic examples like the Baltimore fire (1904) where equipment from neighbouring cities did not work because of a difference in hose couplings. Even older examples from the ancient Greeks (500,000 to 700,000 year ago) are present in literature (Anh, 2007).

Often used examples include ISO 9000 (and ISO 14000), AC/DC voltage (McNichol, 2006), and railway gauges (Spivak & Brenner, 2001), and more recently the VHS/betamax case (Park, 2006) and different DVD standards (Gauch, 2008; Van Wegberg, 2006). Regarding information technology the most common example studied in the nineties is the use of EDI (Electronic Data Interchange). EDI systems provide such widely cited benefits as reductions in paperwork, personnel and inventory costs, order lead time, and data errors (Wang & Seidmann, 1995). 75% of those studies, based on a structured literature review, focused on the benefits of data exchange (Elgarah et al., 2005). These promised significant benefits by facilitating the exchange between business partners, reducing errors, increasing speed, cutting cost, and building as a competitive advantage, were not completely met since EDI standards failed to capture the requirements of the shared context (Damsgaard & Truex, 2000). EDI standards lacked a clear and complete lexicon, did not have fully specified grammar, and had virtually no semantics (Rukanova, Van Slooten, & Stegwee, 2006).

Although much attention has been given to technical tools (communication software) in the EDI-timespan (Rukanova et al., 2006), the community expressed that "EDI is 90 per cent business and 10 per cent technology" (Swatman, Swatman, & Fowler, 1994). In practice, it is difficult to make a distinction between the technical aspects of integration and the organizational issues of implementation and integration (Swatman et al., 1994).

The arrival of XML, a standard foundation, has boosted the development of B2B standards (Zhao, Xia, & Shaw, 2007). Nowadays, XML based standards are common, since XML-based standards involve fewer costs in comparison with EDI standards (Wigand, Steinfield, & Markus, 2005). Many of the latest trends like web services, service oriented architectures, cloud computing, etc. are dependent on standards to fullfil their promise (Kreger, 2003; Zur Muehlen, Nickerson, & Swenson, 2005).

2.1 Standards: typology

The famous quote by Tanenbaum says it all: "The nice thing about standards is that you have so many to choose from" (Tanenbaum, 1989). And there are major differences between different kinds of standards, for instance between pure technical standards and applied EDI standards for inter-organizational communication (Damsgaard & Truex, 2000). Therefore many studies have been performed to create some sort of order in the standardization domain, but several authors question definitions given by others, resulting in many different typologies.

Arguably the most used definition of a standard is the definition used by ISO and IEC (De Vries, 2006; Spivak & Brenner, 2001; Van Wessel, 2008). However, this definition is arguable since it is too focused on traditional formal standardization bodies such as ISO (Van Wessel, 2008):

> *"A standard is a document, 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. Note- Standards should be based on the consolidated results of science, technology and experience, and aimed at the promotion of optimum community benefits."*

Several other definitions are used and discussed as well, for instance De Vries (2006) questions the definition used by Jakobs: *"A publicly available definitive specification of procedures, rules and requirements, issued by a legitimate and recognized authority through voluntary consensus building observing due process, that establishes the baseline of a common understanding of what a given system or service should offer."* And De Vries also questioned the definition used by Tassey, who defines an industry standard as *"a set of specifications to which elements of products, processes, formats, or procedures under its jurisdiction must conform."*

Below we will discuss different typologies based on different perspectives: General, Economics, Technical/IT:

General perspective

Since there are many typologies, De Vries has set up a classification framework for those typologies; De Vries (2006) and also Van Wessel (2008) use the view of the subject matter in their own work:

1. Subject matter related classifications
   a. Related to differences in entities
   b. Related to requirements (basic, requiring, measurement)
2. Classifications related to standards development
   a. Related to actors that are interested or involved
   b. Related to organizations that set the standard
   c. Related to the process of developing standards
3. Classifications related to standards use
   a. Functional classification of standards
   b. Standards related to business sectors
   c. Classifications related to business models
   d. Classification by extent of availability
   e. Classification by degree of obligation

Another useful classification based on three axes comes from Spivak and Brenner (2001):

1. Level (from company, industry, to national, regional, international (voluntary), international (mandatory))
2. Subject (electrical equipment, clothing, transportation, food, ICT, etc.)
3. Aspect (legislation, products standards, testing, inspection, environmental, etc.)

Perera (2007) uses four types of standards useful to describe market acceptance:

- Interference standards
- Quality standards
- Compatibility standards
- Customer interface standards

Compatibility standards can be broken down into horizontal (two functional equivalent objects (e.g. Telephones) and vertical (functionally different: Tracks and Trains or hardware and software) or backwards and forwards (Perera, 2007).

Many authors, including Updegrove (1995) use defacto and dejure standards as a classification, based on the organization which develops and maintains the standard involved. Dejure standards are released by formal bodies like ISO, while defacto standards can be released by industry consortia or any kind of organization. As well as defacto and dejure, regulation and consortium standards are also commonly used (Updegrove, 2007).

On a higher level, Rukanova (2005), based on the earlier work of Stegwee, also made an attempt to classify standards on their abstraction level:

- Method
- Meta-model
- Concrete model
- Operational standard

All these different classifications can be mapped onto the earlier presented framework of classifications. The one to use depends on the intended goal and purpose of the classification; e.g. if you want to select standards that are obligatory by law then a classification based on the degree of obligation would make most sense. If you want to select standards for the healthcare industry, then a subject matter related classification seems obvious.

Economic perspective

David and Greenstein (1990) use the following for the classification of literature on compatibility standards in economics the following, as described by Reinstaller (2008):

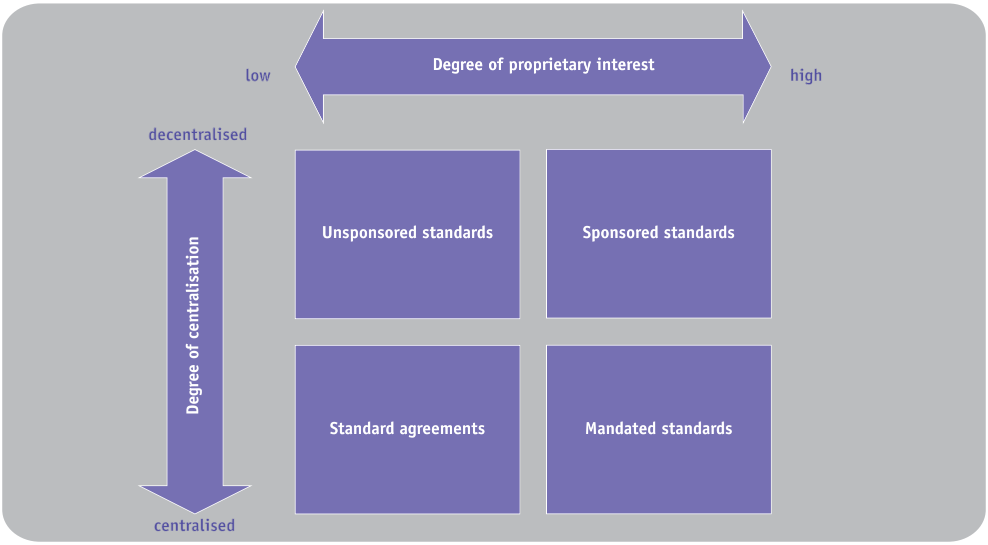


Figure 2 – Economic classification (Reinstaller, 2008).

Other economists use an economic subject classification, where one standard might fit in multiple classes (Blind, 2004; Swann, 2000, 2010):

- Compatibility/interface (e.g. USB interface)
- Minimum quality/safety (e.g. ISO 9000)
- Variety reduction (e.g. clothing sizes)
- Information standards (e.g. tax reporting)

Technical / IT perspective

The earlier mentioned typologies are valid for all kinds of standards. Our research scope is within the IT domain, which justifies a look at specific technical and IT typologies that exist as well. A typology based on the timing of the standard in relation to IT products and services can be differentiated by Anticipatory Standards, Enabling (participatory) Standards and Responsive Standards (Sherif, 2006). For example SMS is an example of a responsive standard (the GSM system was already mature), while WAP is an example of a failing anticipatory standard.

Sherif continues with the introduction of a layered architecture for technical standards:

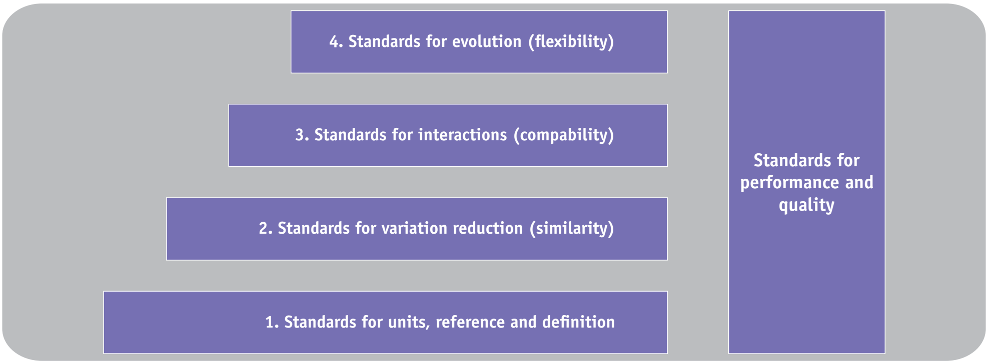


Figure 3 – Layered architecture for technical standards (Sherif, 2006).

The reference standards include well known examples like Volt, Watt, ASCII, the OSI-model, while examples of similarity standards are encryption algorithms and operating systems. Compatibility standards are usually profiles or implementation agreements to reduce the amount of options in a standard in order to achieve interoperability. Flexibility standards focus on compatible heterogeneity, that is, the capability of a single platform to interoperate with different systems and its upward and downward compatibility (Sherif, 2006).

Within the IT domain, Cargill (1989) did some pioneering work by introducing the distinction between:

- Implementation and conceptual standards
- Product and process standards

There is a major distinction between e-business standards and traditional IT standards (Zhao et al., 2007), which might explain why there are several typologies specific for e-business standards. An example of a classification needed for e-business is a pyramid construction with technology at the bottom (Albrecht, Dean, & Hansen, 2005):

Foundation Technology Standards as fundament:

- Data Type Standards
- Scheme Expression Languages
- Common Communication Methods

On top of the fundament, the Marketplace Standards for defining the information exchange:

- Business Categorization
- Product and Service Representation Schemes
- Shared Transaction Templates

On top of the information, the Commerce Services and Applications for defining the interaction:

- Discovery Technology
- Transaction Execution Technology

Another more sophisticated classification for e-business has been made by Chari & Seshadri (2004), who use a layered approach: And then use color codes to distinguish dejure standards from consortium standards.

Industry Domain	Application Domain	Integration Level	Standard
Domain Independent	Data Logic	Transport	Dejure Standard "X"
		Data Format	Consortium Standard "Y"
		Process	
	Business Logic	Transport	
		Data Format	
		Process	
	Presentation Logic	Transport	
		Data Format	
		Process	
Domain Dependent	Data Logic	Transport	
		Data Format	
		Process	
	Business Logic	Transport	
		Data Format	
		Process	
	Presentation Logic	Transport	
		Data Format	
		Process	

Table 1 – Classification for e-business standards (Chari & Seshadri, 2004).

Due to a rising star called "services", Blind (2009) defines empirically-based taxonomies for services and for e-business. Although both taxonomies contain a second more detailed level, only the main items will be mentioned here:

Taxonomy of standards for services:	Taxonomy of standards for e-business:
• Service Management	• Environmental, Health and Safety Management
• Service Employee	• Customer Interaction
• Service Delivery	• Service Delivery
• Customer Interaction	• Data Flows and Information Systems
• Data Flows and Security	• Data Security

Table 2 – Taxonomies for services and e-business (Blind, 2009).

Although we have shown a broad range of classifications, many more classifications are possible, for instance based on interoperability levels, resulting in technical, semantic and organizational interoperability standards.

Summary of terms

The more specific terms used in literature are business transaction standards (Rukanova, 2005) and Vertical Industry Standards (VIS) (Steinfield, Wigand, Markus, & Minton, 2007). The latter is based on the abstraction levels of the Open System Interconnection model – from the physical connectivity level, through the data link, network, transport, session, and presentation levels, to the application level.

"Standards at the presentation and application levels are often referred to as semantic standards, while standards below these levels are called syntactical standards. The internet protocol is an example of a syntactical communication network standard; and EDI standards are an example of semantic information systems standards – the type on which we concentrate here. Semantic IS standards can focus on a single industry sector or purport to be applicable across sectors. An example of a cross-industry standard (under development) is electronic business XML (ebXML). Our focus is on industry specific semantic IS standards, which we refer to as vertical IS standards" (Steinfield et al., 2007).

We do not want to exclude cross sector semantic IS standards, hence we stick to the term Semantic IS standards and by doing so we include both "vertical" and "horizontal" standards. But then we avoid the word "industry" as we do not want to exclude government oriented standards. This leads us to the following description:

"Semantic IS standards are designed to promote communication and coordination among the organizations; these standards may address product identification, data definitions, business document layout, and/or business process sequences." (Adapted from Steinfield et al., 2007)

2.2 Standards: the processes and the product

Based on the ISO booklet The Aims and Principles of Standardization, Spivak and Brenner (2001) mention the following generic aims of standardization:

- Simplification for society, prevents unneeded variation in products.
- Interchangeability: When varieties are limited interchangeability will increase.
- Standards as a means for communication: Communication between producer and consumer.
- Symbols and codes to reduce the effects of different languages.
- Safety: As well as specific safety products, a uniformity of product failure conditions.
- Consumer and community interest: Product labels like energy consumption, flammability.
- Reduction of trade barriers: To avoid the imposition of unique standards by nations to exclude the products of others.

ISO continues by defining the process of standardization, including two notes (Spivak & Brenner, 2001; Van Wessel, 2008):

"The activity 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.

Note 1: In particular, the activity consists of the processes of formulating, issuing, and implementing standards.

Note 2: Important benefits of standardization are improvement of the suitability of products (including services) and processes for their intended purposes, prevention of barriers of trade and facilitation of technical cooperation."

Another De Vries definition used by several others (Hanseth, Jacucci, Grisot, & Aanestad, 2006; Van Wessel, 2008) is: "Standardization is the activity of establishing and recording a limited set of solutions to actual or potential matching problems, directed at benefits for the party or parties involved, balancing their needs and intending and expecting that these solutions will be repeatedly or continuously used, during a certain period, by a substantial number of the parties for whom they are meant."

From an economic perspective, the aim of a standardization process, and the criteria by which it needs to be judged, is twofold (Van Wegberg, 1999):

1. Develop and select the best standard, that is, the one that (over its lifetime) will generate the highest value to society as a whole (the stakeholders).
2. Organise this process of standards development and selection at the lowest transaction costs.

When transaction costs (of the development of the standard) are decreased, more parties try to get involved in the standardization process (Van Wegberg, 1999) since organizations only participate in the standardization process when the expected benefits are higher than the expected costs of participation. Zhao et al. (2007) mention three main reasons for participation in standards development:

1. Orient the standard to their own business practices and systems.
2. The better the standard and the faster it is developed, the greater the benefit there is for the developers who are also standard users.
3. Companies also benefit from in-depth discussions in the development process with their peers.

Life cycle model of standards

Cargill (1995) describes a five-stage life cycle model for standards.

Stage 1: Initial Requirements
Stage 2: Base Standards Development
Stage 3: Profiles/Product Development
Stage 4: Testing
Stage 5: User Implementation Feedback

A similar model of supportive phases during a standards' lifetime (Krechmer, 2006) is:

0. Creation of the standard
1. Fixes (changes)
2. Maintenance (changes)
3. Availability (no changes)
4. Rescission

Söderström (2004) compared seven different standards life cycles, and based on the existing ones created a new general standards life cycle. Each of the seven is useful as a classification, but Söderström extended them to a general lifecycle that seems to be the best of all worlds.

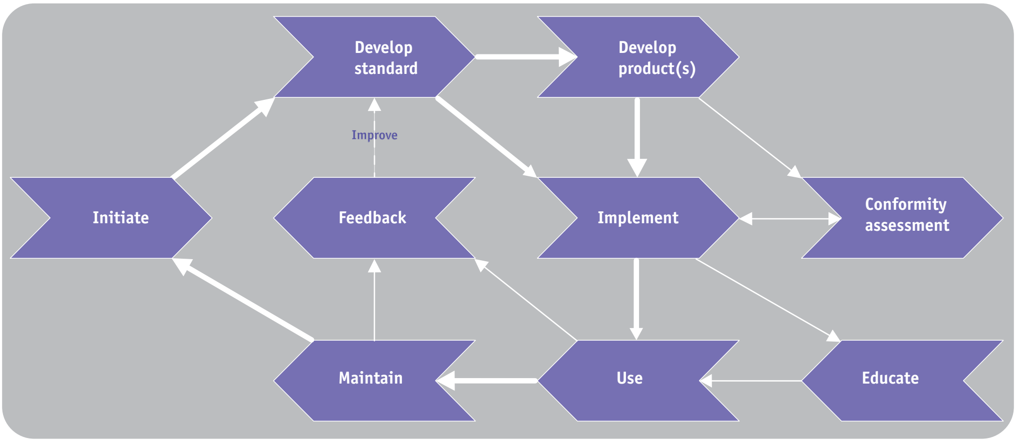


Figure 4 – Generalized (thick lines) and Extended (thin lines) lifecycle (Söderström, 2004).

There are many relations between the phases within a lifecycle model. For example, Zhao et al. (2007) describe the double sided interactions between the development and adoption stages. Organizations have to make a decision about two related strategic choices: whether to get involved in the development of the standard and also whether to adopt the standard.

From a standardization organization perspective, the life cycle is often simplified to a development and maintenance phase, each having its own process. Research often focuses on the development process, resulting in useful knowledge when involved in the understanding of the dynamics of standardization.

A study on web services choreography standards (Nickerson & Zur Muehlen, 2006), showed that:

- Working groups in Internet standard development function as a population ecology, i.e. a living organism that lives and eventually dies.
- Standard developers function as part of an interactional field, whereby their actions are interdependent with those of other standard makers. (Standard makers are professionals who sometimes switch jobs but remain involved in standard making within the same workgroup.)
- The bylaws of the organization are the source of institutional stability in Internet standard making.

This contribution shows the importance of the standards organization, which will be discussed in the next paragraph.

2.3 Standards organization

Different terms are used, but the most common is the Standards Development Organization (SDO), the organization that develops and maintains standards. More recently, the terms Standards Setting Organization (SSO) (Cargill & Bolin, 2007; Krechmer, 2006; Simcoe, 2007; West, 2007) and Standards Setting Body (SSB) (Jakobs, 2009) or informal standards development organization (Song, Jiang, & Wu, 2007) are used. Often the term SDO is reserved for the formal/traditional development organizations (Cargill, 1989; Spivak & Brenner, 2001), while SSO includes all the organizations that develop standards, like OASIS, W3C and IETF.

The formal international SDOs include (Cargill, 1989; Frenkel, 1990; Simons & Vries, 2002; Song, Jiang, & Wu, 2007):

- Global: ISO, IEC en ITU
- Regional (Europe as an example): CEN, CENELEC, ETSI
- National: ANSI, NEN, DIN, BSI, etc.

Many authors describe the process of national, European and international formal standardization, most probably because it is fairly complex (Blind, 2004; Cargill, 1989; Cargill & Bolin, 2007; De Vries, 2007; Hesser & Czaya, 2007; Jakobs, 2009; Simcoe, 2007; Spivak & Brenner, 2001).

However the world has changed, which many studies (Branscomb & Kahin, 1995; Cargill, 1995; Updegrove, 1995; Wagner, Cargill, & Slomovic, 1995) have shown, but was accurately described by (Hawkins, 2009):

> *"By the late 1980s, spurred largely by the burgeoning Internet phenomenon, most of the significant standardization activity in computing and much of the telecom activity (especially in the higher value-added segments) was occurring in a rapidly expanding array of independent consortia that were dominated by major ICT vendors."*

Although ISO created a special committee for Information Technology (JTC1), consortia that have no relation to JTC1 are increasingly producing the important IT standards (Rada, 1998). The result is that important IT domain standardization organizations are not part of the formal SDO world, including organizations like W3C, OMG, OASIS, OAGI, GS1, and more specifically, all sector specific standardization organizations. This consortia movement has led to the fragmentation of standardization (Van Wegberg, 2006), and consortia now dominate the world of IT standardization (Rada & Ketchell, 2000).

Different terms are used for these organizations including SSO, but also industrial consortia or fora, to stress the voluntary characteristics of contributing to the development of these standards. One of the reasons why IT standards have been developed outside the traditional SDOs is the need for fast development times, which is possible within SSOs (Rada, 2000; Simons & Vries, 2002; Van Wegberg, 2006), although the need for faster development times and the assumption that SDO's are slow is questionable (Mähönen, 2000).

Also mentioned is the role of consensus decision making which differs between formal SDO's (consensus) and consortia, which has an impact on the speed, and might have an impact on openness as well. This could be to the advantage of formal SDO's (Rada, 1995; Rada, Cargill, & Klensin, 1998). However this might be overtaken in practice (Egyedi, 2003).

Other reasons that IT standards are developed outside traditional SDO's may be confidentiality and Intellectual Property Rights (De Vries, 2007; Simons & Vries, 2002). Others suggest economic motives:

- Van Wegberg (1999) states that to enable the development of a standard with low transaction costs, an increase in division of labour is needed, leading to specialised standardization bodies, which explains the growing number of highly specialised standardization bodies.
- "One indication of the perceived private and social gains from standardization is the increasing effort – much of which centres on information technology industries – to improve the performance of existing standards-setting bodies and, where that appears infeasible, to form new organizations" (David & Greenstein, 1990).

Although these organizations appear to be growing in number and are influencing information technologies which are playing an increasingly important role in advanced economies (David & Greenstein, 1990), this has not been picked up accordingly in policies and research. Far less attention has been devoted by e.g. economists and political economists to examine the workings of standards-writing organizations (fora) (David & Greenstein, 1990). Consequently, not many studies are performed on how SSOs work in practice, with the exception of IETF (Simcoe, 2007). It is also not picked up in formal policies, for instance the European Union's policy, which did not keep pace with the market developments and stick to the old world:

"The commissioners favor the adoption of a unified worldwide terminology, and consider that standards are only those developed by recognized standardization organizations. At the international level, ISO and IEC are such organizations; at the European level they are CEN, CENELEC, ETSI." (Bucciarelli, 1995)

The existing SSOs differ enormously in nature. Their credibility should not only depend on producing sound standards, but also on avoiding the temptation to abuse standards in making them a cash cow for the organization (Samuelson, 2006). In order to compare different SSOs (and SDOs), especially for the selection of an organization to support a standardization process, a framework has been set up, which has been tested on several SSOs, including OASIS, OMG, W3C and others (Jakobs & Kritzner, 2009).

Although it is impossible to state which SSO is the best, some think that IEEE is the best SSO (Cole, 2004), and others mention IETF as a good example of an open SSO (Krechmer, 2008). Related aspects are the speed of the process, consensus in decision making, and free or sold standards, all of which are addressed in the Communications of the ACM (Rada, 1995; Rada & Berg, 1995; Rada et al., 1998). The latter requires changes within the standardization world. Although several formal SDOs do release their standards for free on the Internet (ITU-T, IETF).

Standards development

Other than the standards development organizations, some expert organizations exist to try to professionalize the process of standards development, including SES (Standards Engineering Society, IFAN (International Federation for the Application of Standards) and EURAS (European Academy for Standardization). The SES developed a standard on standards (Spivak & Brenner, 2001), and at the moment those are ANSI/SES standard ANSI/SES-1-2002 - Recommended Practice for the Designation and Organization of Standards and SES 2:2006 - Model Procedure for the Development of Standards. Concomittantly, ISO has availed its ISO/IEC Directives Part 2, Rules for the structure and drafting of International Standards. The British Standards Institution (BSI) released a standard for standards as guidance in the development process of standards.

To professionalize the volunteers involved in standards making, several organizations developed guidelines for the development process (Freericks, 2010), some of which are specific for service standards:

- CEN: CHESSS: Guidance document for the preparation of service standards
- ISO/IEC: Guide 76: Development of service standards
- IFAN: Guide 3: Guidelines to assist members of committees in preparing user-oriented European standards.

One of the key challenges in the standardization process is to achieve active participation of different stakeholders. Different kinds of standards users exist (Jakobs & Kritzner, 2009):

- Direct users: users of standards; e.g. ICT vendors service providers
- Mediators: e.g. consultants
- Indirect users: users of standards implementations

Hawkins (2009) describes the stakeholder triad, with ICT vendors, ICT Consumers and ICT Appliers as stakeholders that dominate the standards arena.

Standards and Interoperability

3

CHAPTER THREE

"In a 1966 Harvard Business Review article, Felix Kaufman implored general managers to think beyond their own organizational boundaries to the possibilities of extra-corporate systems. His was a visionary argument about newly introduced computer time-sharing and networking capabilities."

(Cash & Konsynksi, 1985)

As early as 1993, a number of businesses and governments alike had already recognized the importance of standards for ensuring interoperability (Rada, 1993). Standards are the means to achieve the goal of interoperability. “Standards are necessary both for integration and for interoperability” (Dogac, Kabak, Namli, & Okcan, 2008). “Adopting standards-based integration solutions is the most promising way to reduce the long-term costs of integration and facilitate a flexible infrastructure” (Chari & Seshadri, 2004). Some go even further: “Inter-organizational collaboration requires systems interoperability which is not possible in the absence of common standards” (Gerst, Bunduchi, & Williams, 2005). Like standards, interoperability is a concept with many different meanings. A study on interoperability definitions found 22 different meanings (Kosanke, 2006). An often used definition is from IEEE: Interoperability is the ability of two or more systems or components to exchange information and to use the information that has been exchanged (Legner & Lebreton, 2007; Rukanova et al., 2006). Another used definition is used by the U.S. Department of Defense in their LISI (Levels of Information Systems Interoperability): The ability of systems, units, or forces to provide services and accept services from other systems (Legner & Lebreton, 2007).

Based on a comparison of different definitions, Van Lier (2009) concludes that interoperability deals with the making of agreements on three levels:

- Technical (technical exchange)
- Semantic (content and meaning)
- Context (interpretation, processing, apply)

This seems in line with the European Interoperability Framework (EIF); it agrees that interoperability is more than a pure technical subject. The EIF version 1 divides interoperability into three layers (European Commission, 2004):

- Technical: Interconnecting computer systems and services on a technical level (e.g. data integration, message transfer, and network)
- Semantic: creating a common understanding and guaranteeing processability of exchanged information in a “meaningful manner” (e.g. data processing, data standards)
- Organizational: definition of cross-organizational business goals and business process modelling (e.g. administrative issues, collaboration agreements)

The second version of the EIF has added a new layer called legal interoperability for aligned legislation for cross border information exchange (European Commission, 2010). Based on the original EIF, but with an additional distinction between technical and syntactic, Kubicek and Cimander (2009) arrived at a four level interoperability approach which is similar to ETSI's approach (Van der Veer & Wiles, 2006):

- Technical: Technically secure data transfer (signals)
- Syntactic: Processing of received data (data)
- Semantic: Processing and interpretation of received data (information)
- Organizational: Automatic linkage of processes among different systems (processes)

Pragmatic interoperability, the effect of data exchange, is sometimes used in combination with semantic interoperability as well (Asuncion & Van Sinderen, 2010).

3.1 Integration and interoperability

Interoperability is defined by: coexistence, autonomy and a federated environment, whereas integration refers more to the concepts of coordination, coherence and uniformization (Chen, Doumeingts, & Vernadat, 2008). A fully integrated system is tightly coupled indicating that components are interdependent and cannot be separated. Interoperability means loosely coupled implying that components are connected and can interact but still contain their own logic of operation (Chen et al., 2008).

A different, more sophisticated and focused view on interoperability

A starting point for a more sophisticated view on interoperability might be the well known OSI (Open Systems Interconnection) model. This model consists of the following layers:

- Application: interacts with software applications
- Presentation: establishes context between Application layer entities
- Session: controls the dialogues (connections) between computers
- Transport: transparent transfer of data between end users
- Network: functional and procedural means of transferring data between networks
- Data-Link: transfer data between network entities
- Physical: electrical and physical specifications for devices

The last four can be called "Bit Streams" while the upper thee are called "Message Streams" (Libicki, 1995). Unfortunately the top layer (application) contains subjects like FTP or X.400 implying that semantic IS standards are much higher in the stack than can be expressed. Rukanova (2005) uses Stamper's semiotic framework to define interoperability. This semiotic framework involves signs; organizations communicate in signs, and for signs to have a meaning they need to be interpreted at six different levels: physical, empirical, syntax, semantic, pragmatic, and in the social world. Based on this fundament a distinction is made by Stegwee & Rukanova (2003) between interworkability, interoperability and interchangeability (see table 3), while the fundament is also used to define the concept of inter-organizational interoperability as "the ability of two or more socio-technical systems to exchange information, to interpret the information that has been exchanged and to act upon it in an appropriate manner" (Rukanova, 2005). According to Gerst, Iversen and Jakobs (2009) the distinction between "e-business" and "infrastructure" is artificial, and they state that any assessment of the effect of standards on e-business has to take all the standard layers into account. Rukanova's definition takes this into account.

Type	Purpose	Technical	Human	Process
Interconnectivity	Enables two systems to communicate with each other	Communication standards, like TCP/IP or X.25	Communication systems like speech and writing	Providing for external inputs and outputs
Interchangeability	Enables two systems to exchange information	Data representation standards, like ASCII or HTML	Language systems like natural language and vocabularies	Displaying the same behavior in terms of input/ output
Interoperability	Enables two systems to operate together as one	Interaction standards like SMTP or SOAP	Behavioral scenarios and procedures, attached to e.g. military orders	Providing for external controls on process behavior

Table 3 - Interconnectivity, Interchangeability & Interoperability (Stegwee & Rukanova, 2003).

Kosanke shows that it gets complicated when these terms are also used in an IEC study, albeit differently. Kosanke describes the levels from IEC TC 65/290/DC, with increasing compatibility (Kosanke, 2006):

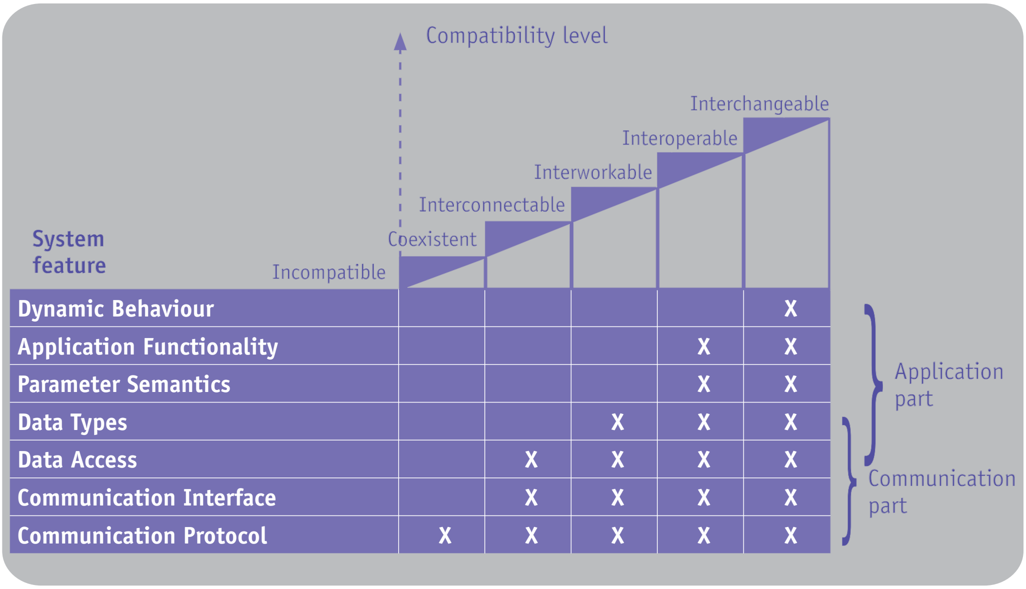


Figure 5 - IEC 65/290/DC compatibility levels (Kosanke, 2006).

The three most interesting top level definitions (from IEC) for the three terms are (Kosanke, 2006):

1. Interworkability: ability of two or more devices to support transfer of device parameters;
2. Interoperability: ability of two or more devices to work together in one or more applications;
3. Interchangeability: ability of two or more devices to replace each other in working together in one or more application.

And Kosanke maps both models on each other that shows, interestingly, that both have a complete different opinion about the definition of interchangeability (Kosanke, 2006):

IEC TC 65/290/DC) [10]	Stegwee and Rukanova [11]
	interconnectivity
interworkability	interchangeability
interoperability	interoperability
interchangeability	

Table 4 – The mapping of categories (Kosanke, 2006).

We stick to the term inter-organizational *interoperability* which is a contrast to other terms like interchangeability and commonly grounded. We use inter-organizational to stress the automated communications between organizations (Rukanova, 2005), in line with a distinction based on the organization perspective (Benders, Batenburg, & Van Der Blonk, 2006):

1. Intra-organizational standardization
   Common reporting routines for example. However, in practice standardization often occurs at a system level (e.g. SAP for everything).

2. Inter-organizational homogenization
   "Homogenization between organizations is considerably more complex than the explicit motive of achieving common working procedures within an organization" (Benders et al., 2006).

Inter-organizational interoperability refers also to the often used term Inter-Organizational (Information) System (IOS), for example used by (Lu, Huang, & Heng, 2006; Rukanova, Wigand, & Tan, 2009). IOS is defined as an automated information system shared by two or more companies (Cash Jr & Konsynski, 1985). Johnston & Vitale (1988) add: "to facilitate the creation, storage, transformation and transmission of information".

Johnston and Vitale (1988) made the distinction in the IOS between content platform, delivery platform and trading partner base, and categorize different types of IOS based on:

- Business purpose
- Relationship between the sponsoring organization and the other participants
- Information function

The value of an IOS is expressed in the following quote (Lu et al., 2006): "The strategic value of IOS has been well recognized for its realtime interaction, higher transaction security, more efficient and quicker payments, rapid response, reduced search costs, reduction in inventory and tighter link to customers. These benefits enable all parties to have high operational efficiency and capability, and more and more corporations tend to adopt IOS in order to gain competitive advantages." The above definition of IOS encompasses many systems such as extranets, EDI, Internet EDI, B2B e-commerce and e-SCM.

Zhu, Kraemer, Gurbaxani, and Xu (2006) also use IOS, and make a distinction with EDI through the use of the term Internet-based IOS:

Internet-based IOS is characterized as being, on the content side: based on open XML based standards, low complexitity and not that partner-specific; while on the delivery side: based on open internet communication protocols, highly interoperable and low communication costs. It also has a broad trading partner scope. Based on these characteristics, this can also be called an open standards IOS.

In summary, IOS is a broad term including concepts like data integration, but it differs from normal internal distributed systems by its ability to exchange information with the outside world (Johnston & Vitale, 1988).

Inter-organizational relationships discriminate themselves by having the following characteristics (Löwer, 2005):

- Goal: Efficiency
- Direction: Vertical
- Resources: Coordinated
- Contract: Neo-classical
- Activities: Primary
- Formalization: High

Löwer (2005) sums up the different terms used for inter-organizational standards which to a large extent are synonyms: “Inter-organizational System Standards and Process Innovations”, “Open E-Business Standards”, “Standards for Domain-Specific Interoperability”, “Vertical Industry Languages”, “Vertical IS Standards”, “XML-Based E-Business Frameworks” and “XML-based E-Business Standards”.

3.2 Framework for interoperability

Interoperability is seen as an extremely important topic for an organizations IT strategy and it is on the top of every CIO’s wish list (Park & Ram, 2004), which might explain the abundance of interoperability frameworks.

Architecture frameworks are often used in IT, like for instance the Zachman Framework (Zachman, 1997), and these frameworks can also be used to look at interoperability. There are also dedicated interoperability frameworks as, for example, LISI (Kasunic & Anderson, 2004) from the American Department of Defence and the Athena framework (Berre et al., 2007) developed within a European Union funded project.

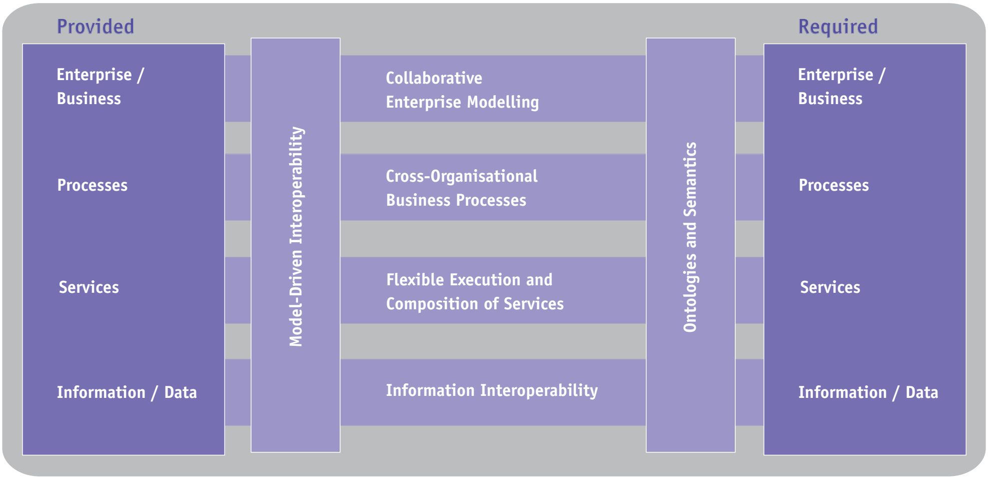


Figure 6 - The Athena Interoperability Framework (Berre et al., 2007).

Based on the work of Athena, a framework for Enterprise Interoperability has been developed, which is in the progress of becoming an CEN/ISO standard 11354-1 (Naudet, Latour, Guedria, & Chen, 2010).

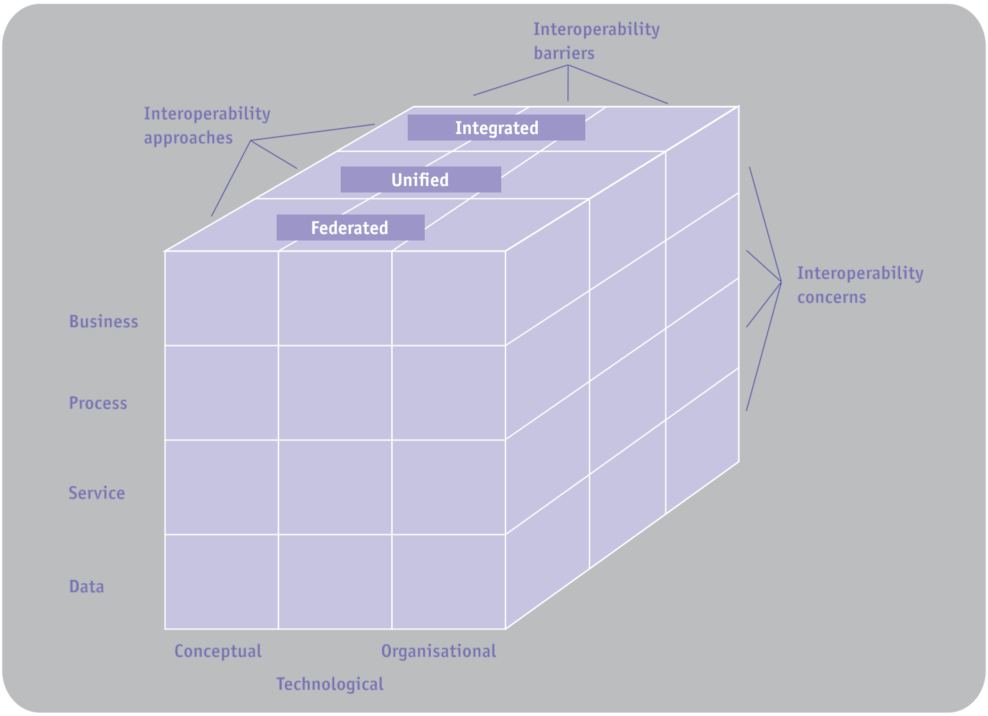


Figure 7 – Framework for Enterprise Interoperability (draft CEN/ISO 11354-1) (Dogac, Pattenden, & Zelm, 2010).

The *interoperability approach* is the desired level of integration; these levels are standardised in ISO 14258 (Kosanke, 2006). An *interoperability barrier* viewpoint has been identified to capture the incompatibilities and mismatches that obstruct the sharing and exchanging of information and other entities. Three categories of barriers are defined: conceptual, technological and organizational. *Interoperability concerns* defines the content of interoperation that may take place at various levels of the enterprise (data, service, process, business) (Ullberg, Chen, & Johnson, 2009).

The FInES report sums up several interoperability frameworks (Dogac et al., 2010), including the CEN/ISO 11354 framework as presented:

Organisation	Name/Description
ISO 15745	Framework for Application Intergration
CEN/ISO 11354	Requirements for establishing manufacturing enterprise process interoperability
ATHENA FP6 IP	BIF: Business Interoperability Framework[43]
CEN-ISSS EBIF	CEN eBusiness Interoperability Roadmap
UN/CEFACT	UN/CEFACT e-Business framework
OMG	Service Driven Architecture
iDABC	European Interoperability Framework for Pan-European eGovernment Services

Table 5 – Interoperability Frameworks (Dogac et al., 2010).

Interoperability Maturity Model

A maturity model exists for the measurement of the level of enterprise interoperability and it is similar to the CMMi model for software engineering. The LISI interoperability maturity model was set up in 1993, and it is also made up of five levels (Kasunic & Anderson, 2004), with a technical focus. LISI is much more than 5 interoperability levels. It contains several models, and an assessment process containing interoperability metrics. It contains a questionnaire for the identification of the appropriate interoperability level (Tolk, 2003) and an interoperability scorecard including quality attributes associated with interoperability (Kasunic & Anderson, 2004). These attribute measures are: connectivity, capacity, system overload, underutilization, undercapacity, data latency and information interpretation and utilization, showing the technical emphasis.

However development has begun for an Enterprise Interoperability Maturity Model (EIMM) that builds upon the framework of enterprise interoperability (ISO 11354-1) as presented earlier. The EIMM (Berre et al., 2007; Knothe & Jochem, 2007) or MMEI (Maturity Model for Enterprise Interoperability) (Guedria, Chen, & Naudet, 2009) as it is known nowadays, contains 5 levels: unprepared (level 0), defined (level 1), aligned (level 2), organized (level

3) and adapted (level 4), and it includes metrics as well. Since the model is fairly new, usage is limited, but this might change when this model is given an ISO (11354-2) status.

Interoperability & standards

It is generally accepted that standards are needed to achieve interoperability: “Setting and adopting a common standard for B2B transactions, therefore, is a natural step to enhance compatibility or interoperability among companies, generating great value for individual firms and the industry overall” (Zhao et al., 2007). But although it seems common sense, there is little evidence for that (Wybo & Goodhue, 1995).

Although many standardization literature describe standardization challenges or problems (for instance the adoption problem), real critical studies are scarce. One empirical study (Wybo & Goodhue, 1995) does not show the theoretical expected interdependence with the level of usage of semantic IS standards. One possible explanation is that data standards are not the only solution, e.g. some simple semantic inconsistencies might be easy to solve by mapping or transformation. Or the problems caused by semantically inconsistent data are smaller than presumed (Wybo & Goodhue, 1995). Thus, a semantic IS standard may not be the optimal solution (too complex/expensive) for a simple interoperability goal.

From the EDI time span, Steel (1994) proposes to standardize only the meta structure of the message exchange, because there are several problems to EDI standardisation resulting in a myriad of implementations causing lack of interoperability. He mentions as problem that the standardization process takes too long and involves multiple standardization organizations. Also, updates of standards multiply the number of standards in use, just as by having local industry working groups that write implementation guides how to interpret the standard. Standards need to accommodate too wide ranges of business processes, and finally he also questions if the standardization solution is able to accommodate the demands in the new dynamic business world of ad-hoc business deals (Steel, 1994).

Other solutions might be found in the area of data fusion and information integration: a topic on which a lot of time is spent within large enterprises. Integration activities cover any form of information re-use, such as moving data from one application’s database to another’s, translating a message for business to business e-commerce, and providing access to structured data and documents via a web portal (Bernstein & Haas, 2008).

A framework for interoperability containing different kinds of standards is presented by Jian and Zhao (2003). The figures contain the framework and are filled in with exemplary standards.

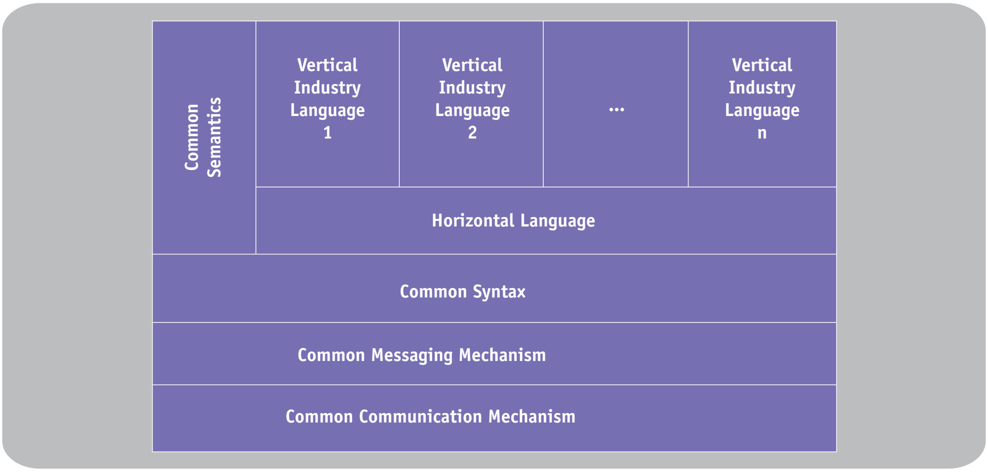


Figure 8 – Framework for interoperability standards (Jian & Zhao, 2003).

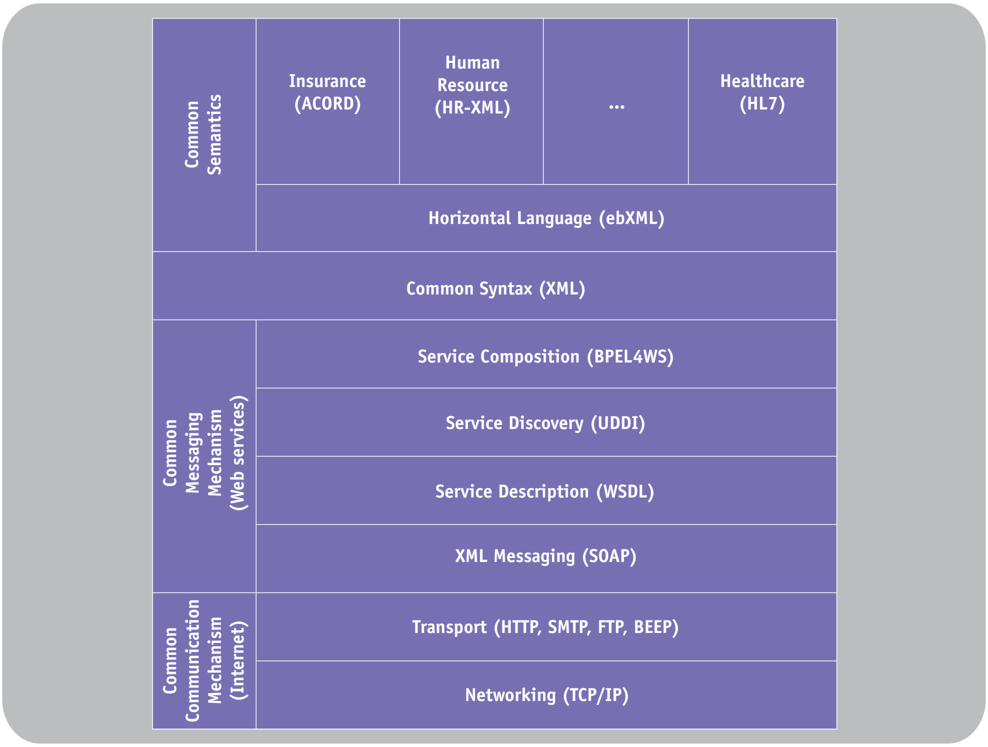


Figure 9 – Framework for interoperability including standards (Jian & Zhao, 2003).

This research is focused on the common semantics: what we call Semantic IS standards.

Other interoperability approaches

Previous sections have shown several frameworks for interoperability, but there are more. This section will mention several others shortly. Another interoperability framework (Elvesæter, Hahn, Berre, & Neple, 2006) proposes a distinction between:

1. Conceptual integration: which focuses on concepts, metamodels, languages and model relationships to systemise software model interoperability
2. Technical integration: which focuses on software development and execution environments
3. Applicative integration: which focuses on methodologies, standards and domain models. It provides us with guidelines, principles and patterns that can be used to solve software interoperability issues.

Curtis Royester (DoD/DISA/Center of Standards) developed the Five Cs of interoperability (Wagner et al., 1995):

- Conversation (User)
- Conversion (Data)
- Comprehension (Application Services)
- Communication (Infrastructure Services)
- Connection (Operating Systems/Platforms)

Esper, Sliman, Badr and Biennier (2008) define three interoperability constraints:

- Organizational Interoperability: means that enterprises must share the same goal and have compatible management strategies.
- Industrial Interoperability: means that enterprises must share information regarding products and production processes such as the process maturity level and the required real time of execution.
- Technical Interoperability: means that the different applications of the information system can exchange information.

Tolk, Turnitsa, Diallo and Winters (2006) define seven interoperability layers:

- Level 0: No Interoperability
- Level 1: Technical interoperability
- Level 2: Syntactic interoperability
- Level 3: Semantic interoperability
- Level 4: Pragmatic interoperability
- Level 5: Dynamic interoperability
- Level 6: Conceptual interoperability

Or even a specific model for coalition interoperability (defence), ranging from organizational interoperability (top layers) to technical interoperability (lower layers) (Tolk, 2003):

- Political objectives
- Harmonized Strategy/Doctrines
- Aligned Operations
- Aligned Procedures
- Knowledge/Awareness
- Information interoperability
- Data/Object Model interoperability
- Protocol interoperability
- Physical interoperability

3.3 The impact of interoperability

Very few publications address the impact of interoperability (Legner & Lebreton, 2007).

Probably the first and most used is the US automotive case, suggesting that imperfect interoperability costs the US automotive industry about $1 billion per year and delays the introduction of new models by at least two months. (Brunnermeier & Martin, 2002)

This study separates costs into:

- Avoidance costs (e.g. Investments to avoid future costs.)
- Mitigation costs (e.g. Additional coordination costs.)
- Delay costs (e.g. Loss of marketshare because of late entry.)

Another study within the capital facilities industries contains a conservative estimate of $15.8 billion on inadequate interoperability costs (Gallaher, O'Connor, Dettbarn Jr., & Gilday, 2004). The case of the electro technical industry (Nelson, Shoonmaker, Shaw, Shen, & Wang, 2002) does not quantify, but shows a return on investment of less then 2 years (both sides), a reduction of transaction costs and cycle time. Based on the work within the European Framework project Athena, an interoperability costs breakdown is presented (Legner & Lebreton, 2007):

- Connectivity costs (per partner): Costs to establish or improve partner relations.
- Coordination costs (per transaction): Costs to enable and execute transactions.
- Control costs (per transaction): Costs to monitor transactions.

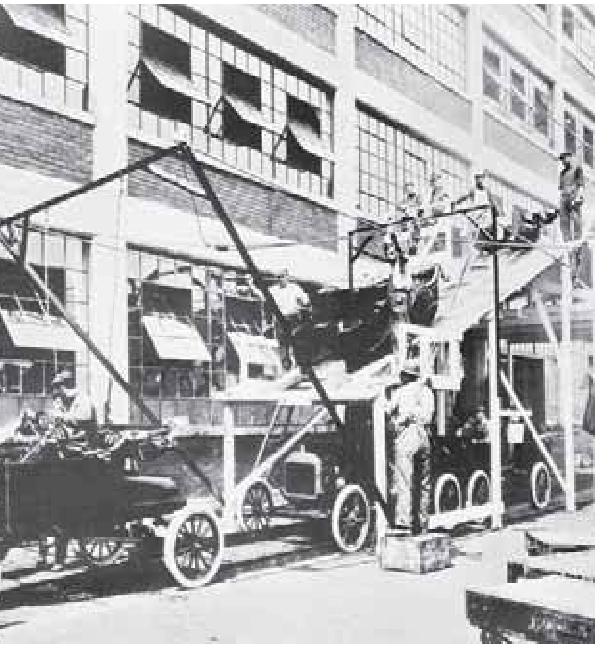
This work has led to the Interoperability Impact Assessment Model (IIAM) which shows the direct and strategic impact of investments in interoperability (Lebreton & Legner, 2007).

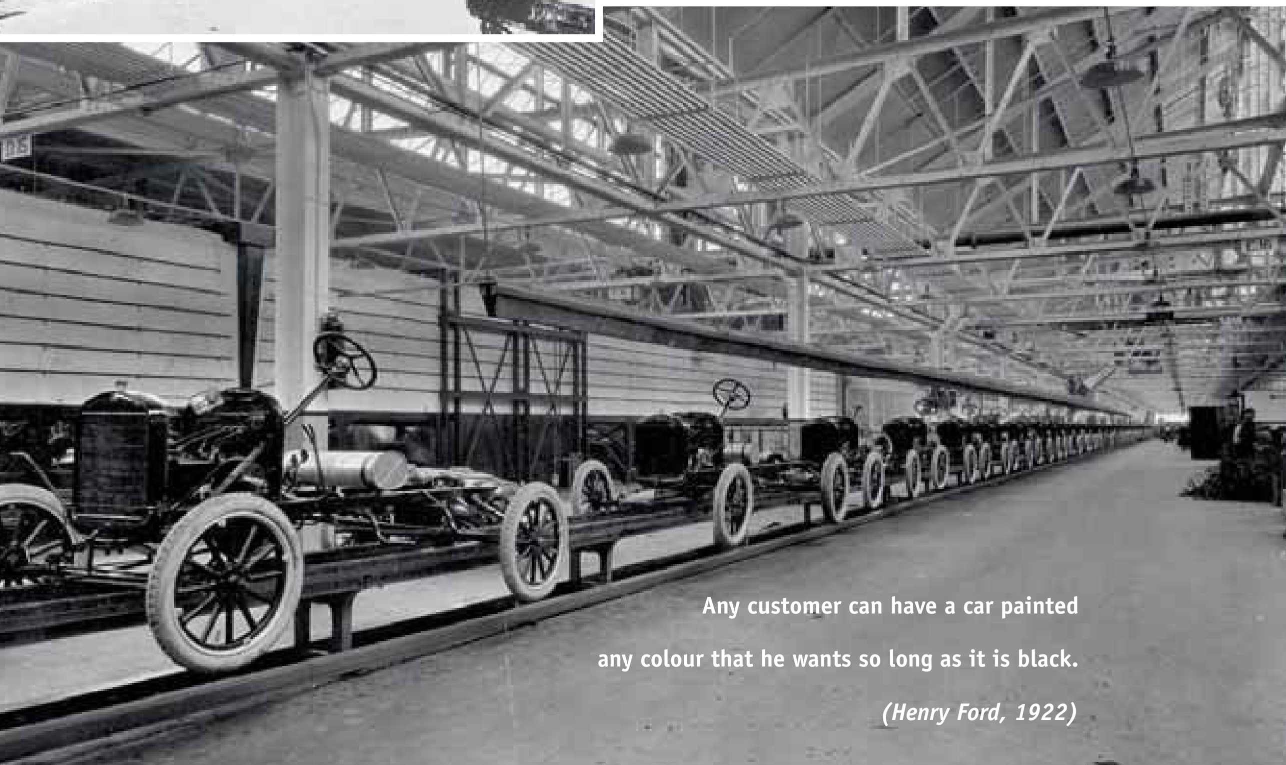
The healthcare domain also demonstrates the importance of interoperability and standardization to society. Venkatram, Bala, Venkatesh and Bates (2008) highlighted the relevance by citing reports from the Institute of Medicine about the errors in healthcare.

The figures are impressive: 98,000 people die in hospitals due to errors (1999), and these errors costs hospitals $29 billion every year, while three out of four errors can be eliminated by better use of information technology. The lack of standardization and integration among the systems has made it difficult to reduce the medical errors. Lack of integration and data standardization is making health care services inefficient and costly (Venkatraman et al., 2008).

The Economics of Standards

CHAPTER FOUR





Any customer can have a car painted

any colour that he wants so long as it is black.

(Henry Ford, 1922)

This chapter will discuss the main economic theories relevant to standardization, the acclaimed impact of standards, and will conclude with current dilemma's in standardization landscape.

4.1 Main theories

It is widely acclaimed that innovation related to standards is a primary driver of industrial productivity (David & Greenstein, 1990; Zhu et al., 2006). Starting in the eighties this topic has been studied extensively (David & Greenstein, 1990) and focuses on two particular economic phenomena (Blind, 2004):

1. Network effects (or network externalities), with important contributions from (Farrell & Saloner, 1985; Farrell & Saloner, 1986b; Katz & Shapiro, 1985, 1986).
2. Switching costs (Farrell & Shapiro, 1988).

Network effects:

In general Katz & Shapiro (1985) define network effects as the utility that a user derives from consumption of the good increases with the number of other agents consuming the good.

Standards network effects have been described as a positive correlation between the number of users of a standard and its utility (Von Westarp, Weitzel, Buxmann, & Köning, 2000; Weitzel, Wendt, Beimborn, & Köning, 2006).

A distinction is made by Katz & Shapiro between direct and indirect network effects. Direct network effects describe the physical effects which the number of users has upon the utility of the standard. For instance, using a particular EDI standard becomes more valuable when more business partners use that standard. Indirect network effects arise from interdependencies in the consumption of complementary goods. Meaning that the widespread use of a standard can be expected to lead to an increased supply of complementary products, like software and consulting services surrounding a new technology (Von Westarp et al., 2000).

Katz & Shapiro examined two key questions: (a) whether compatibility is socially desirable and (b) whether the private incentives for compatibility are consistent with the social incentive (Park, 2006). Farrell & Saloner studied adoption timing of new over old technology with network effects taken into account. It shows that when information is not complete, inefficient adoption can occur, which is hard to repair (Farrell & Saloner, 1985).

Switching costs:

Transaction costs occur when finding and establishing a relationship with a supplier takes place.

When a buyer changes supplier, these relation-specific assets create the concept of switching costs (Farrell & Shapiro, 1988). When the sum of these switching costs becomes too high, "lock-in" occurs (Farrell as cited by Egyedi, 2009; Egyedi & Blind, 2008).

In the information economy, lock-in is the norm, caused by the use of specific systems (Shapiro & Varian, 1999b). Several studies describe the switching costs concept (e.g. (Pham, 2007)), but in comparison with network effects the more elaborate studies like the ones by Chen and Forman, 2006; Farrell and Shapiro, 1988; Shapiro and Varian, 1999b on switching costs are more scarce.

4.2 Benefits of standardization

The impact of standards can be generic (e.g. enabling communication), within the company (e.g. not re-inventing the wheel), or outside the company (e.g. demonstrate product quality) (De Vries, 2007). In short, the following economic effects of standards are well known (Hesser, Czaya, & Riemer, 2007):

- Reducing transaction costs
- Gaining economies of scale
- Reducing external effects
- Influencing market constitution

On the other hand, economics differ for different kinds of standards. Weitzel, Beimborn and König (2006), amongst others, distinguishes sponsored (with vendor/government interests resulting in proprietary or dejure standards) and unsponsored (user interest, defacto) standards. From an economic perspective, sponsored standardization processes differ sharply from unsponsored processes (David & Greenstein, 1990). Voluntary standards-writing organizations are of analytic interest because they widen the number of strategic options for firms to influence standards. Because of this complexity there is little theoretical research available (David & Greenstein, 1990).

A more sophisticated summary of general effects related to four different kind of standard's goals is presented by Swann (2000) and adapted by Blind (2004). Semantic IS standards can be seen as both compatibility and information standards.

	Positive effects	Negative effects
Compatability / interface	• Network externalities • Avoiding Lock-ins • Increased variety of systems products	• Monopoly
Minimum quality / safety	• Correction for adverse selection • Reduced transaction costs • Correction for negative externalities	• Regulatory capture 'Raising rival's costs'
Variety reduction	• Economies of scale • Building focus and critical mass	• Reduced choice • Market concentration
Information standards	• Facilitates trade • Reduced transaction costs	• Regulatory capture

Table 6 – Effects of standards (adapted from Blind, 2004).

In addition to the benefits, standards do also change the game as the following examples will show (Shapiro & Varian, 1999b):

- Expanded Network Externalities: Standards enhance interoperability, generating greater value for users by making the network larger.
- Reduced uncertainty: Standards reduce the technology risk faced by consumers
- Reduced Consumer lock-in: Consumers will not be worried about lock-in when it is an open standard. "Even mighty Microsoft has been forced to move towards open standards such as XML in order to reassure its clientele that they will be able to exchange data with other users."
- Competition for the Market versus Competition in the Market: Instead of competition for the market, companies compete within the market.
- Competition on Price versus Features: Since many features become "standard", competition is moved to the pricing.
- Competition to Offer Proprietary Extensions: Strong incentive to suppliers to differentiate.
- Component versus Systems Competition: No competition on complete audio/video system, but on components.

Swann (2010) gives an overview of the economic effects related to standardization (see figure 10).

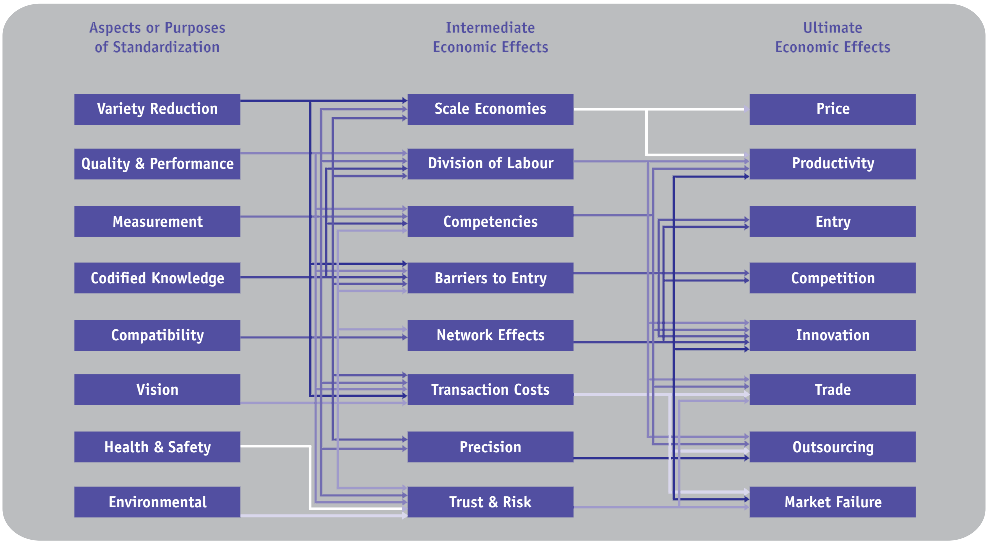


Figure 10 – Model of the economic effects of standardization (Swann, 2010).

Many studies have been performed on the quantifiable benefits of standardization and all show positive effects. An overview of 6 studies is given by Weissinger (2010). In order to be able to measure the impact of standardization ISO developed a methodology in 2009 (Weissinger, 2010).

4.3 Dilemma's in standardization

The following sections will discuss some dilemmas described in standardization literature.

The value of standards

The value of a standard to one user is dependent on others using it as well (Weitzel, Beimborn et al., 2006). Also, not all organizations benefit equally, and the benefits received depend on the implementation choices of business partners as well (Wigand, Steinfield et al., 2005). This leads to the well-known penguin effect of standardization:

> *"Penguins who must enter the water to find food often delay doing so because they fear the presence of a predator. Each would prefer some other penguin to test the water first" (Farrell & Saloner, 1986a; Weitzel, Beimborn et al., 2006).*

This is also where the bandwagon effect occurs: when a standard gains adherents and is being adopted, it becomes more attractive for others to climb aboard (David & Greenstein, 1990; Katz & Shapiro, 1986).

The asymmetry between individual and collective standardization gains is sometimes solved (internal organization) by communication, while others require an explicit redistribution of standardization costs and benefits. Consortia could provide institutional settings for binding agreements between agents (Weitzel, Beimborn et al., 2006).

The number of standards

It seems that the number of standards can hardly ever be appropriate. If standardization costs are too high we face the startup problem, but on the other hand if standardization costs are too low, we will face the inefficient multi-standard equilibrium (Weitzel, Beimborn et al., 2006).

Even selecting the most appropriate standard seems difficult: "Unfortunately, it is when the gain from standardization is largest, that the process, whether market or committee is most likely to make a mistake. The technological uncertainty makes it very difficult to tell which standard should be preferred" (Cowan, 1991).

Standards and flexibility

Network externalities hamper flexibility. When a standard is widely used the effort required to change it will increase (Hanseth, Monteiro, & Hatling, 1996). In this kind of situation one finds too much standardization inefficiency (Farrell & Saloner, 1986b). Standards do also enable flexibility by making decomposition and modularization possible (Hanseth et al., 1996).

4.4 Trends in literature

Two prominent, long ongoing trends are noticeable in economic related standardization literature:

1. Intellectual Property Rights
2. Standards Wars

Intellectual Property Rights (IPR)

Many standards include patents, especially if it has been described as a money maker (West, 2007). Standards including IPR seem in conflict with the principle of open standards, but even well known ISO standards might include patents. This is not without risk since a hold-up might occur when standard setting organizations include patented technology in their standards (Farrell, Hayes, Shapiro, & Sullivan, 2007). Patent hold-up can be extremely painful in industry consortia standardization.

"The economics of hold-up and opportunism provide a solid foundation for concerns about consumer welfare and economic efficiency when patent holders engage in deception or strategically postpone disclosure and assertion of their patents" (Farrell et al., 2007).

For semantic IS standards this is less of an issue, probably because IOS are mainly built on open standards (Zhu et al., 2006).

Standard Wars

Many markets face a strong trend toward standardization – the adoption of a common standard by all market participants.

This leads markets towards "winner-takes-it-all" outcomes where a single standard emerges victorious, while the others disappear. These battles are known as standards wars (Stango, 2004).

There are different kinds of wars. In the market, the choosing of an inefficient standard (e.g. the case of QWERTY keyboard layout (David, 1985)) which is locked in the old standard, leads to conflicts when a new standard appears (CD). There may also be conflicts between two or more standards (ODF/OOXML). In all cases, switching costs are extremely important for standards battles. Arguably the first standards war was between AC and DC for electricity grids (McNichol, 2006). There is an excessive presence of cases in literature, with both historical examples (e.g. Shapiro & Varian, 1999a) and recent examples (e.g. Chappert & Mione, 2009; Den Uijl & De Vries, 2009; Gauch, 2008; Van de Kaa, 2009), while the latest studies try to predict the outcome of standards wars (Van de Kaa, 2009). In many case studies, factor models are used e.g. Suarez (2003) or Frambach and Schillewaert (2002).

None of the case studies describe a semantic IS standards battle, which might be explained by the two modes of standardization (Cowan, 1991):

1. Market Exclusion: standardization takes place or it does not (e.g. other options will not be available anymore),
2. Joint modification.

The mode of market exclusion is prone to standards wars, because the winner takes it all (Stango, 2004). Standardization by market exclusion typically takes place early in the life cycle of a technology. In the joint modification mode there are degrees of standardization or compatibility exists because the driver is interconnected with multiple technical solutions (Cowan, 1991). The latter mode is often present in semantic IS standards. Fodor and Werthner (2004) makes a distinction between types of clashes, which is useful for the selection of the appropriate strategy to deal with the clash:

- Semantic clashes (conceptual clashes)
- Representational clashes (structural clashes)

Semantic IS standards are used to share data among firms, which rarely compete with each other directly through standards. This is in contrast to IT product standards that can be used as competitive weapons in the marketplace (Zhao et al., 2007).

Although battles in the world of semantic IS standards are scarce, some conceptual clashes will occur, often within the standardization process.

Semantic IS Standards

CHAPTER FIVE

5

On the semantics of language in a random telephone conversation

between a hotel receptionist and an angry customer:

“Don’t shout at me: I hear you, I hear you, but I don’t understand you!!”

The core research subject within this state-of-the-art is the semantic IS standard. This chapter will further define this concept and discuss examples of both horizontal and vertical standards, and will slightly touch the subject of technologies used for semantic IS standards.

5.1 What is a semantic IS standard?

As mentioned in chapter 2, we use the following definition of a semantic IS standard, which is quite similar to the definition of vertical IS (VIS) standards:

"Semantic IS standards are designed to promote communication and coordination among the organizations; these standards may address product identification, data definitions, business document layout, and/or business process sequences" (Adapted from Steinfield et al., 2007).

Three other appropriate descriptions of semantic IS standards are:

1. "Vertical information systems (VIS) standards are technical specifications designed to promote coordination among the organizations within (or across) vertical industry sectors" (Markus & Gelinas Jr., 2008).
2. "Trends are converging in new forms of cooperation among IT-using organizations, for example, the user-led development of voluntary, open, industry-specific interorganizational coordination standards, here called vertical information systems (VIS) standards" (Steinfield et al., 2007).
3. "Vertical IS standards prescribe data structures and definitions, document formats, and business processes for particular industries" (Wigand, Steinfield et al., 2005).

Standards are signs, words, phrases and symbols (Brzezinski, 2010b). This statement is used to discuss how the world of semiotics can be used as a donor for developing theories for the standardization world which currently lacks theories (Brzezinski, 2010b). One example for that is for instance Stamper's semiotic framework (as cited by Rukanova, 2005) which is also applicable in the standardization world, either to identify interoperability levels or to classify standards.

Semantics deal with the meaning of signs, symbols, words and phrases in the special sense of how these notifiers relate to reality, how they represent, designate and signify things (Rukanova, 2005). Problems related to semantic mismatch and misunderstanding are common, while some think they will vanish over time whilst others think they won't (Rebstock, 2009). If everyone were to use a single standard then semantic referencing would not be necessary, and although developments like core components are steps towards standards convergence, one universal standard would be an illusion. This means we have to cope with multiple e-business standards permanently, which will keep changing, resulting in a lasting situation of semantic variety, and will then be the source of mismatch and misunderstanding (Rebstock, 2009).

To be useful in real business, standards need semantic profiles that define restrictions for a specific context (e.g. specific domain, business processes, country, etc.) (Brutti, Cerminara, D'Agosta, Sabbata, & Gessa, 2010).

This is especially needed for horizontal semantic IS standards, but sometimes also for vertical ones. Otherwise, these standards have too much redundancy and uncertainty that limits interoperability in practice.

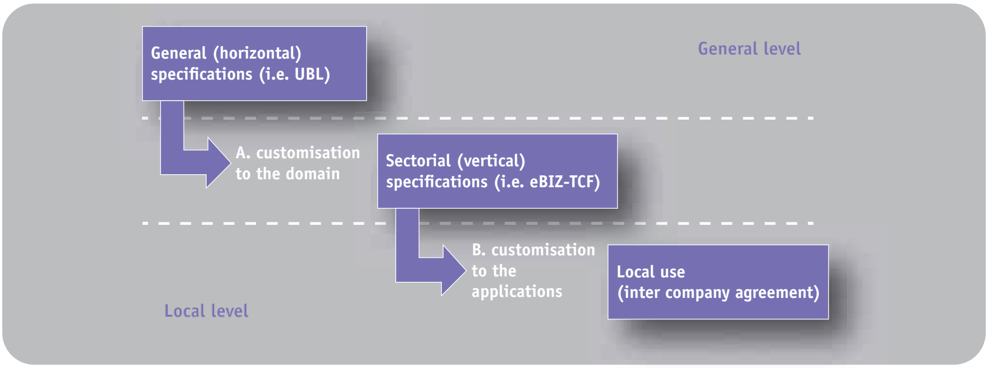


Figure 11 – The need for sectorial (vertical) standards (Brutti et al., 2010).

In the literature a distinction can be found between horizontal cross-sector semantic IS standards that define information and its meaning versus methods and languages that can be used to define semantics. The latter include XML, UML, OWL, BPEL, BPMN and so on. These are two different types of standards and will thus be treated separately.

XML is one of the languages that provides a basis for defining the semantics of a term. Many authors have underlined the need for aligning semantics (Legner & Lebreton, 2007). There have been many XML based semantic information system standards, already since the early 21st century; in august 2001 XML.org contained 105 different standards spanning 25 vertical and 7 horizontal industries, while "XML in Industry" contains 450 submissions spanning 54 vertical and 9 horizontal industries (Nelson et al., 2002).

In the remainder of this chapter, section 5.2 will deal with horizontal semantic IS standards and section 5.3 with vertical semantic IS standards. Section 5.4 will contain the lessons learnt for semantic IS standards based on documented case studies. Finally section 5.5 will end this chapter by introducing standard methods/languages to describe semantics.

5.2 Horizontal semantic IS standards

The use of the term vertical would imply that there are also horizontal standards. However, in the literature, a good definition of horizontal standards is hard to find. The main characteristic of horizontal semantic IS standards is that they can be used by various industries and sectors and is thus cross-sector oriented. Examples of horizontal, or cross-industry frameworks are for example cXML, OAGIS and xCBL (Nurmilaakso & Kotinurmi, 2004). Other important horizontal standards include UBL, GS1 XML and ebXML. The latter has specifically initiated the concept of core components, elements that can be used as the core and starting point of vertical semantic IS standards that make use of these core components (Folmer, Hinderer, & Otto, 2003; Van Blommestein, 2007). Since 2005 the ebXML Core Components Technical Specification (CCTS) has become an official ISO standard (ISO/TS 15000-5:2005).

A horizontal case study dealing with collaborative planning, forecasting, and replenishment (CPFR) based on a standards point of view (amongst others) is present in current literature (Markus & Gelinas Jr., 2008). The survey and analysis of horizontal standards (Kabak & Dogac, 2010) included EDI, UN/CEFACT CCL, UBL 2.0, OAGIS BOD 9.0 and GS1 XML and with the exception of EDI, they all use the CCTS in some (different) way. Other differences between these standards include the document artifacts, the use of code lists, the use of name spaces, and the naming and design rules used (Kabak & Dogac, 2010). Also important is the fact that there are major differenes in how these standards do accommodate customization and extensibility.

The horizontal OAGIS BODS are used in many vertical semantic IS standards, among others AiAG, ODETTE, STAR, AAIA (all automotive), but also in the human resources (HR-XML), chemical and aerospace industries (Kabak & Dogac, 2010).

5.3 Vertical semantic IS standards

With time many authors have included lists of semantic IS standards, including (Chari & Seshadri, 2004; Hasselbring, 2000; Lampathaki, Mouzakitis, Gionis, Charalabidis, & Askounis, 2009; Nelson, Shaw, & Qualls, 2005; Steinfield et al., 2007; Von Westarp et al., 2000). Since the list on xml.org has ceased, a new list is available on semanticstandards.org, containing nearly 100 standards and growing. Many of those are "industry specific" (vertical) for instance electronics (RosettaNet), chemicals (CIDX), Assurance (ACORD), petroleum (PIDX) (Steinfield et al., 2007). Others cover horizontals, like the semantics of product data. The following sections will describe some literature from specific vertical domains.

Health care

Interoperability in the health care is well documented (Dogac et al., 2008; Eichelberg, Aden, Riesmeier, Dogac, & Laleci, 2005; Mori & Consorti, 1998). Several standards are available, and an overview is given by Eichelberg et al. (2005). Introducing an Electronic Patient/ Health Record (EPR/EHR) is also seen as setting a standard (Hanseth et al., 2006), although it is a complex one and is not suitable for current standardization processes. With respect to standardization, the EPR/EHR is characterized by several problems (Sahay, Akhtar, & Fox, 2008):

- Most hospitals still use obsolete standards or protocols
- Healthcare standards are not stable
- IT or Healthcare professionals may diverge from the use of the meaning that is defined by various healthcare standards (e.g. HL7, CEN 13606, openEHR, etc.).
- Healthcare standards in XML solve the interoperability problem at syntactical level, but domain specific solutions are required to achieve semantic interoperability.

There are several competing standards approaches available which have been compared and show that achieving interoperability in the EPR/EHR domain has a long way to go (Blobel & Pharow, 2009).

Education

There are many e-learning standards, in line with the Tanenbaum quote, for which overviews are available (Friesen, 2005; Hoel, Hollins, & Pawlowski, 2010). The IMS Global Learning Consortium Inc. (IMS) develops and promotes open specifications for facilitating online distributed learning activities (Friesen, 2005), but also ADL, IEEE, ISO, and other communities release standards for the e-learning domain. Often used standards are IEEE Learning Object Metadata (LOM), for the discovery of learning objects based on metadata. IMS Learning Design is a meta-language which can be used to model learning processes. ADL (Advanced Distributed Learning) SCORM (Sharable Content Object Reference Model) deals with real-time communication within the learning environment and deals also with the packaging of the learning material. SCORM aims at reusability, interoperability, durability and accessibility, and SCORM can be used in conjunction with LOM (Gonzalez-Barbone & Llamas-Nistal, 2007).

Tourism

In the worlds largest industry, tourism, many standardization efforts have failed because of their lack of flexibility (Fodor & Werthner, 2004). Given the heterogeneity of the market because of the web, the specific history of standards in the tourism domain, and the lack of a central authority that can impose such a standard, it seems unlikely that one global, all-embracing standard will be achieved. Instead, different standards for different market segments will co-exist (Fodor & Werthner, 2004).

Building and construction

In the building and construction sector, a couple of XML based standards have been developed, such as bcXML and IFC (ISO 12006-3 and eCognos) (Barresi, Rezgui, Lima, & Meziane, 2008). The EDI based standardization in the Dutch Building industry was used as a case study by Thissen and Stam (1992). The main lessons learnt include:

- EDI *among* organizations is receiving increasing attention in the business community. The emphasis is on electronic communication of business transactions in a standard format. It initially concentrated on technical protocols rather than on the content. Attention has shifted since the nineties towards higher-level layers of the OSI stack.
- Critical success factors for inter-organizational systems are:
    - Awareness of the strategic, long-range benefits;
    - High-level management support;
    - Support of industry leaders and/or the government
    - Strong participation and membership in industry-wide organizations (needed for standardization).
- Standardization strategy was a lower-level result of the central issue of improving industry competiveness!

Automotive

The main standardisation initiative in the automotive sector is taken by STAR (Standards in Automotive Retail) in which the AIAG (Automotive Industry Action Group) is participating (Anicic, Ivezic, & Jones, 2006; Brunnermeier & Martin, 2002). The development of the Internet hub Covisint has been described by (Gerst et al., 2005).

5.4 Lessons learnt from case studies

The literature on semantic IS standards is often related to case studies regarding the adoption of the standard. For example, the adoption of STEP (Thomas, Probets, Dawson, & King, 2008), MISMO (Markus, Steinfield, Wigand, & Minton, 2006) and RosettaNet (Boh, Soh, & Yeo, 2007). This section deals with specific lessons learnt from case studies within the semantic IS standards domain. The more general issues around development, adoption and maintenance of semantic IS standards are captured in chapter 6 on development and adoption.

Based on a case study, Steinfield et al. (2007) identify the following maintenance characteristics and issues that are specific for semantic IS standards:

- Ongoing maintenance, since the user requirements of the vertical sector can change often in order to react to a flexible environment.
- An impertinent organization may not be adequate and a more formal institutional structure is needed for structure and the removal of uncertainty: Create a permanent organization
- Early steps for legal challenges (IPR)
- Show how the standards can evolve as newer technology arrives.

With respect to adoption, implementation of ERP can be seen as a standardization of processes (intra-organizational interoperability). Many implementation related issues from ERP will be useful for standards as well. Benders et al. (2006) mention:

1. Best practice (competitors will use the same best practices, and catch up quickly)
2. Risks of non-conformance (ERP system does not fit)
3. Power position of individuals
4. Costs
5. Implementation methodologies (SAP: ASAP, Oracle: FastTrack, Baan: DEM)

In comparison with standards, the first four are well known, although the power position of individuals is lacking attention. However, implementation methodologies are new to the standardization arena: Implementation methodologies offered for standards are very hard to find.

Another interesting case study is the adoption of RosettaNet which is well documented in (Boh et al., 2007; Chong & Ooi, 2008). Rosetta has one of the biggest organizational memberships among supply chain standards consortia (Nelson et al., 2005; and cited by Boh et al., 2007). The case study of RosettaNet in China is described by (Lu et al., 2006). Within the context of Malaysia the adoption factors trust, partner's power and product characteristics have influenced the adoption of RosettaNet positively, while the Malaysian Government's policy (financial incentives) seems not to have contributed (Chong & Ooi, 2008).

Lessons learnt in the building and construction sector show that a plan of action for standardization must include a strategy for promotion, development, implementation and maintenance of vertical standards (Thissen & Stam, 1992).

Several strategies have been introduced; including the do nothing approach (standardization will occur eventually). The other strategies fall into three categories (Thissen & Stam, 1992):

1. Stimulation of user consciousness of the need for standardization
2. The introduction or use of power-related mechanisms as vehicles for speeding up the willingness for change and innovation, including standardization.
3. Coordinated theoretical development of standards, including the creation of a special organization to accomplish it.

Last but not least, successful consortia are able to manage three main results (Boh et al., 2007):

- Promote a focus on solving real-world business problems.
- Move the standard-setting process along quickly without negatively affecting the quality of the standards, and
- Ensure open sharing of valuable knowledge across a range of stakeholders.

Main conclusions on semantic IS standards

Semantic IS standardization differs from IT product standardization. It is dangerous to generalize the research outcome to both groups. One of the differences for instance is the concept of standards war. In product IT standardization this is a common phenomenon where various small groups can arise that want to standardize a certain IT product in their specific way. Within semantic IS standardization, this is not likely because a semantic IS standard needs the support of all stakeholders. Semantic IS standardization is characterized by the heterogeneity of interests among participating user organizations.

Markus et al. (2006) state that standardization is very challenging and sets four main propositions on semantic IS standards, which are in detail described in section 6.2. This paper ends by asking several questions for further research. Amongst others, these are (Markus et al., 2006):

1. The relation between VIS standards initiatives: To what extent are they borrowing from each other or proceeding independently? And thus trying to invent the wheel again?
2. What problems, if any, are created by the many industry-specific initiatives currently underway when it comes to cross-industry interconnection, and how can those problems be solved?
3. Differences between VIS standardization and other standardization research. VIS is developed by many different organizations. Does this division of labour lead to a decrease or an increase of standards diffusion?

The first question relates to the trend of a changing standardization world, which will be described in paragraph 7.2. The second question will become more important in the next few years, when vertical based standards become more and more adopted resulting in achieved interoperability within the vertical domain, and challenges in cross-sector interoperability. The first conflicts have been reported in literature, for instance competences that have been standardized within different domains (e.g. HR-domain and Education domain) leading to conflicting standards and the need for models to deal with it (Grant & Young, 2010). The topic of standards adoption, which relates to the above question three, will be addressed in chapter 6.

5.5 Languages and semantic approaches

Besides specific horizontal and vertical semantic IS standards, there are also standards that can be used to describe (part of) the semantics that have to be defined by the standard. These include XML, UML, OWL, BPEL, BPMN and other similar types of standards.

The open standard based IOS uses semantic IS standards based on XML technology. The XML (eXtensible Markup Language) 1.0 specification was introduced in 1998 by the World Wide Web Consortium (W3C) and was designed to improve the functionality of the internet by providing flexible information structuring (Nurmilaakso & Kotinurmi, 2004). An XML document can be validated against an XML schema (XSD) that is included or referenced from the XML document. XML Schema Definition Language is an XML language for describing the valid structure of XML documents (Nurmilaakso & Kotinurmi, 2004). Alternatives for XML Schema are DTD (Document Type Definition), Schematron and RelaxNG. XML documents can be transformed by using another important XML standard called XSLT: eXtensible Stylesheet Language Transformations (Nurmilaakso, Kotinurmi, & Laesvuori, 2006).

Semantic Web technologies offer possibilities to express knowledge about the objects on the web. Standards in this area are RDF (Resource Description Framework), RDFS (Resource Description Framework Schema) and OWL (Web Ontology Language). Other core technology is UN/CEFACT CCTS (Core Components Technical Specification; ISO 150000-5) which presents a methodology for developing a common set of semantic building blocks that represent the general types of business data in use today and makes a provision for the creation of new business vocabularies and the restructuring of existing ones (Lampathaki et al., 2009). As described in section 5.2, the CCTS is implemented in many horizontal standards like UBL 2.0 and OAGIS (Kabak & Dogac, 2010), and some verticals mainly the ones that build upon OAGIS.

Ontologies can also help by relating different semantic IS standards. For instance OWL is used to create an upper ontology of the CCTS specifications, to which different semantic (horizontal) standards can be linked like UBL 2.0, GS1 XML and OAGIS 9.1 (Dogac et al., 2010). If they do work, interoperability can be achieved among organizations that are using different standards.

Finally, the Web Services standards (SOAP, WSDL and UDDI) are used to create services based on XML. SOAP (Simple Object Access Protocol) defines the message, while WSDL (Web Services Description Language) defines the service itself. UDDI (Universal Description, Discovery and Integration) is used to search for trading partners. While on the one hand Web Services are dependent on standards (Kreger, 2003), on the other hand these standards are the fundament for the development of IOS and semantic IS standards.

Semantic IS Standards: Development and Adoption

CHAPTER SIX

6

It is very easy to create a bad standard and rather difficult to create a good one. Even minor and quite innocent design flaws have a tendency to get magnified out of all proportion because standards are provided once, but are called many times

(adapted from Michi Henning, 2009)

This chapter deals with the literature and current state-of-the-art with respect to development and adoption of semantic IS standards. According to Zhao et al. (2007) development and adoption are interrelated since choices in development phases will influence adoption. Zhao defines a three-stage model of consortium based e-business standardization, simulating firms' strategic decisions:

1. First stage: Consortium Participation
2. Second stage: Standard Development
3. Third stage: Standard Adoption

In addition, Zhao et al. (2007) notices that developers are adopters and most probably the early adopters. Moreover, the members' contribution is critical to the sustainability and success of a standards consortium and thus of the adoption of the standard. There are three ways to improve firms' involvement, as they will only contribute if the expected payoff is higher than otherwise:

1. Increase awareness of the potential benefits.
2. Improving inside benefits: Membership benefits like voting rights.
3. Reduce development costs.

Of note is the use of the wording of diffusion and adoption. Diffusion & adoption are slightly different concepts: Whereas adoption is normally used as the stage in which the standard is selected by an organization, diffusion is used to spread the standard for application. Adopted does not necessarily mean implemented: An organization may have chosen to adopt the standard but decided to wait with the implementation of (some of it's) products or services. Here, we use the words adoption and diffusion as synonyms.

The activities of consortia fall broadly into two categories: development and diffusion (Boh et al., 2007). These categories will be described in the following sections.

6.1 Development

The state-of-the-art literature on the development of semantic IS standards is mainly concerned with the reasons for joining a standardization development trajectory. Zhao et al. (2007) present various reasons for being involved in development. One reason is to contribute and to orient the standard towards one's own business practices.

The better the standard and the faster it is developed, the greater is the direct benefit for the developers. By being involved in the development of the standards, there is an increase in the understanding of the standard details which helps to reduce future implementation costs. (Zhao et al., 2007)

In addition to the work of Zhao et al. (2007), Boh et al. (2007) describe the paradox of participation in standards development. The greater the number of stakeholders, the more difficult it is to achieve consensus. It will slow down the process. On the other hand, involved stakeholders will be early adaptors. There are various practical cases that show the different factors that play a role in the success of standard development.

One of these examples is Rosettanet. The Rosettanet standards-setting process is not really open, and this might be one of the success factors (Boh et al., 2007). The strategies that have been used for standards development in RosettaNet are:

- Commitment of resources to the milestone program.
- Clear roles and restrictions.
- Validation beyond full implementation.
- Informal norms and social networks.

Boh et al. (2007) also discuss the adoption case of RosettaNet and derives some lessons learnt on the development process:

- Only involve the organizations that are committed to solving the problem.
- Focused, quick, problem solving approach to standard setting.
- There is no one right approach for the standards development process, not even a full open approach.

Another case that describes a certain success factor for standard development is the MISMO case (Markus et al., 2006). Markus et al. state that to successfully develop a vertical standard that meets the business needs for interoperability it is necessary to ensure participation of representative members of heterogeneous user groups, and avoid the natural tendency to splinter into rival homogeneous groups. Thus, the challenge is to involve all stakeholder groups (and thus not all individual stakeholders) and to make sure they do not drift apart during standardization.

Thus, semantic IS standardization must find a way to ensure the collective participation of representative members of heterogeneous user groups (including IT vendors).

Another example of an open development process is the process of ebXML that has been studied by (Choi, Raghu, & Vinze, 2004) and has led to the following propositions (adapted from Choi et al., 2004):

1. An open standardization process helps collaborators to create a functionally comprehensive standard and it is not a "closed" standardization effort.
2. An open standardization process promotes the convergence of technologies in the long run, paving the way to its domination over "proprietary" standards.
3. User participation is a moderating factor in an open standardization process for achieving a comprehensive and converged standard.
4. Interoperability, backward compatibility, feasibility and sponsor support (both SSO and technology providers) are critical factors that influence the creation of standards.

To achieve legitimacy in standardization some suggestions are made for the development process (adapted from Werle & Iversen, 2006):

- Openness to and direct representation (participation) of all actors interested in or potentially affected by a standard.
- Work in accordance to impartial and fair procedural rules.
- Decision-making should be based on concensus and an open inclusive discourse, to the benefit of all standards addressees.
- All interests are considered (but not directly represented) in the standardization process.

In addition to the involvement of stakeholders and the development process itself, a building industry case also gives some insight into the question of "what to standardize" (Thissen & Stam, 1992). The building industry case shows that it is important to choose a focus of standardization based on:

- Maximum benefits from standardization and expanded use of information technology may be expected;
- Visible results may be achieved in the short term, and where a need is felt by the industry itself;
- A certain degree of formalization and structuring of activities has already occurred.

ISO 10303, the Standard for the Exchange of Product Model Data (STEP),has been adopted worldwide and is often used in literature (Brunnermeier & Martin, 2002; Hardwick, Spooner, Rando, & Morris, 1996; Wagner et al., 1995; Wapakabulo Thomas, 2010). Based on a case study of the adoption of STEP at the UK Ministery of Defence several barriers and facilitators of the adoptions have been identified (Thomas, Probets, Dawson, & King, 2010):

Barriers	Facilitators
Difficulty understanding the standard	Other implementations (network effects)
Standards revision process	Pilots and demonstrations
Cost of the standard	Internal (economic) drivers

Table 7 - 6 (out of 17) barriers and facilitators of the STEP standard (Thomas et al., 2010).

A comparison of multiple cases on inter-organizational system standards development in vertical industries is given by Nelson et al. (2005). Based on a comparison of nine different vertical standards, Nelson et al. identify key drivers, differences and similarities. Key drivers for vertical standards development are:

1. Technological innovations (Internet, XML, etc.)
2. Need for interoperability (to survive)
3. Value proposition of the vertical standards consortium (pooling of R&D, time saving renegotiating with each new trading partner, etc.)

Differences between vertical standards include alignment with more established organizations, balance between vertical and horizontal focus, and adoption of the target domains including the use of tracking mechanisms for monitoring adoption. Similarities include non-profit status, vertical orientation, provision of standards freely, vendor neutral, platform independent, membership and fee structures. Another important contribution of Nelson et al. (2005) is the inter-organizational system (IOS) standards development cycle, containing the following phases:

1. Choreography & Modularity (key cross-company business processes)
2. Prioritize & Schedule (planning of business processes)
3. Document & Standardize (develop specifications sets, including technology)
4. Review & Test (permit user community to provide feedback)
5. Implement & Deploy (provide implementation support and forecast adoption)
6. Compliance & Certification (validate standards conformance to ensure interoperability)

More generally, Zhao, Xia and Shaw (2005) mention some unique characteristics of the vertical, semantic, e-business standards development process. They prove the uniqueness of e-business standards, in comparison with other standards (in particular IT product standards). They describe challenges faced by the vertical e-business SDO's (a different organization than traditional SDO's like ISO) such as rapid technology development and divergent preferences of stakeholders. And most importantly a Participants - Technical content - Institutional structure framework is presented for studying vertical e-business standards. These three components are interrelated and determine the performance of the SDO, implying that the SDO should address all three components in an efficient and balanced way. The three components consist of the following features (Zhao et al., 2005):

- Participants (number, sector, bargaining power)
- Technical contents (maturity)
- Institutional structures (structure, procedures, openness)

Since semantic IS standards are being developed by many different SSOs, it might be expected that they will make a lot of (re)-use of each other's specifications. However the contrary seems true. There seems to be a lot of re-inventing of the wheel, based on a study of 33 SSOs (Löwer, 2005) (including horizontals like ebXML, cXML, W3C, etc. and verticals like ACORD, OTA, etc.). Exceptions are RosettaNet, which makes significant use of the specifications of 8 other SSOs, and the specifications of UN/CEFACT are used by 10 other SSOs. The 33 SSOs that were studied only make marginal use of other specifications (Löwer, 2005).

6.2 Adoption

Understanding standards adoption (and diffusion) stands out as an important research topic (Lyytinen and Rose 2003 as cited by Zhu et al., 2006) - probably because widespread standards adoption is critical. Simply explained: by the fact that semantic IS standards, like other network technologies, are susceptible to network externalities (Boh et al., 2007; Cathomen & Klein, 1997; Katz & Shapiro, 1985).

There was some related research (empirical study) on adoption during the EDI-era (e.g. Von Westarp et al., 2000). And others like (Cathomen and Klein, 1997; Hart and Saunders, 1997; Kaefer and Bendoly, 2000; Kauffman and Mohtadi, 2004). A good overview containing even more studies is presented by Löwer (2005). Other comparisons have resulted in models to predict the adoption (Chwelos, Benbasat, & Dexter, 2001; Kaefer & Bendoly, 2000).

The research on adoption of IS standards continued in the XML standards-era according to Zhao et al. (2007), probably because of the low adoption of EDI-based solutions. Despite all promotional efforts, only 5% of the organizations that could benefit from the standard use it (Beck & Weitzel, 2005), or an estimated 2% of businesses worldwide (Wigand, Markus, & Steinfield, 2005). Several adoption models have been constructed primarily to predict and explain adoption (Chen, 2003; Kelly, Feller, & Finnegan, 2006; Mendoza & Ravichandran, 2007).

Many case studies, like STEP (Thomas et al., 2008), RosettaNet (Boh et al., 2007; Chong & Ooi, 2008; Löwer, 2005; Nelson et al., 2002), XBRL (Chang & Jarvenpaa, 2005) and MISMO (Markus et al., 2006; Steinfield et al., 2007; Wigand, Steinfield et al., 2005) focus on diffusion, leading to a strong research fundament.

To explain adoption the following theories are often used:

- Diffusion of Innovation (DOI)
- Economics of Standards (including Network effects and Switching costs)
- Game theory

DOI (Rogers, 2003) is often used, amongst others by (Hovav, Patnayakuni, & Schuff, 2004) to analyze the adoption of IPv6, a technical standard. Some, like Weitzel, Wendt et al. (2006) use both DOI and Network Effects. DOI lists five innovation attributes that influence the adoption decision, these include: relative advantage, compatibility, complexity, trialability and observability. Studies into the setting up of adoption models specificaly for standards use complete DOI (Chen, 2003) or the DOI concepts complexity, compatibility and relative advantage (Kelly et al., 2006; Mendoza & Ravichandran, 2007), but they add other concepts that are, for instance, in the organizational and external context .

Hovav et al. (2004) introduce two paths to standards adoption: Adoption through replacement and adoption through co-existence; XML and EDI is an example of the latter. Schwind, Stockheim and Weiss (2008) introduce “Determinants and parameters simulating diffusion dynamics in supply networks”. This is a model with factors, and each factor (determinant) is respresented by one or more metric (parameters). Based on these metrics (including formulas), diffusion can be simulated.

Diffusion of inter-organizational systems (IOS) has, just like a new product, a life cycle (Cathomen & Klein, 1997). The image of the life cycle depends on several factors (Cathomen & Klein, 1997):

- IOS: comparative advantage, compatibility, complexity, observability, cost, risk, availability
- Providers: strategy, structure, pressure, applicability, potentials
- Market: industry, tradable goods and services, competition
- Environment: economy, technology, law, society

We conclude this section by summarizing several important knowledge contributions regarding adoption of standards. Zhu et al. (2006) is probably, on a conceptual level, the most related since it focuses on the migration to an inter-organizational system (IOS) based on open standards, including XML based horizontal and vertical semantic IS standards.

Study	Migration to Open-Standard Interorganizational Systems: Network Effects, Switching Costs and Path Dependency (Zhu et al., 2006)
Type	Conceptual - Adoption
Contribution	The paper focuses on the migration to an inter-organizational system (IOS) based on open standards, including XML-based horizontal and vertical standards. It provides a conceptual model, supported by a large scale survey, for open standard IOS adoption. This conceptual model indicates three variables influencing adoption of the standard: 1. Network Effects (Trading community influence, Peer adoption) 2. Expected Benefits (influenced by Network Effects) 3. Adoption costs (Financial costs, Managerial complexity, Transactional risk, Legal barriers) While adoption costs are a significant barrier there is a dependency based on the path taken. In this study non-EDI users were insensitive to adoption costs, in contrast to EDI users.

Study	Industry-Wide Information Systems Standardardisation as a Collective Action: The Case of the U.S. Residential Mortgage Industry (Markus et al., 2006)
Type	Case Study – Adoption
Contribution	This study focused on the development and diffusion (adoption) of the MISMO standard based on the viewpoint of collective action. Based on the MISMO case four propositions are formulated for vertical standards development and adoption in general, of which three are related to adoption. 1. Semantic IS standardization must find a way to ensure the collective participation of representative heterogeneous users. 2. Semantic IS standard initiatives must ensure user groups participation whereby both have committed themselves to adoption but are also able to influence other organizations to adopt the standard. 3. Each semantic IS standard initiative should set up a set of tactics that bring together the development and the adoption dilemmas. 4. The chosen tactics for development will influence the adoption of the standard, because the tactics for development will influence the content (quality), which also (the content) will influence adoption. In order to successfully achieve adoption it must be ensured that user-groups that have the greatest ability to influence adoption must be present in the development process without having a disproportionate influence on the content of the standard. The organization that has a crucial role in the diffusion of the standard should likewise be involved in the development of the standard, and be committed to adoption. (User groups that are the key to standards diffusion should not be excluded from standards development or be allowed to influence the standards development at the expense of other user groups.). This suggests that there is a relation between the development choices and the adoption of the standard. Successful VIS standardization is characterized by jointly setting up tactics for development and diffusion. In addition, this set of tactics should fit to the VIS situation. Every VIS domain is different, and requires its own specific set of tactics. What works in the MISMO case does not have to work in the hr-XML case, or any other case. The success of the adoption of the standard is affected by the technical content of the standard, which is affected by the tactics used to solve the development dilemma. In addition, "Despite best efforts, the compromises involved in reconciling heterogeneous interest in the face of equally heterogeneous resources is likely to require compromises that affect the nature and quality of the standards developed, thereby increasing the challenges of subsequent standards diffusion." MISMO shows that the "keep it simple, stupid" approach to promote diffusion is better than a perfectly designed technical standard.

<table>
<tr><td>Study</td><td>Standards Development and Diffusion, A Case Study of RosettaNet (Boh et al., 2007)</td></tr>
<tr><td>Type</td><td>Case Study – Adoption</td></tr>
<tr><td>Contribution</td><td>It focuses on the adoption of RosettaNet standards, and presents categories of adoption strategies and lessons learnt regarding development and adoption. Adoption (Diffusion) strategies can be classified in four categories:
1. Market: Promote awareness among potential adopters about capabilities and benefits of the standard and how to implement.
2. Technology: Improve standard (lowering the costs of implementation and increasing the ease of implementation and use)
3. Policy: Change social and regulatory environment
4. Relational: Co-opt key players to pressure their trading partners

The presented lessons learnt from the RosettaNet case are:
• Investing significantly in standards adoption.
• Adoption strategy should be aligned with the development process.
• The set of adoption strategies (see above) should be locally adapted.</td></tr>
</table>

<table>
<tr><td>Study</td><td>A Unified Economic Model of Standard Diffusion: The impact of standardization cost, network effects and network typology (Weitzel, Beimborn et al., 2006)</td></tr>
<tr><td>Type</td><td>Conceptual - Adoption</td></tr>
<tr><td>Contribution</td><td>This paper focuses on the question: what are the causes of standardization problems, and how can their magnitude – available standardization gains – be operationalized? The answer to the question is that there is an asymmetry between individual and collective standardization gains and that there are thus multiple equilibria between the two extremes. The standardization gap as a difference between the theoretical first-best and the realistic second-best standardization outcome, determines maximum possible coordination gains. Thus, depending on the situation, some available standardization gains can be internalized by communication (ballot problem: identify affected agents, arrange round-table talks). Others require an explicit redistribution of standardization costs and benefits (welfare problem: side payments). Consortia could provide institutional settings for binding agreements between agents.
Another contribution of the paper is the observation that if standardization costs are too high we face the start-up problem and if standardization costs are too low we will face inefficient multi-standard equilibria (for high and low standardization costs (as compared to network effects) monopoly outcome is quite rare). The implication of this observation is that with high standardization costs, standards adoption is less likely in decentralized coordinated networks. With low standardization costs, the first mover advantage is limited and it should not be expected that partners simply follow.</td></tr>
</table>

Study	Promoting e-business through vertical IS standards: Lessons from the US home mortgage industry (Steinfield et al., 2007)
Type	Case study - Adoption

Contribution	This paper describes the following lessons learnt on the adoption of vertical IS standards in the US home mortgage industry:
	• Structure:
	    • create a social group
	    • limited scope (to keep intra-organizational conflicts out of the scope)
	    • governance (open memberships, voluntary participation in particular workgroups, transparency in decision making, fair voting rules, efforts to reduce costs of participation, separate governance committee)
	• Active efforts for further participation
	• Distribute standards through the Internet
	• Data dictionary (critical importance; avoiding standards drift)
	• Key stakeholders involved

Trends in Standardization

7

CHAPTER SEVEN


Standards a failing paradigm? *(Carl Cargill, 2007)*

There are two related trends worth mentioning in this state of the art. First, the concept of openness, which is related to standards but also to other topics like open data, open enterprise, open society, open R&D, or open source software. The trend of open standards is related to the second trend, the rise in criticism of the traditional world of formal standardization (procedures) which does not reflect the world of IT. This chapter will discuss both trends.

7.1 Openness

The trend of open standards is acknowledged by many authors (Lemley, 2002; Pedersen, Fomin, & Vries, 2009) and was noticed already in the previous decade (Branscomb & Kahin, 1995). One of the main reasons for the current re-emphasis for the call for open standards is the current environment in the IT industry and the rise of global network-based manufacturing (Rachuri, 2007).

For instance Markus et al. (2006) state the following:

> *"It is generally agreed that open standards such as the Internet and open source software development methods have significant potential implications for information systems theory and practice. For example, open standards increase the connectivity of device and software, therby enabling the development of new information technology applications and new strategies of electronic business and, consequently, the restructuring of IT-using industries (Wigand et al., 2005). Open source software development threatens the hegemony of proprietary IT products and services, thereby leading to changes in the structure of the IT industry. Both trends are converging in new forms of cooperation among IT-using organizations, for example, the user-led development of voluntary, open, industry-specific inter-organizational coordination standards, here called vertical information systems (VIS) standards."*

So according to Markus semantic IS standards would not exist without open standards.

There are numerous definitions of open standards, and lead to arguments between different standards stakeholders. These discussions are not new: already in 1995 Microsoft used a very different definition than SUN (Band, 1995). Often standards are characterized as open or proprietary, but this does not hold in practice since there are many gradations in between ("the many shades of gray" (West, 2007)). Standards have multiple dimensions on openness, and even an open standard can be more open on one dimension than on another dimension. To assess the openness of standards it is more valuable to look at models that capture those dimensions, than to make use of an arguable definition of openness.

Krechmer (2006, 2008, 2009) did important work on setting up a model to facilitate the discussion on openness of standards. He introduced the creator, implementer and user viewpoints and set up requirements for each viewpoint resulting in 10 requirements (Krechmer, 2009):

1. Openness (Open Meeting (Krechmer, 2006, 2008)): All stakeholders may participate.
2. Consensus: All interests are discussed and an agreement is found with no domination.
3. Due Process: Balloting and an appeals process may be used to find a resolution.
4. One world (Open world (Krechmer, 2006, 2008)): The same standard for the same function, worldwide.
5. Open IPR: Low or no charge for for the IPR required to implement the basic standard.
6. Open documents: All may access and use committee documents, drafts, and completed standards for their intended purpose.
7. Open change: All changes are proposed and agreed within the standardization organization.
8. Open interfaces: Support migration (backward compatibility), and allow proprietary advantage, but standardized interfaces are not hidden or controlled.
9. Open access (Open use (Krechmer, 2006, 2008)): Objective conformance mechanisms for implementation testing and user evaluation.
10. Ongoing support: Standards are supported until user interests cease.

This model is important since it shows that there is more to openness than the question of IPR on standards.

For example, Krechmer stresses the importance of open change; a standard in which one single actor is in full control of change procedures is not really open. This work is used by, for instance, Danish and Dutch governments to assess the openness of several standards (Andersen, 2008; Lammers, Folmer, & Ehrenhard, 2010).

Based on the work of Krechmer an open and closed state can be characterized as shown in the table (Kelly et al., 2006).

	Completely Open Standard	Completely Closed Standard
Barriers to participation	No	Yes
Discussion of interests and agreement found	Yes	Between members
Due process (use of balloting and appeals)	Yes	Between members
Global standard with the same capability	Yes	At the discretion of members
IPR available to all implementers	Yes	No
Forum for presenting changes	Open	Closed
User/implementer access to interfaces	Yes	Between members
On-going support	Through a standard's life cycle	At the discretion of members

Table 8 – Open and closed state of standards (Kelly et al., 2006).

According to West (2007), the Krechmer model focuses only on openness, which is one side of the balance, while West introduces a model containing both the open and closed states. These are the end states of both sides of the balances, and many more options are possible in between.

Phase	Stage	Category	Dimension of openness	Open state	Closed state
Creation	policy	access	Access to standardization process	Anyone can participate	Only founding firm(s) can participate
Creation	policy	competition	Control of standardization process	All participants have a vote	Decisions are made arbitrarily by sponsor(s)
Implementation	policy	cost	Cost of standard specification	Free	Expensive
Implementation	policy	access	Access to standard to implement	Any firm can make an implementation	Only sponsor(s) can implement standard
Implementation	policy	access	Access to standard to complement	Any firm can make an complements	Complements limited to vertically integrated sponsor(s)
Implementation	policy	cost	Free use of standard IPR	IPR is licensed royalty free	IPR separates firms into “haves” and “have nots”
Implementation	outcome	cost	Ratio of IPR cost to implementation costs	IPR costs are negligible	Implementation costs are dominated by IPR royalties
Implementation	policy	cost, access	Shared reference implementation	A reference implementation reduces implementation costs	Everyone implements from scratch
Implementation	outcome	competition	Competing implementations	Low barriers make implementations a commodity	Only one implementation exists
Implementation, Use	policy	competition, cost, access	Free complete implementation	A shared implementation is available for all to use	Everyone builds their own implementation
Use	policy	access	Access to standard to use	Users have full rights to use the standard	Use is restricted to specific firms
Use	policy	access	Access to standard to use	Users can use the standard for any purpose	Certain types of uses are not allowed (e.g., rival implementations)
Use	policy	cost	Access to standard to use	No further payment is required to use an implementation	Additional payments must be made to standards or IPR owner to use the implementation

Table 9 – Dimensions of standards openness (West, 2007).

Krechmer and West's models show us the bandwidth that is present regarding the openness of standards.

On European government level definitions for open standards have been set up as part of the European Interoperability Framework. The first strict univocal, with the exception of what is "nominal", definition from version one is (European Commission, 2004):

- The standard is adopted and will be maintained by a not-for-profit organisation, and its ongoing development occurs on the basis of an open decision-making procedure available to all interested parties (consensus or majority decision etc.).
- The standard has been published and the standard specification document is available either freely or at a nominal charge. It must be permissible to all to copy, distribute and use it for no fee or at a nominal fee.
- The intellectual property - i.e. patents possibly present - of (parts of) the standard is made irrevocably available on a royaltyfree basis.
- There are no constraints on the re-use of the standard.

Although it is not mentioned why there was a need for a definition change the second version of the European Interoperability Framework contains a quite different definition. It might have to do with the long and turbulent development process involving the lobby work of many organizations. The new definition of open is (European Commission, 2010):

- All stakeholders have the same possibility of contributing to the development of the specification and public review is part of the decision-making process;
- The specification is available for everybody to study;
- Intellectual property rights related to the specification are licensed on FRAND terms or on a royalty-free basis in a way that allows implementation in both proprietary and open source software.

The first item might be the result of the lobby work of formal SDOs, which explain the explicit mentioning of the public review which they have incorporated in their development processes. The second item states explicitely "to study", which raises the question of what about "to use"? But the third item will lead to most discussion in the field since it is multi-interpretable, and might be explained as an antithesis in itself since the combination of FRAND licence and implementation within open source software is arguable. The result of this definition is unclear, standards that were labelled as open may need to remove that label (based on point 1), while the other way around (formerly not open standards might now be labelled open) is certainly true as well (based on point 2 and 3).

Although there are enough arguments that open standards will lead to economic and social welfare, it is a myth that all interoperability problems will be solved with open standards. For instance, vendors are still able to maintain high switching costs even with open standards (Chen & Forman, 2006). Based on an extensive empirical study, the results raise a cautionary flag to optimists who believe that the use of open standards will reduce product switching costs to zero and create a level playing field for vendors. There are three remarkable results from this study (Chen & Forman, 2006):

1. Vendors maintain significant switching costs despite the presence of open standards.
2. Vendors can influence switching costs.
3. The vendor with the largest installed base of older technology is able to influence the speed of new technology adoption.

But also the playing field of open standards is complex and not without threats. Two fundamental threads are (Shapiro & Varian, 1999b):

1. There is no real sponsor of the standard in charge of setting the direction.
2. Who is willing to invest in improvements into the standard?

Moreover, open standards are prone to splintering or fragmentation and can be hijacked by companies seeking to extend them in proprietary directions (Shapiro & Varian, 1999b). Solutions have to be found to deal with these aspects.

Indicators have been developed to predict the tendency towards open standards (Schwind et al., 2008):

- Low relationship stability
- Highly connected supply chains
- Low centrality of supply structures
- Homogeneous market power

If the market is characterized by the characteristics above, then there will be a tendency to open standards. The trend in openness is relevant for both formal SDOs and industry fora (SSOs). Some think that formal standards (like ISO) are open and industry standards will be proprietary, but more often the contrary is true. West (2007) cites Egyedi (2003) on this: "dominant rhetoric underestimates the openness of most industry consortia and overestimates the democratic process in formal standards committees".

SSOs are tempted to claim they are open when they aren't, or to be open for some purposes but closed for others, or even to encourage openness without requiring it. According to Lemley (2002): Any of these options would almost certainly be a mistake. There is little to be gained from wishy-washy IP policies that "prefer" but do not mandate non-proprietary standards. Expectations will be raised and dashed; problems will ensue.

An SSO is either committed to making its standards open and non-proprietary or it isn't. If it is, the only way the SSO can further reach that goal is by requiring the assignment or royalty-free licensing of IP rights that cover the standard (Lemley, 2002). Another aspect of allowing IPR is that it will hinder the adoption of the standard, which is the reason that W3C seeks to issue their recommendations royalty-free (Updegrove, 2007). But, within the broad range of IT, not many SSOs are fully committed to open standards (Lemley, 2002).

In many domains, for example multimedia, proprietary standards are a big problem for interoperability and digital sustainability and longevity. Luckily, not in the area of inter-organizational interoperability since most e-business standards are freely available and exhibit good public features (Zhao et al., 2007). But we have to remember that there is no free lunch in IT standardization (West, 2007).

7.2 Required changes in the standardization world

The formal standards world needs changes to satisfy the needs of the users; an opinion often heard at IT and open source conferences. Standardization has a long and rich history, but is has not been able to adapt to the changing needs especially in the IT-area. An example of not keeping up the pace is the fact that nowadays 70% of the European GDP is related to services, while only 1% of the CEN standards is related to services (Freericks, 2010). Another problem that requires changes is the role of SME in standardization. Although SME compromises 99% of the enterprises in the EU, their involvement in standardization development processes is limited. Since development and adoption of standards are inter-related, this will affect the adoption of standards within SMEs. Even when SME participation might not be needed for the technical development, its importance for the adoption of the standards is highly relevant (Jakobs, 2006).

Cargill (1995) expressed the need to move towards a new standardization Open Process already in 1995, because according to Cargill the old world of standardization is a failing paradigm. Cargill and Bolin (2007) argue that standardization is failing to serve the interests of the sponsoring organizations, the public, the industry, the nation and this failure will have complex and far-reaching consequences for all.

In short, the problem is the following:

1. The explosion of SSOs. For every single issue, an SSO is created. Often they fail, but the next attempt is started immediately. Companies are setting up SSO's, and companies are even competing with SSO's.
2. Proliferation of specifications: "Today, we are in a situation in which all of these SSOs produce specifications, and few, if any of them, interoperate with specifications produced by other SSOs. They have lost sight of two fundamental principles of standardization: (1) The purpose of standardization is to facilitate interoperability, giving users more and better product choices while expanding the overall market for vendors; and (2) the only way to achieve this goal is through cooperation and collaboration with other market players who are often competitors." (Cargill & Bolin, 2007)
3. Lack of definition: The term standard is being abused. Nowadays everything might be called a standard.

For the latter Cargill and Bolin (2007) renew the definition of the standard, although it is not that strict:

A standard is a technical specification that codifies a set of interfaces which describe the necessary methodology to achieve interoperation between disparate programs. The standard does not say how the interfaces are to be met, only that the interfaces must be open (that is, not proprietary), accessible, and fall within the realm of reality. It would also be nice if the interface recognizes that there are global requirements. This specification is the result of action by an SSO.

It is remarkable that although the arguments are very recognizable in practice, only a few other studies describe similar problems. Based on his research on the standardization of the electronic patient record, Hanseth et al. (2006) conclude that efforts aimed at reducing complexity through standardization might result in the opposite outcome. Traditional standardization processes can not deal with such complexity appropriately.

Another relic from the old paper-era is the selling of standards for a fee which is done by formal SDO's like ISO (an exception is ITU-T). In the current era of Internet this seems rather outdated, and needs to change: Or like Rada & Berg (1995) question: Why spend millions on standards and then limit their use?

The old formal world is protecting its position and neglecting the changing environment. An example is the results of a panel-discussion that evaluates the European standardization systems; although it recognizes the rise of SSOs its recommendations are limited to improved cooperation with SSOs (Pindar, 2010). However the value of this report can be questioned since mainly experts from the old formal standards world contributed and it could be called a "self-evaluation".

The work to solve these problems is not really noticeable in the field, while the problem is growing.

"If this unmitigated output of standards, especially competing standards, continues, the market will fragment to the point where interoperability will become impossible" (Cargill & Bolin, 2007). Solutions to the problems might focus on the public sector instead of the private sector,because when the private sector fails the government has the duty to take action. Part of the solution might be in certification/legislation of the SSO (Cargill & Bolin, 2007).

Currently SSOs are still growing in output and importance (Werle & Iversen, 2006). SDOs and SSOs are not changing, and governments do not pick up the duty to take action. If this trend continues, this will have an impact on the quality of standards and on achieved interoperability.

However some signs of change are present. Within the education domain signs of creating a best of both worlds situation (traditional SDO and new communities/consortia) are becoming apparent. Several standards (e.g. XCRI, SWORD and LEAP2A) are developed in new communities and when they become mature, they investigate links with the formal standards bodies, mainly for status and maintenance reasons (Wilson, 2010). Since there are so many standard setting bodies, user organizations have to carefully select in which body to participate. To support that selection, evaluation criteria have been set up to evaluate the standards setting bodies against the strategic goals of the user organization (Jakobs, 2007). Finally changes are expected at the European policy level (Jakobs, 2010).

Quality and Standards

CHAPTER EIGHT

8

Quality has much in common with sex. Everyone is for it. (Under certain conditions, of course.) Everyone feels they understand it. (Even though they wouldn't want to explain it.) Everyone thinks execution is only a matter of following natural inclinations. (After all, we do get along somehow). And, of course, most people feel that all problems in these areas are caused by other people. (If only they would take time to do things right.) In a world where half the marriages end in divorce or separation, such assumptions are open to question.

(Crosby, P.M., Quality is free, The art of making quality certain, 1979, McGraw-Hill.)

Quality has multiple meanings in different domains. Although our interest lies in quality related to standards it is worthwhile to study different domains where quality has a rich history. The fundament of quality has been laid by gurus like Deming, Juran and Crosby, especially aimed at the quality of physical products. Since the nineties, ISO (9001) and other quality standards have become quite popular, while focusing on the processes, instead of the end product. These process-related standards have become quite popular in software engineering. CMMi is a well known standard related to software quality. Software engineering has, in comparison with information systems, a longer history in quality which makes it interesting to study both domains. Within the information system discipline, data quality is seen as a relevant area focusing on the quality of information inside an organization. Studies from this field might become useful with respect to our focus, the quality of standards.

Many more disciplines, like the management discipline (EFQM, Six Sigma, etc.), might contain relevant studies relating to quality, but in this state-of-the-art we chose to limit the study to probably the most relevant disciplines related to standards. Each discipline is captured within a distinct paragraph within the appendix A. However since data quality is heavily related to standards quality, the topic of data quality will be covered in paragraph 8.1. The second paragraph of this chapter (8.2) will deal with quality from the standards domain itself.

In summary, this state-of-the-art addresses quality from different perspectives:

1. Product engineering/manufacturing domain (Appendix A.1)
2. Software engineering domain (Appendix A.2)
3. Information System quality (Appendix A.3)
4. Data quality domain (Paragraph 8.1)
5. Standards domain (Paragraph 8.2)

Based on the quality dimensions from mainly software engineering, information systems, and data quality domain, a specific quality model has been constructed for knowledge management systems (Owlia, 2010). This work shows some valuable insights into how many quality dimensions are available within existing literature with slightly different nomenclature and meanings.

8.1 Data quality

Data or information quality is part of the IS success models presented in Appendix A.3. However it is an important area of research: 60% of the surveyed firms (500 medium-size corporations with annual sales of more than $20 million) have problems with data quality (Wand & Wang, 1996; Wang & Strong, 1996). Within the domain of data quality, Juran's definition of fitness for use is commonly used (Wang & Strong, 1996; Zhu & Wu, 2010). To improve data quality the need was evident to understand what data quality means to data consumers, for which a conceptual framework of data quality has been constructed (Wang & Strong, 1996). This framework consists of 15 dimension within the following four categories (Wang & Strong, 1996):

- Intrinsic Data Quality (Believability, Accuracy, Objectivity, Reputation)
- Contextual Data Quality (Value-added, Relevancy, Timeliness, Completeness, Appropriate amount of data)
- Representational Data Quality (Interpretability, Ease of understanding, Representational consistency, Concise representation)
- Accessibility Data Quality (Accessibility, Access security)

This work was followed up with the development of a model (Kahn, Strong, & Wang, 2002):

	Conforms to Specifications	Meets or exceeds Consumer Expectations
Product Quality	Sound Information • Free-of-Error • Concise Representation • Completeness • Consistent Representation	Useful Information • Appropriate Amount • Relevancy • Understandability • *Interpretability* • *Objectvity*
Service Quality	Dependable Information • Timeliness • Security	Useable Information • Believablity • Accessiblity • Ease of Manipulation • Reputation • Value-Added

Table 10 – Quality model (Kahn et al., 2002).

Another set of data quality dimensions is presented by Wand and Wang (1996) (the first mentioned dimensions are more cited than the latter mentioned dimensions):

	Dimensions
Internal View design operation)	***Data-related*** accuracy, reliability, timeliness, completeness, currency, consistency, precision ***System-related*** reliability
External View (use, value)	***Data-related*** timeliness, relevance, content, importance, suffiency, useableness, usefulness, clarity, conciseness, freedom from bias, informativeness, level of detail, quantitativeness, scope, interpretability, understandability ***System-related*** timeliness, flexibility, format, efficiency

Table 11 – Data Quality dimension (Wand & Wang, 1996).

Many more information or data quality frameworks have been created. A comparison of 12 different quality models all containing different quality characteristics has been made by Knight and Burn (2005). Based on the comparison, a summary of the most common dimensions including the occurrence frequency in the twelve frameworks is provided in the following table:

Dimension	# of times	Definitions *conform Wang & Strong (1996)
1 Accuracy	8	extent to which data are correct, reliable and certified free of error*
2 Consistency	7	extent to which information is presented in the same format and compatible with previous data*
3 Security	7	extent to which access to information is restricted appropriately to maintain its security*
4 Timeliness	7	extent to which the information is sufficiently up-to-date for the task at hand*
5 Completeness	5	extent to which information is not missing and is of sufficient breadth and depth for the task at hand
6 Concise	5	extent to which information is compactly represented without being overwhelming (i.e. brief in presentation, yet complete and to the point)*
7 Reliability	5	extent to which information is correct and reliable*
8 Accessibility	4	extent to which information is available, or easily and quikly retrievable*
9 Availability	4	extent to which information is physically accessible
10 Objectivity	4	extent to which information is unbiased, unprejudiced and impartial*
11 Relevancy	4	extent to which information is applicable and helpful for the task at hand
12 Useability	4	extent to which information is clear and easily used
13 Understandability	5	extent to which data are clear without ambiguity and easily comprehended*
14 Amount of data	3	extent to which the quantity or volume of available data is appropriate*
15 Believability	3	extent to which information is regarded as true and credible*
16 Navigation	3	extent to which data are easily found and linked to
17 Reputation	3	extent to which information is highly regarded in terms of source or content*
18 Useful	3	extent to which information is applicable and helpful for the task at hand*
19 Efficiency	3	extent to which data are able to quickly meet the information needs for the task at hand*
20 Value-Added	3	extent to which information is beneficial, provides advantages from its use*

Table 12 – Quality dimensions based on an analysis of 12 quality frameworks (Knight & Burn, 2005).

8.2 Quality and standards

In the field of standardization, most research focuses on how standards develop, adoption decisions, types of existing standards, and those needing further development (Rukanova, 2005). Both Rukanova and Söderström found that there is little research in the area of standards implementation and even less on how to evaluate the fit between the requirements of a specific situation and a standard (Rukanova, 2005; Söderström, 2004). This fitness for use in a specific situation is what we call quality.

However, from previous paragraph and the appendix we know that we can learn from other domains: e.g. CMM stresses the importance of configuration management and requirements management; both concepts are applicable to standards as well. Even the Software Quality Assurance is a concept that could be copied to a Standards Quality Assurance for developing standards. Furthermore, from the product engineering domain concepts are useful for the standards domain as well. For instance the quality grid by Crosby (which is also used in CMM) is applicable to standards as well, although most SDOs will be part of stage 1 – Uncertainty, and not ready for the more sophisticated stages 2-5 (from awakening to certainty). However in the standards domain the quality subject is less mature than in the earlier mentioned domains. Still, there are several studies that touch the topic, which we will summarize within this section.

General standardization

In literature, quality is sometimes related to the adoption of the standard in practice. For instance Zhao et al. (2005) mention the penetration rate of a standard as a proxy for standards quality. Although adoption is important, this does not line up with a view on quality of "fitness for use", for which adoption might be a proxy with many limitations. A distinction is often made of a standards quality between the standardization process and its outcome.

Stakeholders

Different stakeholders have different views on quality, as they have different interests (Sherif, Jakobs, & Egyedi, 2007). This stakeholder viewpoint is quite interesting because it is not the producer of standards but the end-user who bears the cost of change (Egyedi & Blind, 2008). “In particular where lack of quality of an initial standard is the reason for a revision, the people responsible may not be the ones to pay” (Egyedi & Blind, 2008; Sherif et al., 2007). Or like Sherif et al. (2007) put it (Egyedi, 2008):

> *“The diverse interests that affect standardization, the distributed nature of its management process and the time lag between a standard and its implementation in products and services mean that there is no clear accountability in terms of profit and loss responsibilities due to deficiencies in an ICT standard. In some cases, those who pay the cost of the lack of quality are not those who made the decisions. Thus, market mechanisms will rarely provide the driving incentive to carry out the intensive planning and coordination across organizational boundaries that are needed to produce a quality standard.”*

The abundance of corrective market incentives to address lack of standards quality also applies to the corrupt use of standards, another issue regarding standards implementation (Egyedi, 2008).

The fact that different stakeholders will have different interests has been translated to a project management view on quality for the telecom domain. The core of the view is that within different aspects of project management like scope management, resource management, quality management, etc., quality needs to be addressed and symptoms of poor quality might be sighted (Sherif et al., 2007).

Stakeholder	Angle of interest	Quality Emphasis	Relevant Project
Owner (standards body)	Legitimacy Due process	P	Resource
Producer (technical committee)	Technical Due process	O, P	Quality, resource, time
Supplier (committee participant and standard developer)	Technical Due process	O	Resource, quality, documentation
Sponsor (Companies financing participants)	Marketing Financial (possibly technical)	O	Time, cost, resource
Consuments (implementers of standard)	Technical Ease of implementation	O	Quality, documentation
End-users (users of standard-compliant product)	Useability (interoperability and functionality) of standard-compliant product or service	O	Quality
Regulators	Legitimacy Due process	O, P	Quality, documentation

Figure 12 – Stakeholders' interest in standards quality (O=Outcome, P=Process) (Sherif et al., 2007).

Standard Development Process

Egyedi (2000) proposes there should be more focus on the procedures of standard development organizations, because among others, there is a concern for the quality of standards. This concern is not new. Farrell already showed in 1996, based on a game theoretical model, how diverse interests of standard developers will cause delays in standardization and will influence a standard's quality. Farrell suggests that the relevant participants, the technical focus, and the internal processes of an SDO simultaneously influence its performance in terms of speed and quality (Zhao et al., 2005). A study by Jakobs (2009) shows that the quality of the standard is highly impacted by the position and the quality of workgroup members. This is supported by the work of Teichmann (2010) who agrees that the quality and quantity of the technical work produced by standards workgroups is affected by the management of the committees/workgroups, and on the individual effectiveness of the individual members. The selection of the participants within the workgroups will have an impact on the quality of the standard. Participants in working groups have a different background, but do need certain qualities (like familiarity with technical aspects, speak English, and have skills in technical writing) and motivation in order to be effective.

In another empirical study (Egyedi & Heijnen, 2008), the stability of standards is presented but is limited to ISO/JTC1 ICT standards. The results show that 40% of the standards have changed over the years. Whether these changes are the result of a lack of quality is not known.

One approach to improve the quality of the telecom standards is to develop so called anti-products in parallel development (Brzezinski, 2010a). The antiproduct assesses the quality of the main product, because by parallel developing and sharing knowledge both the main product and the antiproduct will gain quality. For telecom standards this comes down to the development of four products (Brzezinski, 2010a): The base specification with an anti-product during early implementation. And includes a test specification (to validate the testability of the requirements from the base specification) with a test system as its antiproduct.

Standard implementation

Implementers of standards are using the specification document of the standard which has a certain quality regarding for instance the readability of or referencing to other documents. However quality should not be limited to the specification document of the standard since users require more information to effectively make use of the standards. For instance there should be additional documentation (like education material, FAQ) available next to specification (Freericks, 2010).

Many specification documents are written by non-native English speakers. The linguistic quality will have an impact on the fitness for use of the standard in general (Teichmann, 2010).

What is remarkable is that according to a study by Aben (2002) the number of user complaints concerning language equals the number of complaints about the technical content of the standard (Teichmann, Vries, & Feilzer, 2008).

Implementation might be tampered because of other reasons (Egyedi, 2008):

- The idea that underlies a standard may not be implementable (e.g. too comprehensive).
- The ideal of consensus decision-making may affect the standards process (e.g. lead to too many options) and, indirectly, the implementability of the standard.
- Different use of terminology in a standard specification may lead to problems of interpretation, implementation and interoperability.

- Modest user requirements and cost-constraints in the implementation process may lead to partial standard compliance and incompatible implementations.

These problems might be related to the standards specification (S), the conceptual idea (C), development process (P) and its implementation process (IP), as different parts of the standardization ecosystem. Based on a discussion with a panel of experts, Egyedi (2008, 2009) studied causes of interoperability problems within the standardization ecosystems. The results are presented within the table below.

Causes of incompatibility	Locus
Errors, ambiguities, inconsistencies	SP/S
Ambiguity of natural language	SP/S
Missing details, monopoly on tacit knowledge	S/IP
Ill-structured standards	S
Unclear how to handle options	S
Uncertain compatibility of non-binding recommendations	S
Complexity of comprehensive, ambitious standards	C
Too many options and parameters	SP/S/IP
Backward compatibility	C
Unclear official status of standards' companion book	S
Single company pushing for standard, weak specifications	SP
Overload of standards	C/IP
Deviation from and partial implementation of a standard	IP
Interference between standards	C/IP

Table 13 – Causes of incompatibility by a panel of experts (Egyedi, 2008, 2009).

Although the causes contain overlaps, and also the scoring seems a bit questionable (which might be explained by using a panel of experts as a research method), we still can say that 8 out of 14 causes relate to the specification document. Using the viewpoint of the standard as the combination of the idea, the process and the specification, one can argue that 13 out of 14 causes relate to the quality of the standard.

Proposed improvements to standardization

Based on the conclusion that interoperability is affected by several quality related issues, Egyedi (2007,2008) suggests improvements for the standardization system that might have a positive impact on quality in the sense of achieving interoperability.

Institutional measures towards reducing standard-based interoperability problems	
Drafting of standards	• provide institutional support for editors and rapporteurs on standards engineering • involve technical editors • use pseudo-code or formal languages in a focused way • adopt a unified naming convention • clarify the type of options involved • specify how to deal with options (e.g. profiles) • specify the consequences of (not) impementing options • make the rationale that underlies choices in the specification explicit • issue a reference guide with the standard • organize wider scrutiny of the standard • translate the standard also to uncover ambiguities • co-ordinate interrelated standardization of different standards bodies
Pre-implementation	• validate standards before implementation in products ('walk-throughs') • develop a reference implementation/pre-implementation • develop a reference environment • include standard conformance and interoperability testing • organize interoperability events with different vendors (e.g. plug tests) • organize dialogue between standard developers and implementers
Post-implementation	• supply test suites • improve consistent use and integrity of standards with e.g. compliance and interoperability conformance statements compatibility logos, certification programmes
Standards policy	• prioritize implementability as a standard's requirement • reconsider desired level of consensus across all areas

Table 14 – Improvement suggestions for the standardization system (Egyedi, 2007, 2008).

From a more generic point of view, Morell and Stewart (1995) describe best practices for standards development based on a workshop method. The best practice consists of using Quality Function Deployment for the needs and requirements analysis of the standard. Total Quality Management (TQM) and Continuous Improvement (CI) can be used to keep the process ongoing and to assure progress is made. The best practice also includes two kinds of metrics:

- To assess the progress of the process.
- To measure the quality of the standards that are produced.

The best practice contains only some guidelines for metrics and the first attempt to suggest several metrics, including metrics like the number of redundant standards (process metric) and meeting the user needs of products (product metric). It stresses the importance of quality metrics even at early stages, because knowledge of those metrics can be used to set objectives and to install a sense of mission (Morell & Stewart, 1995).

Openness

The openness of standards is seen more and more as a major selection criterion for standards to be supported by governments, software vendors and other users. Although openness is important it does not guarantee a high quality standard, and moreover it does not guarantee to be a good solution to the interoperability problem. Openness is just one quality attribute out of several. To achieve interoperability in an efficient manner, it is not enough to have openness as a single selection criterion. An overall view of quality is needed for selection purposes.

Quality of semantic IS standards

Semantic IS standards development is different to the development of other standards. For instance, intrinsic motivation is particularly important in the context of a semantic committee (Teichmann, 2010). Intrinsic motivation can be compared to having a hobby in standards development, which impacts motivation and quality.

Two well-known case-studies regarding semantic IS standards are related to the MISMO and RosettaNet standards, and in both studies traces of the importance of quality can be found. In the search for critical success factors for a RosettaNet Inter-organizational information system (IOS) project, quality was identified as a critical success factor, in the opinion of respondents: "Thanks to the high quality of RosettaNet standards, the implementation of IOS in Cisco and Xiao Tong was very efficiently carried out and at low cost" (Lu et al., 2006). Based on the case study of the MISMO standard within the mortgage industry, a proposition has been set up:

> *"The success of VIS standards diffusion is affected by the technical content of the developed standard, which is, in turn, affected by the tactics used to resolve the dilemma of VIS standards development" (Markus et al., 2006).*

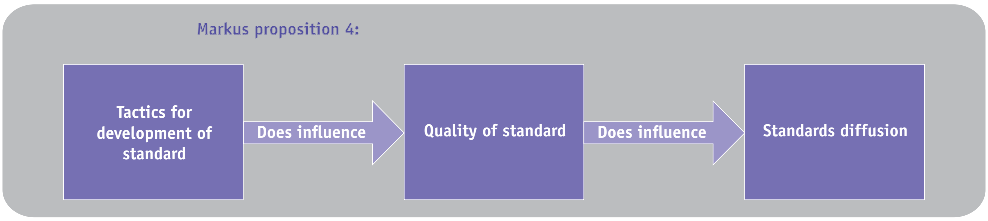


Figure 13 – Proposition that relates the development process and adoption to the standards quality (Markus et al., 2006).

Quantifiable quality

Nowadays most semantic IS standards are ultimately expressed in the technical XML format. Although the technical format is a representation of the content of the semantic IS standard it still might be useful as an indicator of the quality of the semantic IS standard.
Based on ISO 9126, a set of XML Schema metrics were developed that measure the quality of the XML Schema and the exploitation of advanced features of XML Schema. These are (McDowell, Schmidt, & Yue, 2004):

- Number of: Complex Type Declarations, Simple Type Declarations, Annotations, Derived Complex Types, Global Type Declarations, Global Type References and Unbounded Elements.
- Average: Number of Attributes per Complex Type Declaration, Bounded Element Multiplicity Size, Number of Restrictions per Simple Type Declaration and Element Fanning.

Element fanning is the average of the number of child elements and number of references each element has. Each of those measures are indicators of quality and complexity: for instance a large number of Complex Type Declarations will indicate a complex XML Schema, while a large number of annotations will indicate a well documented XML Schema.

Based on the analysis of quality of different XML specifications, the complexity of standards is assumed to have two parameters (Brutti et al., 2010):

1. Uncertainty: The number of distinct data containers that exist for a single specific type of information in a document (for example, the possible alternatives to specify the Order ID in an XML instance)
2. Redundancy: The total number of possible distinct data containers in a document to support a specific business example.

The table shows an example of uncertainty in practice within UBL; two elements with the same semantics.

	XPATH of element	Description	Occ
1	OrderResponse/cbc:SalesOrderID	An identifier for the Order issued by the Seller	0..1
2	OrderResponse/cac:OrderReference/ cbc:SalesOrderID	Identifies the referenced Order assigned by the Seller	0..1

Table 15 – Two different elements with the same semantics in UBL (Brutti et al., 2010).

A case study was set up to test the redundancy parameter. For several document templates (e.g. order, invoice) the number of required data objects was defined, and then tested to see how many options (redundancy) for storing this data object were available in different standards: in the horizontal standard (UBL 2.0), the vertical standard (Moda-ML XML) and a domain profile on UBL (eBiz-TCF). The table below shows the results:

Document template	*eBIZ-TCF Textile clothing scenario: data to be transferred*	UBL 2.0 XML Schemas # of XPATHs containing data	Moda-ML XML Schemas for a fabric purchase proces # of XPATHs containing data	UBL Use Profile for a retail-side purchase process from eBiz-TCF # of XPATHs containing data
catalogue	55	38.630	99	60
order	22	2.893.732	163	36
order response	28	2.895.909	163	39
despatch	27	915.815	136	40
receipt advice	29	913.812	69	41
invoice	37	61.162	148	66

Table 16 – Case study results for testing redundancy (Brutti et al., 2010).

One might expect that a number closest to the number mentioned in the second column has the highest chance of achieving interoperability. And, on the other hand, a number much higher than in the second column might suggest low quality because this standard will be difficult to implement and will probably not lead to interoperability. Although just based on a single case, it shows that the risks of redundancy and uncertainty are much lower in vertical standards than in horizontal standards. This is because vertical standards are already much more tailored for a specific task within a more specialized context from the real world.

It also shows the importance of "profiles or localizations", which limit the redundancy and uncertainty of a specification. In contrast to horizontal standards, "vertical standards appear much more focused and effective to support real eBusiness" (Brutti et al., 2010).

Instead of measuring within the specification itself, implementations might also be a valuable source of information to determine quality. This viewpoint was used to assess the concepts of completeness and relevancy (from the data quality domain) of the US GAAP

XBRL-taxonomy based on defined quantifiable metrics (Zhu & Fu, 2009; Zhu & Wu, 2010). Completeness of a data standard is the extent to which the data standard specifies all the data elements needed by standard users. Relevancy of a data standard is the extent to which the data standard specifies only the specific data elements needed by standard users (Zhu & Wu, 2010). Both are measured by counting the number of custom added elements and used elements within implementations. Adding custom data elements might indicate that the standard does not specify all data elements needed by the standard users. The number of used elements, in relation to the number of available elements indicates the relevance. The study shows a dramatic view on the quality of US GAAP, probably leading to a non-existing semantic interoperability.

Although it is a limited view of quality, both quantified studies are, to the authors' knowledge, the first to quantify the quality of semantic IS standards.

Recommendations

In practice, semantic IS standards evolve in a fragmented and distributed fashion. To make integration and interoperability more efficient and scalable, the fragmented specifications need to fit into a coherent, semantic model (Kulvatunyou, Morris, Ivezic, & Frechette, 2008). They need to be logically consistent and contain minimal duplication. Additionally, semantically overlapping data structures should be related or annotated, because every term and data structure should have unique semantics.

Technically speaking, the following 'common sense' recommendations are made:

1. Reduction of the XML Schema elements in the library (delete unused components, and refine cardinalities) makes it much easier to manage and understand (Brutti et al., 2010).
2. Definition in the library, using the schematron code, of constraints that are common for multiple standards (XML Schemas) (Brutti et al., 2010).
3. If the standard is encoded in XML Schema then its syntax and semantics must conform to W3C XML Schema specification (Kulvatunyou et al., 2008).
4. Best practices like the UN/CEFACT Naming and Design Rules (NDR) to be used (Kulvatunyou et al., 2008).

Quality measurement of semantic IS standards

Some of the disadvantages of using horizontal rather than vertical or sector related specifications could be overcome by using profiles that can be automatically processed (Brutti et al., 2010). Second, the problem of achieving a critical mass of adopters in sectors characterized by the large presence of SMEs is challenging both for policy makers and IT research. However, this can be overcome by specific sector initiatives. Unfortunately, vertical standards are not present in every domain, and not every problem will be solved.

Competition between semantic IS standards seems limited because of the domain restriction that is present on vertical semantic IS standards. Unfortunately this does not hold for the medical domain where several competing standards for the Electronic Health Record (EHR) exist. Seven of those standards have been qualitatively compared with no clear winner as a result (Eichelberg et al., 2005). Quality can be broken down into four parts, specific for EHR, but generalizable (Eichelberg et al., 2005):

1. The level of interoperability support: Does the EHR provide structured content suitable for automated processing? Does it specify content distribution rules?
2. Functionality: Does the standard allow for an explicit retrieval of records (or parts thereof) for a specific patient, based on an incoming request? Can it contain multimedia data? What kind of security mechanisms are supported for accessing healthcare records?
3. Complementarity: Since not all the standards provide all the necessary features, is it possible to combine them in a complementary way? Do the standard initiatives affect one another?
4. Market relevance: Is the standard accepted in the marketplace? Are there commercial implementations available or any signs of uptake by the industry?

However, often these semantic IS standards seem far from being perfect since they are overlapping, incompatible, and not limited to their main scope (Mykkanen & Tuomainen, 2008). Even the gaps between the requirements and standards limit their usefulness (Mykkanen & Tuomainen, 2008), and thus quality issues.

This is the reason why selection and evaluation frameworks for these standards should be studied which according to the authors is useful for quality evaluation of these semantic IS standards (Mykkanen & Tuomainen, 2008). The framework consists of nine subjects, ranging from meta-topics, technical aspects, semantics, domain-specific, etc. An evaluation form has been constructed for each of them, consisting of, in total, 54 questions, excluding the many lower level questions. It includes a process model of how to perform the evaluation. More work should be done on validating the model and the forms. However it seems without doubt that the answer to the question on the evaluation forms will support an evaluation in some way.

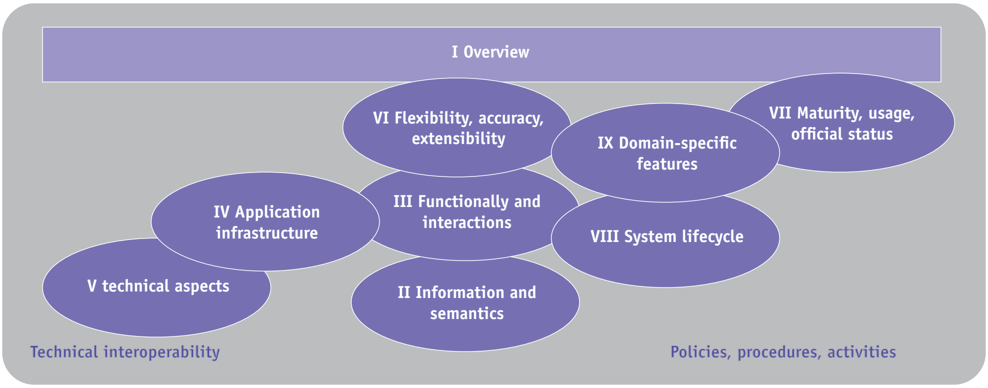


Figure 14 – The parts of the evaluation framework (Mykkanen & Tuomainen, 2008).

EVALUATION FORM FOR INTEROPERABILITY STANDARDS			SerAPI project www.centek.fi/serapi
Evaluation date:	[YYYY-MM-DD]		
Evaluator	[Names, contact information]		
I BASIC INFORMATION AND SCOPE OF THE STANDARD			
1. Abbreviation	[official abbreviation preferred]		
2. Name of the specificatrion	[official]		
3. Version	[or date of the specification, if applicable		
4. Standard organization and availability:	[name of organization, how available (address, limited/freely etc.)		
5. Scope statement of the standard	[citation]		
6. Intended audience	☐ technical	☐ business domain:	☐ combination/other
7. If domain specific: what is the business domain and detailed sub-domain (see also form IX)	[description]		
8. Number the relevant aspects (only), which standard specifies in relation to applications [20] (1 = most relevant)			
a) Organizational or individual goals, procedures or activities b) Information or data in information systems or interfaces		[#] [#]	
c) Functionally, operations or workflows in information systems or interfaces		[#]	
d) System architecture, components and connections		[#]	
e) Interface or implementation technologies		[#]	
9. For the numbered aspects above, which are specified on concrete (what) level, which are «...»		Concrete (what is in the solution):	[a-e]

Table 17 – Part of the evaluation forms (Mykkanen & Tuomainen, 2008).

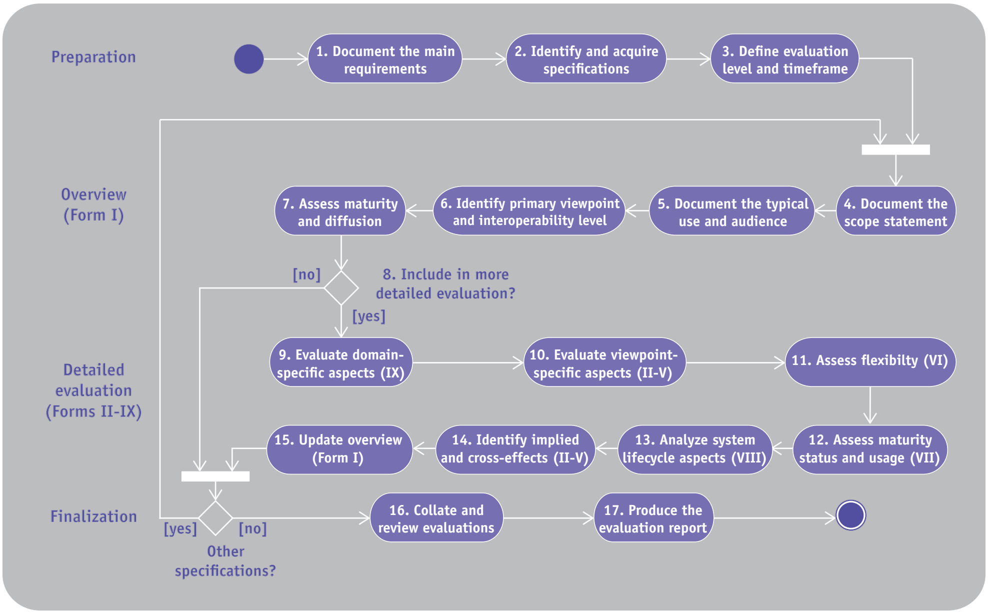


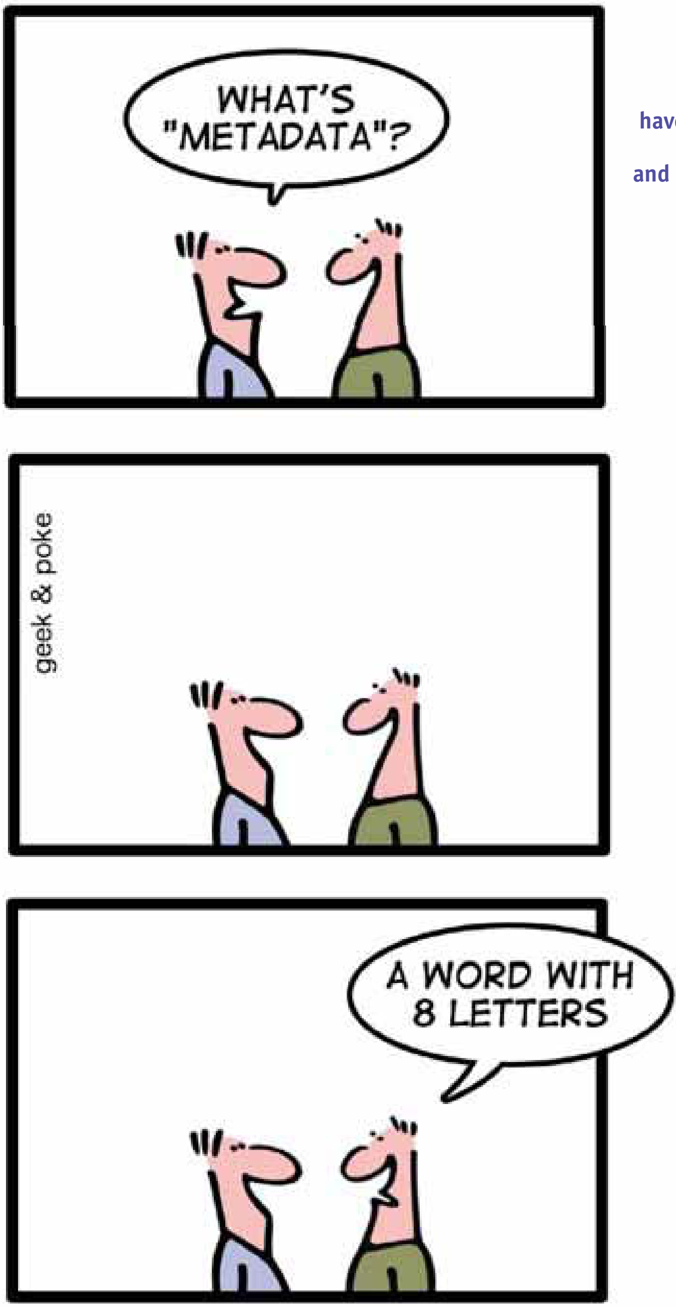
Figure 15 – The evaluation process (Mykkanen & Tuomainen, 2008).

Another model for the analysis of standards is called the Reference Model Analysis Grid (RMAG) (Pawlowski & Kozlov, 2010). Although intended for learning technology models, it is generally applicable. It includes different categories for standards classifications and a long list of analysis and assessment aspects and metrics for evaluation. Finally it consists of a structured survey to be used when evaluating the standard. Several categories deal with metadata like the objectives, domain, methodology and documentation of the standard. The category "In-depth analysis" deals specifically with interoperability on different levels: practical, semantic, and technical integration (Pawlowski & Kozlov, 2010). In comparison with the earlier presented evaluation framework of Mykkanen & Tuomainen (2008) this RMAG evaluation contains fewer details and might be more practical (less time investment) to use, but the results will be less detailed as well.

Final Remarks

9

CHAPTER NINE



"The greatest discoveries have come from people who have looked at a standard situation and seen it differently." *(Ira Erwin)*

A state-of-the-art captures the published knowledge about a certain topic at a certain moment in time. Our topic is semantic IS standards, but our timing excludes newer publications from 2011 onwards.

We tried to be as inclusive as possible by, for instance, including the results (43 papers) of a structured literature review in top journals about semantic IS standards (Folmer et al., 2009; Folmer, Berends, Oude Luttighuis, Van Hillegersberg, & Lammers, 2010). We added work related to standards and interoperability in general. Finally we added some quality related studies from different domains. But surely we are not finished.

Although the topic of quality in semantic IS standardization has been declared as a research gap (Folmer et al., 2009), this state-of-the-art has shown that many relevant and interesting studies have been carried out in the area of semantic IS standards and interoperability.

However, the state-of-the-art did not come up with an instrument to measure the quality of semantic IS standards. A problem survey by one of the authors (to be published), showed that the quality of semantic IS standards needs to be improved, and these improvements will lead to improved interoperability. However without knowing the quality of the current standards it is not possible to improve the quality. Like Lord Kelvin already said: "If you can not measure it, you can not improve it.", which was repeated by De Marco who says that one cannot control something that can not be measured (McDowell et al., 2004). And not to forget: Measurement supports innovation! (Swann, 2009, 2010).

A Ph.D. dissertation is being undertaken by one of the authors on these topics, with an aim to develop and validate an instrument to measure the quality of semantic IS standards, specifically intended to improve the quality of such standards. Progress on the dissertation and related publications can be found on www.semanticstandards.org.

If you want additional reading, we suggest the bibliography, but our unfounded top 4 would be as follows:

- Markus, M. L., Steinfield, C. W., Wigand, R. T., & Minton, G. (2006). Industry-wide Information Systems standardization as collective action: The case of U.S. residential mortgage industry. MIS Quarterly, 30, 439-465.
- Greenstein, S. M., & Stango, V. (Eds.). (2007). Standards and public policy. Cambridge [etc.]: Cambridge University Press.

- Nelson, M. L., Shaw, M. J., & Qualls, W. (2005). Interorganizational System Standards Development in Vertical Industries. Electronic Markets, 15(4), 378-392.
- Zhao, K., Xia, M., & Shaw, M. J. (2005). Vertical e-business standards and standards developing organizations: A conceptual framework. Electronic Markets, 15(4), 289-300.

If you have had enough of these academic publications and need some practical guidance, then our suggestion is to read BOMOS version 2, publicly available on the internet (www.semanticstandards.org) or by contacting the authors.

The current standardization landscape is changing (Jakobs, 2010). Hopefully this will lead to a shift in the emphasis on (quality of) semantic IS standards in standardization research and publications.

Bibliography


"I really had a lot of dreams when I was a kid, and I think a great deal of that grew out of the fact that I had a chance to read a lot." *(Bill Gates)*

Abran, A., Khelifi, A., & Suryn, W. (2003). Usability Meanings and Interpretations in ISO Standards. *Software Quality Journal, 11*, 325-338.

Abran, A., Moore, J. W., Bourque, P., & Dupuis, R. (Eds.). (2004). *SWEBOK: Guide to the Software Engineering Body of Knowledge*. Los Alamitos, California: IEEE Computer Society.

Albrecht, C. C., Dean, D. L., & Hansen, J. V. (2005). Marketplace and technology standards for B2B e-commerce: Progress, challenges, and the state of the art. *Information and Management, 42*(6), 865-875.

Andersen, P. (2008). *Evaluation of Ten Standard Setting Organizations with Regard to Open Standards*. Copenhagen: IDC.

Anh, V. T. (2007). An Introduction - The History of Standardization. In W. Hesser (Ed.), *Standardisation in Companies and Markets* (pp. 45-76). Hamburg: Helmut Schmidt University.

Anicic, N., Ivezic, N., & Jones, A. (2006). An Architecture for Semantic Enterprise Application Integration Standards. In D. Konstantas, J.-P. Bourrières, M. Léonard & N. Boudjlida (Eds.), *Interoperability of Enterprise Software and Applications* (pp. 25-34). London: Springer-Verlag.

Asuncion, C. H., & Van Sinderen, M. J. (2010). *Pragmatic Interoperability: A Systematic Review of Published Definitions.* Paper presented at the Enterprise Architecture, Integration and Interoperability (EAI2N), part of WCC2010, Brisbane.

Bailey, J. E., & Pearson, S. W. (1983). Development of a tool for measuring and analyzing computer user satisfaction. *Management Science, 29*(5), 530-545.

Band, J. (1995). Competing Definitions of "Openness" on the NII. In B. Kahin & J. Abbate (Eds.), *Standards Policy for Information Infrastructure* (pp. 351-367). Cambridge: The MIT Press.

Barresi, S., Rezgui, Y., Lima, C., & Meziane, F. (2008). Semantic Resources Integration and Interoperability in the Construction Domain. In Y. Manolopoulos, J. Filipe, P. Constantopoulos & J. Cordeiro (Eds.), *Enterprise Information Systems* (Vol. 3, pp. 336-347): Springer Berlin Heidelberg.

Beck, R., & Weitzel, T. (2005). Some Economics of Vertical Standards: Integrating SMEs in EDI Supply Chains. *Electronic Markets, 15*(4), 313 - 322.

Benders, J., Batenburg, R., & Van Der Blonk, H. (2006). Sticking to standards; Technical and other isomorphic pressures in deploying ERP-systems. *Information and Management, 43*(2), 194-203.

Bernstein, P. A., & Haas, L. M. (2008). Information integration in the enterprise. *Communications of the ACM, 51*(9), 72-79.

Berre, A., Elvesæter, B., Figay, N., Guglielmina, C., Johnsen, S., Karlsen, D., et al. (2007). The ATHENA Interoperability Framework. In R. J. Gonçalves, J. P. Müller, K. Mertins & M. Zelm (Eds.), *Enterprise Interoperability II - New Challenges and Approaches* (pp. 569-580): Springer London.

Blind, K. (2004). *The economics of standards; theory, evidence, policy*. Cheltenham [etc.]: Edward Elgar.

Blind, K. (2009). A Taxonomy of Service Standards and a Modification for E-Business. In K. Jakobs (Ed.), *Information Communication Technology Standardization for E-Business Sectors; Integrating Supply and Demand Factors* (pp. 24-30). Hershey: Information Science Reference.

Blobel, B., & Pharow, P. (2009). Analysis and evaluation of EHR approaches. *Methods Inf Med, 2009*(48), 162-169.

Boehm, B. W. (1973). *Characteristics of software quality*. Redondo Beach, CA: Thompson Ramo Wooldridge Systems Group, Systems Engineering and Integration Division.

Boehm, B. W., Brown, J. R., & Lipow, M. (1976). *Quantitative evaluation of software quality*. Paper presented at the Proceedings of the 2nd international conference on Software engineering.

Boh, W. F., Soh, C., & Yeo, S. (2007). Standards development and diffusion: A case study of RosettaNet. *Communications of the ACM, 50*(12), 57-62.

Branscomb, L. M., & Kahin, B. (1995). Standards Processes and Objectives for the National Information Infrastructure. In B. Kahin & J. Abbate (Eds.), *Standards Policy for Information Infrastructure* (pp. 3-34). Cambridge: The MIT Press.

Brunnermeier, S. B., & Martin, S. A. (2002). Interoperability costs in the US automotive supply chain. *Supply Chain Management, 7*(2), 71-82.

Brutti, A., Cerminara, V., D'Agosta, G., Sabbata, P., & Gessa, N. (2010). Use Profile Management for Standard Conformant Customisation. In K. Popplewell, J. Harding, R. Poler & R. Chalmeta (Eds.), *Enterprise Interoperability IV - Making the Internet of the Future for the Future of Enterprise* (pp. 449-459): Springer London.

Brzezinski, K. M. (2010a). On Aligning the Properties of Standards with the Needs of Their Direct Users, Netwerk Operators. In K. Jakobs (Ed.), *New Applications in IT Standards - Development and Progress* (pp. 70-94). Hershey - New York: Information Science Reference.

Brzezinski, K. M. (2010b). *Standards are Signs.* Paper presented at the 15th EURAS Annual Standardisation Conference "Service Standardization", Lausanne.

Bucciarelli, P. (1995). The Current Debate on IT Standardization Policy in the European Union. In B. Kahin & J. Abbate (Eds.), *Standards Policy for Information Infrastructure* (pp. 421-429). Cambridge: The MIT Press.

Cargill, C. F. (1989). *Information Technology Standardization: theory, process, and organizations*. Bedford: Digital Press.

Cargill, C. F. (1995). A Five-Segment Model for Standardization. In B. Kahin & J. Abbate (Eds.), *Standards Policy for Information Infrastructure* (pp. 79-99). Cambridge: The MIT Press.

Cargill, C. F., & Bolin, S. (2007). Standardization: a failing paradigm. In S. Greenstein & V. Stango (Eds.), *Standards and Public Policy* (pp. 296-328). Cambridge: Cambridge University Press.

Cash Jr, J. I., & Konsynski, B. R. (1985). IS redraws competitive boundaries. *Harvard Business Review, 63*(2), 134-142.

Castillo, I., Losavio, F., Matteo, A., & Boegh, J. (2010). Requirements, aspects and software quality: The REASQ model. *Journal of Object Technology, 9*(4), 69-91.

Cathomen, I., & Klein, S. (1997). The development of FEDI in Switzerland: A life-cycle approach. *International Journal of Electronic Commerce, 1*(4), 129-145.

Cavano, J., P., & McCall, J., A. (1978). A framework for the measurement of software quality. *3*(5), 133-139.

Chang, C., & Jarvenpaa, S. (2005). Pace of Information Systems Standards Development and Implementation: The Case of XBRL. *Electronic Markets, 15*(4), 365-377.

Chappert, H., & Mione, A. (2009). *Standards war in cooperation context: Do coopetition applly? - The case of ODF and OOXML*. Paper presented at the Proceedings of the 6th International Conference on Standardization and Innovation in Information Technology SIIT 2009, Tokyo, Japan.

Chari, K., & Seshadri, S. (2004). Demystifying integration. *Communications of the ACM, 47*(7), 58-63.

Chase, R. B., & Aquilano, N., J. (1995). *Production and Operations Management: Manufacturing and Services* (7 ed.). Chicago: Irwin.

Chen, D., Doumeingts, G., & Vernadat, F. (2008). Architectures for enterprise integration and interoperability: Past, present and future. *Computers in Industry, 59*(7), 647-659.

Chen, M. (2003). Factors affecting the adoption and diffusion of XML and Web services standards for E-business systems. *International Journal of Human-Computer Studies*(58), 259-279.

Chen, P. Y., & Forman, C. (2006). Can vendors influence switching costs and compatibility in an environment with open standards? *MIS Quarterly: Management Information Systems, 30*(SPEC. ISS.), 541-562.

Choi, B., Raghu, T. S., & Vinze, A. (2004). Addressing a standards creation process: A focus on ebXML. *International Journal of Human Computer Studies, 61*(5), 627-648.

Chong, A. Y.-L., & Ooi, K.-B. (2008). Adoption of interorganizational system standards in supply chains - An emperical analysis fo RosettaNet standards. *Industrial Management & Data Systems, 108*(4), 529-547.

Chwelos, P., Benbasat, I., & Dexter, A. S. (2001). Research Report: Empirical Test of an EDI AdoptionModel. *Information Systems Research, 12*(3), 304-321.

Cole, J. (2004). Raising the bar. *Computer, 37*(9), 112-113.

Cowan, R. (1991). High Technology and the Economics of Standardization. *Intenational Conference on Social and Institutional Factors Shaping Technological Development*

Crosby, P. M. (1979). *Quality is free, The art of making quality certain*: McGraw-Hill.

Damsgaard, J., & Truex, D. (2000). Binary trading relations and the limits of EDI standards: The Procrustean bed of standards. *European Journal of Information Systems, 9*(3), 173-188.

Davenport, T. H. (2005). The Coming Commodization of Processes. *Harvard Business Review, 2005*(June).

David, P. A. (1985). Clio and the Economics of QWERTY. *American Economic Review, 75*(2), 332.

David, P. A., & Greenstein, S. (1990). The economics of compatibility standards: an introduction to recent research. *Economics of Innovation and New Technology, 1*, 3-41.

De Vries, H. J. (2006). IT Standards Typology. In K. Jakobs (Ed.), *Advanced Topics in Information Technology Standards and Standardization Research* (Vol. 1, pp. 1-26). Hershey: Idea Group Publishing.

De Vries, H. J. (2007). Fundamentals of Standards and Standardization. In W. Hesser, A. Feilzer & H. J. De Vries (Eds.), *Standardisation in Companies and Markets* (2 ed., pp. 1-43). Hamburg: Helmut Schmidt University.

De Vries, H. J. (2008). Standardisation: A Business Science Perspective. In A. Hommels, J. Schueler & A. Fickers (Eds.), *Bargaining Norms Arguing Standards* (pp. 18-32). The Hague: STT.

Delen, G. P. A. J., & Rijsenbrij, D. B. B. (1992). The specification, engineering, and measurement of information systems quality. *The Journal of Systems and Software, 17*(3), 205-217.

DeLone, W. H., & McLean, E. R. (1992). Information systems success: The quest for the dependent variable. *Information Systems Research, 3*(1), 60-95.

Delone, W. H., & McLean, E. R. (2003). The DeLone and McLean Model of Information Systems Success: A Ten-Year Update. *Journal of management information systems, 19*(4), 9.

Deming, W. E. (1986). *Out of the crisis : quality, productivity and competitive position*: Cambridge, MA [etc.] : Cambridge University Press.

Den Uijl, S., & De Vries, H. (2009). *Strategic Manoeuvring in the High Definition Optical Disc Standards Battle: The Triumph of Blu-Ray over HD-DVD.* Paper presented at the Proceedings of the 6th International Conference on Standardization and Innovation in Information Technology SIIT 2009, Tokyo, Japan.

Dogac, A., Kabak, Y., Namli, T., & Okcan, A. (2008). Collaborative business process support in eHealth: Integrating IHE profiles through ebXML business process specification language. *IEEE Transactions on Information Technology in Biomedicine, 12*(6), 754-762.

Dogac, A., Pattenden, S., & Zelm, M. (2010). *Future Internet Enterprise Systems (FInES) Standardisation Task Force Report*.

Egyedi, T. M. (2000). Institutional Dilemma in ICT standardization: Coordinating the diffusion of technology? In K. Jakobs (Ed.), *Information Technology Standards and Standardization: A Global Perspective* (pp. 48-62). Hershey: Idea Group Publishing.

Egyedi, T. M. (2003). Consortium problem redefined: Negotioting 'democracy' in the actor network on standardization. *Journal of IT Standards and Standardization Research, 1*(2), 22-38.

Egyedi, T. M. (2007). Experts on Causes of Incompatibility between Standard-Compliant Products. In G. Doumeingts, J. Müller, G. Morel & B. Vallespir (Eds.), *Enterprise Interoperability* (pp. 553-563): Springer London.

Egyedi, T. M. (2008). An Implementation Perspective on Sources of Incompatibility and Standards' Dynamics In T. M. Egyedi & K. Blind (Eds.), *The Dynamics of Standards* (pp. 28-43). Cheltenham: Edward Elgar.

Egyedi, T. M. (2009). Between Supply and Demand: Coping with the Impact of Standards Change. In K. Jakobs (Ed.), *Information Communication Technology Standardization for E-Business Sectors; Integrating Supply and Demand Factors* (pp. 171-185). Hershey: Information Science Reference.

Egyedi, T. M., & Blind, K. (2008). General Introduction. In T. M. Egyedi & K. Blind (Eds.), *The Dynamics of Standards* (pp. 1-12). Cheltenham: Edward Elgar.

Egyedi, T. M., & Heijnen, P. (2008). How stable are IT standards? In T. M. Egyedi & K. Blind (Eds.), *The Dynamics of Standards* (pp. 137-154). Cheltenham: Edward Elgar.

Eichelberg, M., Aden, T., Riesmeier, J., Dogac, A., & Laleci, G. B. (2005). A survey and analysis of electronic healthcare record standards. *ACM Computing Surveys, 37*(4), 277-315.

Elgarah, W., Falaleeva, N., Saunders, C., C., Ilie, V., Shim, J. T., & Courtney, J., F. (2005). Data exchange in interorganizational relationships: review through multiple conceptual lenses. *ACM SIGMIS Database, 36*, 8-29.

Elvesæter, B., Hahn, A., Berre, A.-J., & Neple, T. (2006). Towards an Interoperability Framework for Model-Driven Development of Software Systems. In D. Konstantas, J.-P. Bourrières, M. Léonard & N. Boudjlida (Eds.), *Interoperability of Enterprise Software and Applications* (pp. 409-420). London: Springer-Verlag.

Esper, A., Sliman, L., Badr, Y., & Biennier, F. (2008). Towards Secured and Interoperable Business Services. In K. Mertins, R. Ruggaber, K. Popplewell & X. Xu (Eds.), *Enterprise Interoperability III: New Challenges and Industrial Approaches* (pp. 301-312). London: Springer-Verlag.

European Commission. (2004). *European Interoperability Framework for Pan-European eGovernment Services*. Retrieved 2010-02-15. from http://ec.europa.eu/idabc/servlets/Doc?id=19529.

European Commission. (2010). *European Interoperability Framework (EIF) for European public services*. Retrieved 2010-02-15. from http://ec.europa.eu/isa/strategy/doc/annex_ii_eif_en.pdf.

Farrell, J., Hayes, J., Shapiro, C., & Sullivan, T. (2007). Standard setting, patents, and hold-up. *Antitrust Law Journal, 74*(3), 603-670.

Farrell, J., & Saloner, G. (1985). Standardization, compatibility, and innovation. *RAND Journal of Economics, 16*(1), 70-83.

Farrell, J., & Saloner, G. (1986a). Installed Base and Compatibility: Innovation, Product Preannouncements, and Predation. *The American Economic Review, 76*(5), 940-955.

Farrell, J., & Saloner, G. (1986b). Standardization and Variety. *Economics Letters, 20*, 71-74.

Farrell, J., & Shapiro, C. (1988). Dynamic competition with switching costs. *RAND Journal of Economics, 19*(1), 123-137.

Fenton, N., E., & Neil, M. (2000). *Software metrics: roadmap*. Paper presented at the Proceedings of the Conference on The Future of Software Engineering.

Fodor, O., & Werthner, H. (2004). Harmonise: A step toward an interoperable e-tourism marketplace. *International Journal of Electronic Commerce, 9*(2), 11-39.

Folmer, E., Berends, W., Oude Luttighuis, P., & Van Hillegersberg, J. (2009). *Top IS research on quality of transaction standards, a structured literature review to identify a research gap*. Paper presented at the 6th International Conference on Standardization and Innovation in Information Technology, Tokyo, Japan.

Folmer, E., Berends, W., Oude Luttighuis, P., Van Hillegersberg, J., & Lammers, R. (2010). *Research on Quality of Transaction Standards: The Maturity of a Research Topic.* Paper presented at the Enterprise Architecture, Integration and Interoperability (EAI2N), part of WCC2010, Brisbane.

Folmer, E., Hinderer, H., & Otto, B. (2003). The openXchange framework for ebXML based business process integration. *Proceedings of the 10th ISPE International Conference on Concurrent Engineering Research and Application, Enhanced Interoperable Systems*, 447-453.

Frambach, R. T., & Schillewaert, N. (2002). Organizational innovation adoption - A multi-level framework of determinants and opportunities for future research. *Journal of Business Research, 2002*(55), 163-176.

Freericks, C. (2010). *Workable Service Standard Guides Through Meta-Standards*. Paper presented at the 15th EURAS Annual Standardisation Conference "Service Standardization", Lausanne.

Frenkel, K. A. (1990). Politics of standards and the EC. *Communications of the ACM, 33*(7), 40-51.

Friesen, N. (2005). Interoperability and Learning Objects: An Overview of E-Learning Standardization. *Interdisciplinary Journal of Knowledge and Learning Objects, Volume 1*, 23-31.

Gallaher, M. P., O'Connor, A. C., Dettbarn Jr., J. L., & Gilday, L. T. (2004). *Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry*: NIST.

Garvin, D. A. (1984). What Does "Product Quality" Really Mean? *Sloan management review, 26*(1), 24-43.

Gauch, S. (2008). + vs -: Dynamics and Effects of Competing Standards of Recordable DVD-Media. In T. M. Egyedi & K. Blind (Eds.), *The Dynamics of Standards* (pp. 47-67). Cheltenham: Edward Elgar.

Gerst, M., Bunduchi, R., & Williams, R. (2005). *Social shaping & standardization: A case study from auto industry*. Paper presented at the Proceedings of the Annual Hawaii International Conference on System Sciences, Big Island, HI.

Gerst, M., Iversen, E., & Jakobs, K. (2009). An Integrated View of E-Business and the Underlying ICT Infrastructure. In K. Jakobs (Ed.), *Information Communication Technology Standardization for E-Business Sectors; Integrating Supply and Demand Factors* (pp. 1-7). Hershey: Information Science Reference.

Ghobadian, A., & Speller, S. (1994). Gurus of quality: a framework for comparison. *Total Quality Management, 5*(3), 53-69.

Glass, R. L. (2008). The notion of an information system Apgar score. *Information Systems Management, 25*(3), 290-291.

Gonzalez-Barbone, V., & Llamas-Nistal, M. (2007). *EAssessment: Trends in content reuse and standardization*. Paper presented at the Proceedings - Frontiers in Education Conference, FIE, Milwaukee, WI.

Grant, S., & Young, R. (2010). Concepts and Standardization in Areas Relating to Competence. *International Journal of IT Standards and Standardization Research, 8*(2), 29-44.

Guedria, W., Chen, D., & Naudet, Y. (2009). *A Maturity Model for Enterprise Interoperability*. Paper presented at the OTM 2009 Workshops.

Hanseth, O., Jacucci, E., Grisot, M., & Aanestad, M. (2006). Reflexive standardization: Side effects and complexity in standard making. *MIS Quarterly: Management Information Systems, 30*(SPEC. ISS.), 563-581.

Hanseth, O., Monteiro, E., & Hatling, M. (1996). Developing Information Infrastructure: The Tension Between Standardization and Flexibility. *Science, Technology, & Human Values, 21*(4), 407-426.

Hardwick, M., Spooner, D. L., Rando, T., & Morris, K. C. (1996). Sharing Manufacturing Information in Virtual Enterprises. *Communications of the ACM, 39*(2), 46-54.

Hart, P., & Saunders, C. (1997). Power and Trust: Critical Factors in the Adoption and Use of Electronic Data Interchange. *Organization Science, 8*(1), 23-42.

Hasselbring, W. (2000). The Role of Standards for Interoperating Information Systems. In K. Jakobs (Ed.), *Information Technology Standards and Standardization: A Global Perspective* (pp. 116-130). Hershey: Idea Group Publishing.

Hawkins, R. (2009). Business Models and the Dynamics of Supply and Demand for Standards. In K. Jakobs (Ed.), *Information Communication Technology Standardization for E-Business Sectors; Integrating Supply and Demand Factors* (pp. 31-51). Hershey: Information Science Reference.

Heck, P., Klabbers, M., & van Eekelen, M. (2010). A software product certification model. *Software Quality Journal, 18*(1), 37-55.

Heck, P., & Van Eekelen, M. (2008). *LaQuSo Software Product Certification Model*.

Hesser, W., & Czaya, A. (2007). The Standardization Policy of the European Union. In W. Hesser (Ed.), *Standardisation in Companies and Markets* (pp. 455-510). Hamburg: Helmut Schmidt University.

Hesser, W., Czaya, A., & Riemer, N. (2007). Development of Standards. In W. Hesser (Ed.), *Standardisation in Companies and Markets* (pp. 123-169). Hamburg: Helmut Schmidt University.

Hoel, T., Hollins, P. A., & Pawlowski, J. M. (2010). On the Status of Learning Technology Specifications and Standards. *International Journal of IT Standards and Standardization Research, 8*(2), i-vi.

Hovav, A., Patnayakuni, R., & Schuff, D. (2004). A model of Internet standards adoption: The case of IPv6. *Information Systems Journal, 14*(3), 265-294.

Humphrey, W. S. (1989). *Managing the Software Process*. Reading: Addison-Wesley Publishing Company.

Humphrey, W. S. (1997). *A Discipline for Software Engineering* (6th ed.). Reading: Addison-Wesley Publishing Company.

ISO/IEC. (1999). *ISO/IEC 14598-1 Information technology - Software product evaluation - Part 1: General overview*.

ISO/IEC. (2001). *ISO/IEC 9126-1 Software engineering - Product quality - Part 1: Quality model*.

ISO/IEC. (2003a). *ISO/IEC 9126-2 Software engineering - Product quality - Part 2: External metrics*.

ISO/IEC. (2003b). *ISO/IEC 9126-3 Software engineering - Product quality - Part 3: Internal metrics*.

ISO/IEC. (2004). *ISO/IEC 9126-4 Software engineering - Product quality - Part 4: Quality in use metrics*.

ISO/IEC. (2008). *ISO/IEC 25012 Software engineering - Software product Quality Requirements and Evaluation (SQuaRE) - Data Quality model*.

Issac, G., Rajendran, C., & Anantharaman, R. N. (2006). An instrument for the measurement of customer perceptions of quality management in the software industry: An empirical study in India. *Software Quality Journal, 14*(4), 291-308.

Jakobs, K. (2006). *The Role of the "Third Estate" in ICT standardisation*. Paper presented at the E-Challenges, Vienna.

Jakobs, K. (2007). ICT Standards Development — Finding the Best Platform. In G. Doumeingts, J. Müller, G. Morel & B. Vallespir (Eds.), *Enterprise Interoperability* (pp. 543-552): Springer London.

Jakobs, K. (2009). Perceived Relation between ICT Standards' Sources and their Success in the Market. In K. Jakobs (Ed.), *Information Communication Technology Standardization for E-Business Sectors; Integrating Supply and Demand Factors* (pp. 65-80). Hershey: Information Science Reference.

Jakobs, K. (2010). The European Union's ICT Standardisation Policy: Changes Ahead!? In K. Jakobs (Ed.), *New Applications in IT Standards: Development and Progress* (pp. xiv-xxvii). Hershey - New York: Information Science Reference.

Jakobs, K., & Kritzner, J. (2009). How to Select the Best Platform for ICT Standards Development. In K. Jakobs (Ed.), *Information Communication Technology Standardization for E-Business Sectors; Integrating Supply and Demand Factors* (pp. 81-96). Hershey: Information Science Reference.

Jian, H., & Zhao, H. (2003). *A Conceptual Model for Comparative Analysis of Standardization of Vertical Industry Languages*. Paper presented at the Workshop on Standard Making: A Critical Research Frontier for Information Systems, Seattle, WA.

Johnston, H. R., & Vitale, M. A. (1988). Creating Competitive Advantage With Interorganizational Information Systems. *MIS Quarterly, 12*(2), 153-165.

Juran, J. M., & Gryna, F. M. (Eds.). (1988). *Juran's quality control handbook* (4th edition ed.): McGraw-Hill.

Kaefer, F., & Bendoly, E. (2000). Adoption of Electronic Data Interchange: A model and practical tool for managers. *Decision Support Systems, 30*(1), 23-32.

Kabak, Y., & Dogac, A. (2010). A survey and analysis of electronic business document standards. *ACM Computing Surveys (CSUR), 42*(3), 1-31.

Kahn, B., K. , Strong, D., M. , & Wang, R., Y. (2002). Information quality benchmarks: product and service performance. *Communications of the Acm, 45*(4), 184-192.

Kasunic, M., & Anderson, W. (2004). *Measuring Systems Interoperability: Challenges and Opportunities*: Carnegie Mellon University.

Katz, M. L., & Shapiro, C. (1985). Network Externalities, Competition, and Compatibility. *American Economic Review, 75*(3), 424.

Katz, M. L., & Shapiro, C. (1986). Technology adoption in the precence of network externalities. *Journal of Political eEconomy, 94*(4), 822-841.

Kauffman, R. J., & Mohtadi, H. (2004). Proprietary and open systems adoption in E-procurement: A risk-augmented transaction cost perspective. *Journal of Management Information Systems, 21*(1), 137-166.

Kelly, D., Feller, J., & Finnegan, P. (2006). Complex Network-Based Information Systems (CNIS) Standards: Toward an Adoption Model. In *The Transfer and Diffusion of Information Technology for Organizational Resilience* (pp. 3-20).

Knight, S. A., & Burn, J. (2005). Developing a framework for assessing information quality on the World Wide Web. *Informing Science, 8*, 159-172.

Knothe, T., & Jochem, R. (2007). Quality Criteria for Enterprise Modelling in the Context of Networked Enterprises. In G. Doumeingts, J. Müller, G. Morel & B. Vallespir (Eds.), *Enterprise Interoperability* (pp. 149-158): Springer London.

Kosanke, K. (2006). ISO Standards for Interoperability: a Comparison. In D. Konstantas, J.-P. Bourrières, M. Léonard & N. Boudjlida (Eds.), *Interoperability of Enterprise Software and Applications* (pp. 55-64). London: Springer-Verlag.

Krechmer, K. (2006). Open Standards Requirements. In K. Jakobs (Ed.), *Advanced Topics in Information Technology Standards and Standardization Research* (Vol. 1, pp. 27-48). Hershey: Idea Group Publishing.

Krechmer, K. (2008). Open Standards Requirements. In K. Jakobs (Ed.), *Standardization Research in Information Technology: New Perspectives* (pp. 49-65). Hershey: Information Science Reference.

Krechmer, K. (2009). Open Standards: A Call for Change. *IEEE Communications Magazine*(May), 88-94.

Kreger, H. (2003). Fulfilling the web services promise. *Communications of the ACM, 46*(6), 29-+.

Kubicek, H., & Cimander, R. (2009). Three dimensions of organizational interoperability. *European Journal of ePractice*(6 January 2009).

Kulvatunyou, B., Morris, K. C., Ivezic, N., & Frechette, S. (2008). Development Life Cycle for Semantically Coherent Data Exchange Specification. *16*(4), 279-290.

Lammers, R., Folmer, E., & Ehrenhard, M. (2010). *Narrowing the Gap between Open Standards Policy and Practice: The Dutch E-Government Experience*. Paper presented at the EGES 2010 (part of WCC2010).

Lampathaki, F., Mouzakitis, S., Gionis, G., Charalabidis, Y., & Askounis, D. (2009). Business to business interoperability: A current review of XML data integration standards. *Computer Standards and Interfaces*.

Lebreton, B., & Legner, C. (2007). Interoperability Impact Assessment Model: An Overview. In R. J. Gonçalves, J. P. Müller, K. Mertins & M. Zelm (Eds.), *Enterprise Interoperability II - New Challenges and Approaches* (pp. 725-728): Springer London.

Legner, C., & Lebreton, B. (2007). Preface to the Focus Theme Section: 'Business Interoperability' Business Interoperability Research: Present Achievements and Upcoming Challenges. *Electronic Markets, 17*(3), 176-186.

Lemley, M. A. (2002). Intellectual Property Rights and Standard-Setting Organizations. *California Law Review, 90*, 1889-2002.

Lew, P., Olsina, L., & Zhang, L. (2010). *Quality, Quality in Use, Actual Usability and User Experience as Key Drivers for Web Application Evaluation*. Paper presented at the Web Engineering (ICWE 2010).

Libicki, M. C. (1995). Standards: The Rough Road to the Common Byte. In B. Kahin & J. Abbate (Eds.), *Standards Policy for Information Infrastructure* (pp. 35-78). Cambridge: The MIT Press.

Löwer, U. M. (2005). *Interorganisational Standards - Managing Web Services Specifications for Flexible Supply Chains*. Heidelberg: Physica-Verlag - A Springer Company.

Lu, X. H., Huang, L. H., & Heng, M. S. H. (2006). Critical success factors of inter-organizational information systems - A case study of Cisco and Xiao Tong in China. *Information and Management, 43*(3), 395-408.

Mähönen, P. (2000). The Standardization Process in IT - Too Slow or Too Fast. In K. Jakobs (Ed.), *Information Technology Standards and Standardization: A Global Perspective* (pp. 35-47). Hershey: Idea Group Publishing.

Markus, M. L., & Gelinas Jr., U. J. (2008). Comparing the Standards Lens with Other Perspectives on IS Innovations: The Case of CPFR. In K. Jakobs (Ed.), *Standardization Research in Information Technology: New Perspectives* (pp. 185-201). Hershey: Information Science Reference.

Markus, M. L., Steinfield, C. W., Wigand, R. T., & Minton, G. (2006). Industry-wide Information Systems standardization as collective action: The case of U.S. residential mortgage industry. *MIS Quarterly, 30*, 439-465.

McCall, J. A., Richards, P. K., & Walters, G. F. (1977). *Factors in Software Quality* (Vol. 1-3).

McDowell, A., Schmidt, C., & Yue, K. B. (2004). *Analysis and metrics of XML schema*. Paper presented at the Proceedings of the International Conference on Software Engineering Research and Practice, SERP'04, Las Vegas, NV.

McNichol, T. (2006). *AC/DC: The Savage Tale of the First Standards War*. San Francisco: Jossey-Bass.

Mendoza, R., A., & Ravichandran, T. (2007, Jan. 2007). *Organizational Assimilation of Vertical Standards: An Integrative Model*. Paper presented at the 40th Annual Hawaii International Conference on System Sciences, 2007. .

Milicic, D. (2005). Software Quality Models and Philosophies. In L. Lundberg, M. Matsson & C. Wohlin (Eds.), *Software quality attributes and trade-offs*: Blekinge Institute of Technology.

Moraga, C., Moraga, M. A., Calero, C., & Caro, A. (2009, 24-25 Aug. 2009). *SQuaRE-Aligned Data Quality Model for Web Portals*. Paper presented at the Quality Software, 2009. QSIC '09. 9th International Conference on.

Morell, J. A., & Stewart, S. L. (1995). A Five-Segment Model for Standardization. In B. Kahin & J. Abbate (Eds.), *Standards Policy for Information Infrastructure* (pp. 198-219). Cambridge: The MIT Press.

Mori, A. R., & Consorti, F. (1998). Integration of clinical information across patient records: a comparison of mechanisms used to enforce semantic coherence. *IEEE Transactions on Information Technology in Biomedicine, 2*(4), 243-253.

Mykkanen, J. A., & Tuomainen, M. P. (2008). An evaluation and selection framework for interoperability standards. *Information and Software Technology, 50*(3), 176-197.

Naudet, Y., Latour, T., Guedria, W., & Chen, D. (2010). Towards a systemic formalisation of interoperability. *Computers in Industry, 61*(2), 176-185.

Nelson, M., Shoonmaker, M., Shaw, M., Shen, S., & Wang, R. (2002). Modularized Interoperability in Supply-Chains: A Coadoption study of RosettaNet's XML-based Interorganizational Systems. In M. J. Shaw (Ed.), *E-Business Management - Integration of Web Technologies with Business Models* (pp. 417-438). Boston, Dordrecht and London: Kluwer.

Nelson, M. L., Shaw, M. J., & Qualls, W. (2005). Interorganizational System Standards Development in Vertical Industries. *Electronic Markets, 15*(4), 378-392.

Nickerson, J. V., & Zur Muehlen, M. (2006). The ecology of standards processes: Insights from internet standard making. *MIS Quarterly: Management Information Systems, 30*(SPEC. ISS.), 467-488.

Nurmilaakso, J. M., & Kotinurmi, P. (2004). A review of XML-based supply-chain integration. *Production Planning and Control, 15*(6), 608-621.

Nurmilaakso, J. M., Kotinurmi, P., & Laesvuori, H. (2006). XML-based e-business frameworks and standardization. *Computer Standards and Interfaces, 28*(5), 585-599.

O'Brien, L., Bass, L., & Merson, P. (2005). *Quality Attributes and Service-Oriented Architectures*: Carnegie Mellon University, Software Engineering Institute.

Owlia, M. S. (2010). A framework for quality dimensions of knowledge management systems. *Total Quality Management, 21*(11), 1215-1228.

Park, J., & Ram, S. (2004). Information systems interoperability: What lies beneath? *ACM Transactions on Information Systems, 22*(4), 595-632.

Park, S. (2006). Standardization and Network Externalities. In K. Jakobs (Ed.), *Advanced Topics in Information Technology Standards and Standardization Research* (Vol. 1, pp. 251-281). Hershey: Idea Group Publishing.

Pawlowski, J. M., & Kozlov, D. (2010). Analysis and Validation of Learning Technology Models, Standards and Specifications: The Reference Model Analysis Grid (RMAG). *International Journal of IT Standards and Standardization Research, 8*(2), 1-19.

Pedersen, M. K., Fomin, V. V., & Vries, H. J., de. (2009). Open Standards and Government Policy. In K. Jakobs (Ed.), *Information Communication Technology Standardization for E-Business Sectors; Integrating Supply and Demand Factors* (pp. 188-199). Herhey: Information Science Reference.

Perera, C. (2007). Standardization and Innovation. In W. Hesser (Ed.), *Standardisation in Companies and Markets* (pp. 307-380). Hamburg: Helmut Schmidt University.

Petter, S., Delone, W., & McLean, E. (2008). Measuring information systems successmodels, dimensions, measures, and interrelationships. *European journal of information systems : an official journal of the Operational Research Society, 17*(3), 236.

Pham, T. H. (2007). Economic Aspects of Standardization. In W. Hesser (Ed.), *Standardisation in Companies and Markets* (pp. 77-122). Hamburg: Helmut Schmidt University.

Pindar, A. (2010). *Standardization for a competitive and innovative Europe: a vision for 2020 - Report of the expert panel for the review of the European Standardization System* (No. EXP 384 final).

Rachuri, S. (2007). *Science based information metrology for engineering informatics.* Paper presented at the Performance Metrics for Intelligent Systems (PerMIS) Workshop, Gaithersburg, MD.

Rada, R. (1993). Standards: the language for success. *Communications of the ACM, 36*(12), 17-23.

Rada, R. (1995). Consensus versus speed. *Communications of the ACM, 38*(10), 21-23.

Rada, R. (1998). Corporate shortcut to standardization. *Communications of the ACM, 41*(1), 11-15.

Rada, R. (2000). Consensus versus Speed. In K. Jakobs (Ed.), *Information Technology Standards and Standardization: A Global Perspective* (pp. 19-34). Hershey: Idea Group Publishing.

Rada, R., & Berg, J. (1995). Standards: free or sold? *Communications of the ACM, 38*(2), 23-27.

Rada, R., Cargill, C., & Klensin, J. (1998). Consensus and the Web. *Communications of the ACM, 41*(7), 17-22.

Rada, R., & Ketchell, J. (2000). Sharing standards: standardizing the European information society. *Communications of the ACM, 43*(3), 21-25.

Rebstock, M. (2009). Semantic ambiguity: Babylon, Rosetta or beyond? *Communications of the ACM, 52*(5), 145-146.

Reinstaller, A. (2008). Economic Analysis of Technological Standards and Standard Setting. In A. Hommels, J. Schueler & A. Fickers (Eds.), *Bargaining Norms Arguing Standards* (pp. 70-85). The Hague: STT.

Rodriguez, N., & Casanovas, J. (2010). *A structural model of information system quality; an empirical research.* Paper presented at the AMCIS 2010, Lima, Peru.

Rogers, E. M. (2003). *Diffusion of Innovations* (5th ed.). New York: Free Press.

Rukanova, B. (2005). *Business transactions and standards : towards a system of concepts and a method for early problem identification in standa[r]d implementation projects.* Enschede.

Rukanova, B., Wigand, R. T., & Tan, Y. H. (2009). From national to supranational government inter-organizational systems: An extended typology. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 5693 LNCS*, 317-327.

Rukanova, B. D., Van Slooten, K., & Stegwee, R. A. (2006). Business Process Requirements, Modeling Technique and Standard: how to Identify Interoperability Gaps on a Process Level. In D. Konstantas, J.-P. Bourrières, M. Léonard & N. Boudjlida (Eds.), *Interoperability of Enterprise Software and Applications* (pp. 13-23). London: Springer-Verlag.

Sahay, R., Akhtar, W., & Fox, R. (2008). *PPEPR: Plug and play Electronic Patient Records.* Paper presented at the Proceedings of the ACM Symposium on Applied Computing, Fortaleza, Ceara.

Samuelson, P. (2006). Copyrighting standards. *Communications of the ACM, 49*(6), 27-31.

Schwind, M., Stockheim, T., & Weiss, K. (2008). A Diffusion Model for Communication Standards in Supply Networks. In K. Jakobs (Ed.), *Standardization Research in Information Technology: New Perspectives* (pp. 105-121). Hershey: Information Science Reference.

Sedera, D., & Gable, G. (2004). *A Factor and Structural Equation Analysis of the Enterprise Systems Success Measurement Model.* Paper presented at the ICIS 2004.

Shapiro, C., & Varian, H. R. (1999a). The Art of Standards Wars. *California Management Review, 41*(2), 8-32.

Shapiro, C., & Varian, H. R. (1999b). *Information rules; a strategic guide to the network economy*. Boston, MA: Harvard Business School Press.

Sherif, M. H. (2006). Standards for Telecommunication Services. In K. Jakobs (Ed.), *Advanced Topics in Information Technology Standards and Standardization Research* (Vol. 1, pp. 183-205). Hershey: Idea Group Publishing.

Sherif, M. H., Jakobs, K., & Egyedi, T. M. (2007). Standards of quality and quality of standards for Telecommunications and Information Technologies. In M. Hörlesberger, M. El-nawawi & T. Khalil (Eds.), *Challenges in the Management of New Technologies* (pp. 427-447). Singapore: World Scientific Publishing Company.

Simcoe, T. (2007). Delay and de jure standardization: exploring the slowdown in Internet standards development. In S. Greenstein & V. Stango (Eds.), *Standards and Public Policy* (pp. 260-295). Cambridge: Cambridge University Press.

Simons, C. A. J., & De Vries, H. J. (2002). *Standaard of Maatwerk, Bedrijfskeuzes tussen uniformiteit en verscheidenheid*. Schoonhoven: Academic Services.

Söderström, E. (2004). Formulating a general standards life cycle. *Lecture Notes in Computer Science, 3084*, 263-275.

Song, M., Jiang, H., Lu, T., & Wu, H. (2007). Case Study: Quality Management Methods and ISO 9000 Quality System Certification. In W. Hesser (Ed.), *Standardisation in Companies and Markets* (pp. 687-724). Hamburg: Helmut Schmidt University.

Song, M., Jiang, H., & Wu, H. (2007). International Standardization. In W. Hesser (Ed.), *Standardisation in Companies and Markets* (pp. 347-380). Hamburg: Helmut Schmidt University.

Spivak, S. M., & Brenner, F. C. (2001). *Standardization essentials: principles and practice*. New York [etc.]: Dekker.

Stango, V. (2004). The Economics of Standards Wars. *Review of Network Economics, Volume 3*(Issue 1).

Steel, K. (1994). Another Approach to Standardising EDI. *Electronic Markets* (12), 9-10.

Stegwee, R. A., & Rukanova, B. D. (2003). Identification of Different Types of Standards for Domain-Specific Interoperability (pp. 161-170).

Steinfield, C. W., Wigand, R. T., Markus, M. L., & Minton, G. (2007). Promoting e-business through vertical IS standards: lessons from the US home mortgage industry. In S. Greenstein & V. Stango (Eds.), *Standards and Public Policy* (pp. 160-207). Cambridge: Cambridge University Press.

Suarez, F. F. (2003). Battles for technological dominance: an integrative framework. *Research Policy, 2004*(33), 271-286.

Swann, P. (2000). *The Economics of Standardization*.

Swann, P. (2009). *The Economics of Metrology and Measurement*.

Swann, P. (2010). *The Economics of Standardization: An update*.

Swatman, P. M., Swatman, P. A., & Fowler, D. C. (1994). A model of EDI integration and strategic business reengineering. *Journal of Strategic Information Systems, 3*(1), 41-60.

Tanenbaum, A. S. (1989). *Computer networks*. Englewood Cliffs, N.J.: Prentice-Hall.

Teichmann, H. (2010). *Effectiveness of Technical Experts in International Standardization*. Paper presented at the 15th EURAS Annual Standardisation Conference "Service Standardization", Lausanne.

Teichmann, H., Vries, H. J., de, & Feilzer, A. (2008). Linguistic Qualities of International Standards. In K. Jakobs (Ed.), *Standardization Research in Information Technology: New Perspectives* (pp. 86-103). Hershey: Information Science Reference.

Thissen, W. A. H., & Stam, W. J. (1992). Electronic data interchange in an industrial sector: The case of The Netherlands' building industry. *Information and Management, 23*(1), 15-30.

Thomas, J. W., Probets, S., Dawson, R., & King, T. (2008). A Case Study of the Adoption and Implementation of STEP. In T. M. Egyedi & K. Blind (Eds.), *The Dynamics of Standards* (pp. 117-134). Cheltenham: Edward Elgar.

Thomas, J. W., Probets, S., Dawson, R., & King, T. (2010). A Step Towards the Adoption of Standards Within the UK Ministery of Defence. In K. Jakobs (Ed.), *New Applications in IT Standards - Development and Progress* (pp. 54-69). Hershey - New York: Information Science Reference.

Tolk, A. (2003). *Beyond Technical Interoperability – Introducing a Reference Model for Measures of Merit for Coalition Interoperability*. Paper presented at the International Command and Control Research and Technology Symposium.

Tolk, A., Turnitsa, C. D., Diallo, S. Y., & Winters, L. S. (2006). Composable M&S Web Services for Net-Centric Applications. *JDMS, 3*(1), 27-44.

Ullberg, J., Chen, D., & Johnson, P. (2009). Barriers to Enterprise Interoperability. In R. Poler, M. Sinderen & R. Sanchis (Eds.), *Enterprise Interoperability* (Vol. 38, pp. 13-24): Springer Berlin Heidelberg.

Updegrove, A. (1995). Consortia and the Role of the Government in Standard Setting. In B. Kahin & J. Abbate (Eds.), *Standards Policy for Information Infrastructure* (pp. 321-350). Cambridge: MIT Press.

Updegrove, A. (2007). The Essential Guide to Standards. Retrieved 01-05, 2011, from http://www.consortiuminfo.org/essentialguide/forming1.php

Van Blommestein, F. (2007). Decentralized Metadata Development for Open B2B Electronic Business. In G. Doumeingts, J. Müller, G. Morel & B. Vallespir (Eds.), *Enterprise Interoperability* (pp. 355-364): Springer London.

Van de Kaa, G. (2009). *Standards Battles for Complex Systems; Empirical Research on the Home Network*. Rotterdam School of Management, Rotterdam.

Van der Veer, H., & Wiles, A. (2006). *Achieving Technical Interoperability - the ETSI approach*. Sophia Antipolis Cedex: ETSI.

Van Lier, B. (2009). *Luhmann ontmoet "The Matrix"*. Erasmus University, Rotterdam.

Van Wegberg, M. (1999). The Design of Standardisation Processes in ICT: An evolutionary transaction cost approach.

Van Wegberg, M. (2006). Standardization and Competing Consortia: The Trade-Off between Speed and Compatability. In K. Jakobs (Ed.), *Advanced Topics in Information Technology Standards and Standardization Research* (Vol. 1, pp. 111-127). Hershey: Idea Group Publishing.

Van Wessel, R. M. (2008). *Realizing business benefits from company IT standardization; case study research into the organizational value of IT standards, towards a company IT standardization management framework*. CentER, Tilburg University, Tilburg.

Van Zeist, B., Hendriks, P., Paulussen, R., & Trienekens, J. (1996). *Kwaliteit van softwareproducten; praktijkervaringen met een kwaliteitsmodel*: Kluwer Bedrijfsinformatie.

Van Zeist, R. H. J., & Hendriks, P. R. H. (1996). Specifying software quality with the extended ISO model. *Software Quality Journal, 5*(4), 273-284.

Venkatraman, S., Bala, H., Venkatesh, V., & Bates, J. (2008). Six strategies for electronic medical records systems. *Communications of the ACM, 51*(11), 140-144.

Von Westarp, F., Weitzel, T., Buxmann, P., & Köning, W. (2000). The Standardization Problem in Networks - A General Framework. In K. Jakobs (Ed.), *Information Technology Standards and Standardization: A Global Perspective* (pp. 168-185). Hershey: Idea Group Publishing.

Wagner, C. S., Cargill, C. F., & Slomovic, A. (1995). Open Systems Standards in Manufacturing: Implications for the National Information Infrastructure. In B. Kahin & J. Abbate (Eds.), *Standards Policy for Information Infrastructure* (pp. 178-197). Cambridge: The MIT Press.

Wand, Y., & Wang, R. Y. (1996). Anchoring Data Quality Dimensions in Ontological Foundations. *Communications of the Acm, 39*(11), 86-95.

Wang, E. T. G., & Seidmann, A. (1995). Electronic data interchange: competitive externalities and strategic implementation policies. *Management Science, 41*(3), 401-418.

Wang, R. Y., & Strong, D. M. (1996). Beyond Accuracy: What Data Quality Means to Data Consumers. *Journal of Management Information Systems, 12*(4), 5-33.

Wapakabulo Thomas, J. (2010). *Data-Exchange Standards and International Organizations - Adoption and Diffusion*. Hershey: Information Science Reference.

Washizaki, H., Hiraguchi, H., & Fukazawa, Y. (2008). A metrics suite for measuring quality characteristics of javabeans components, *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* (Vol. 5089 LNCS, pp. 45-60). Monte Porzio Catone.

Weissinger, R. (2010). *Economic and Social Benefits of Standards - The New "ISO Methodology"*. Paper presented at the 15th EURAS Annual Standardisation Conference "Service Standardization", Lausanne.

Weitzel, T., Beimborn, D., & König, W. (2006). A unified economic model of standard diffusion: The impact of standardization cost, network effects, and network topology. *MIS Quarterly: Management Information Systems, 30*(SPEC. ISS.), 489-514.

Weitzel, T., Wendt, O., Beimborn, D., & Köning, W. (2006). Network Effects and Diffusion Theory: Extending Economic Network Analysis. In K. Jakobs (Ed.), *Advanced Topics in Information Technology Standards and Standardization Research* (Vol. 1, pp. 282-305). Hershey: Idea Group Publishing.

Werle, R., & Iversen, E. J. (2006). Promoting Legitimacy in Technical Standardization. *Science, Technology & Innovation Studies, 2*(March 2006), 19-39.

West, J. (2007). The economic realities of open standards: black, white, and many shades of gray. In S. Greenstein & V. Stango (Eds.), *Standards and Public Policy* (pp. 87-122). Cambridge: Cambridge University Press.

Wigand, R. T., Markus, M. L., & Steinfield, C. W. (2005). Preface to the Focus Theme Section: Vertical Industry Information Technology Standards and Standardization. *Electronic Markets, 15*(4), 285 - 288.

Wigand, R. T., Steinfield, C. W., & Markus, M. L. (2005). Information technology standards choices and industry structure outcomes: The case of the U.S. home mortgage industry. *Journal of Management Information Systems, 22*(2), 165-191.

Wilson, S. (2010). Community-Driven Specifications: XCRI, SWORD, and LEAP2A. *International Journal of IT Standards and Standardization Research, 8*(2), 74-86.

Wybo, M. D., & Goodhue, D. L. (1995). Using interdependence as a predictor of data standards. Theoretical and measurement issues. *Information and Management, 29*(6), 317-329.

Zachman, J. A. (1997). Enterprise Architecture: The Issue of the Century. *Database Programming & Design, 10*(3), 44-53.

Zhao, K., Xia, M., & Shaw, M. J. (2005). Vertical e-business standards and standards developing organizations: A conceptual framework. *Electronic Markets, 15*(4), 289-300.

Zhao, K., Xia, M., & Shaw, M. J. (2007). An integrated model of consortium-based e-business standardization: Collaborative development and adoption with network externalities. *Journal of Management Information Systems, 23*(4), 247-271.

Zhu, H., & Fu, L. (2009). *Towards Quality of Data Standards: Empirical Findings from XBRL*. Paper presented at the ICIS 2009.

Zhu, H., & Wu, H. (2010). *Quality of XBRL US GAAP Taxonomy: Empirical Evaluation using SEC Filings*. Paper presented at the AMCIS 2010, Lima, Peru.

Zhu, K., Kraemer, K. L., Gurbaxani, V., & Xu, S. X. (2006). Migration to open-standard interorganizational systems: Network effects, switching costs, and path dependency. *MIS Quarterly: Management Information Systems, 30*(SPEC. ISS.), 515-539.

Zur Muehlen, M., Nickerson, J. V., & Swenson, K. D. (2005). Developing web services choreography standards - The case of REST vs. SOAP. *Decision Support Systems, 40*(1 SPEC. ISS.), 9-29.

Appendix A:
Quality in Other Domains

APPENDIX A

If you can't make it good, at least make it look good. (Bill Gates)

Standard's quality can learn a lot from other domains with a long and rich history in quality. This appendix will present the state of the art of quality in three areas of which the standards domain might re-use existing knowledge:

A.1 Quality in product engineering
A.2 Quality in software engineering
A3. Quality in information systems

The presented work and models might be suitable for standards as well; for instance many of the presented quality characteristic for software engineering and/or information systems might also be valid quality characteristics for standards. Unfortunately this is a new area of research as currently there is no existing research that validates this potential re-use.

A.1 Quality in product engineering

Quality has become a major topic since the reconstructions after the second world war until the eighties especially in the manufacturing industry, but later on it spread its wings beyond manufacturing to both private and public services (Ghobadian & Speller, 1994). Quality in product engineering is really associated with the philosophies of Guru's, like Juran, Crosby, Deming and many others like Feigenbaum, Groocock, Taguchi and Ishikawa.

Juran

Juran's Quality Control Handbook (Juran & Gryna, 1988) is one of the most influential works in product engineering. According to Juran the word quality has multiple meanings, of which two are dominant:

1. Quality consists of those product features which meet the needs of customers and thereby provide product satisfaction. (Product is the output of any process).
2. Quality consists of freedom from deficiencies.

For the company, the definition should be stated in terms of (1) meeting customer needs, and (2) freedom from deficiencies. Product deficiencies take such forms as late deliveries, field failures of goods, errors in invoices, etc. Each creates a problem for customers. A consequence of product deficiencies is that customers are dissatisfied. The customers are the implementers of the standard.

The definition Juran uses for quality is "Fitness for use" consisting of parameters like availability, reliability, maintainability, produce ability (manufacturability). The Quality Function is the entire collection of activities through which we achieve fitness for use, no matter where these activities are performed. The management of quality is done by using the three managerial processes of planning, control and improvement, known as Juran's Trilogy. Juran distinguishes five major dimensions or quality characteristics:

1. Quality of design – The design concept and its specification.
2. Quality of conformance – The match between actual product and design intent.
3. Availability – including reliability and maintainability. These are all time-oriented.
4. Safety – risk of injury due to product hazards.
5. Field use – product conformance and condition after it reaches the customer.

The work by Juran is a complete approach to quality aimed at the entire life cycle of the product, including design, manufacturing, vendor and customer relations and field service, and also on both technical and non-technical aspects (Ghobadian & Speller, 1994).

The costs of quality, a concept introduced by Juran, is nowadays very common in industry and one of the primary tasks of quality departments (Chase & Aquilano, 1995). These consist of:

1. Appraisal costs: inspection and tests costs.
2. Prevention costs: sum of all costs for prevention, including training personnel and redesign.
3. Internal failure costs: costs for defects in the system including re-work and repair.
4. External failure costs: customer warranty replacements, loss of customer goodwill, complaints handling.

Crosby

The work by Crosby (1979) is particularly famous regarding the measurement of quality. Crosby believes that it is a common misbelief that quality is intangible and not measurable. In contrast, quality is measured by the cost of quality which is at the expense of non-conformance. Another misbelief is that there exists an economics of quality, used as an explanation that quality is not relevant in your situation. According to Crosby, quality should be read as "Conformance to requirements", which is a supply-led definition and aims at making quality tangible, manageable and measurable. It focuses on prevention instead of inspection: Zero defects and getting it right the first time. The quality management maturity grid, ranging from uncertainty to certainty, is part of Crosby's work and nowadays is also used in software engineering.

Deming

The name of Deming (1986) is most often associated with the famous Plan Do Act Check circle, also known as the Deming Wheel, which is an instrument for quality management. However Deming's contribution is much more influential; based on his work in Japan (and later at Ford Motor Company) he introduced a philosophy in which quality is related to customer satisfaction in contrast to customers' needs. Statistical methods for quality control play an essential role in his philosophy.

A comparison

In literature, the three gurus (Deming, Juran, Crosby) have been compared based on a framework (table below) (Chase & Aquilano, 1995; Ghobadian & Speller, 1994).

	Crosby	Deming	Juran
Definition of quality	Conformance to requirements (supply-led)	A predictable degree of uniformity and dependability at low cost and suited to the market (customer-led)	Fitness for use (satisfies customer's needs) (customer-led)
General approach	Prevention, not inspection	Reduce variability by continuous improvement; cease mass inspection	General management approach to quality, especially human elements
Applicability	Manufacturing emphasis	Manufacturing emphasis	Manufacturing and services
Structure	14 steps to quality improvement	14 points for management	10 steps to quality improvement
Main emphasis	Conformance to requirements/performance	Process	People
Dominant factor	Zero defects	Control of variation	Fitness for purpose

Table 18 - Comparison of quality guru's (a combination of Chase and Aquilano (1995) and Ghobadian and Speller (1994)).

There are many more definitions of quality from the domain of product engineering, for instance ANSI/ASQC Standard A3-1987 defines quality as the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs.

Other gurus also have some distinct characteristics within their philosophies. For instance Ishikawa links quality to education by insisting on teaching every employee the seven tools of quality (Ghobadian & Speller, 1994):

1. Process flow diagrams – what is done.
2. Check sheets/tally charts – How often it is done.
3. Histograms – What do the overall variations look like.
4. Pareto analysis – What are the significant problems.
5. Cause-and-effect analysis – What causes the problems, and brainstorming.
6. Scatter diagrams – What are the relationships between factors.
7. Control charts – Which variations to control and how.

Total Quality Management

Further to the distinctions between the philosophies of the guru's, there are also many points in common, like the importance of:

1. Controlling the process and not the product.
2. Not forgetting the human process.
3. The role of top management (responsible, commitment, etc.).
4. Education and training.
5. Prevention not inspection.
6. All aspects should be looked at; functional integration (Total Quality Management).

Feigenbaum and Juran (Song, Jiang, Lu, & Wu, 2007) introduced Total Quality Management (TQM) in the sixties. They proposed the following theories:

- Statistical methods are not sufficient and therefore, quality management should also consider quality, price, delivery date, and service instead of just the narrow management quality concept.
- There exists a process of emergence, formation and realization, which requires quality management to implement integrated management in the whole process of quality formation instead of just stressing management in the production process.
- Quality involves all the departments and staff in an enterprise, so all members should be conscious of and responsible for quality.

TQM can be defined as "Managing the entire organization so that it excels" (Chase & Aquilano, 1995). Other concepts like the Deming Wheel and the House of Quality (Quality Function Deployment) fit as tools within TQM (Chase & Aquilano, 1995; Song, Jiang, Lu et al., 2007). The philosophy that product and process improvement is a never-ending process is known as

Continuous Improvements (CI), an integral part of TQM, with two distinguishable elements (Chase & Aquilano, 1995):

1. Management's view of performance standards of the organization.
2. The way management views the contribution and role of its workforce.

Different types of quality

Within the world of physical products a differentiation between the quality of the design and the quality of the manufacturing process is quite common. There are however many different approaches to quality, like Garvin (1984):

1. The transcendent approach.
2. The product-based approach.
3. The user-based approach.
4. The manufacturing approach.
5. The value-based approach.

Juran's definition of fitness for use is a user-based approach, while Crosby's conformance to requirements is exemplary for the manufacturing approach. Other terms often used are design and conformance quality (Chase & Aquilano, 1995). Design quality refers to the inherent value of the product in the marketplace and is thus a strategic decision for the firm. The dimensions of design quality are (Chase & Aquilano, 1995):

- Performance: Primary product or service characteristics.
- Features: Added touches, bells and whistles, secondary characteristics.
- Reliability: Consistency of performance over time.
- Durability: Useful life.
- Serviceability: Resolution of problems and complaints.
- Response: Characteristics of the human-to-human interface (timeliness, courtesy, professionalism, etc.).
- Aesthetics: Sensory characteristics (sound, feel, look, etc.).
- Reputation: Past performances and other intangibles.

Conformance quality refers to the degree to which the product or service design specifications are met. A product/service can have a high design quality and low conformance quality, and vice versa.

A.2 Quality in software engineering

The overall quality level of software is low (Davenport, 2005), which might explain research attention on quality within the software engineering domain. 30 years have passed since the uprise of this subject, but it has still not really penetrated into mainstream software engineering (Fenton & Neil, 2000). The APGAR score (for newborn babies) is also requested for software (Glass, 2008). A 2002 study from the U.S. National Institute for Standards and Technology estimated that software bugs cost the U.S. economy almost $60 billion a year (Davenport, 2005). The quality and cost problem of software development have led to the development of the Capability Maturity Model (CMM) by the Carnegie Mellon's Software Engineering Institute (SEI) in 1987. According to Davenport (2005) CMM has become such a huge success because of its simplicity, government support, its governance structure, and its flexibility in application within organizations.

Software engineering builds on the quality knowledge from the product engineering domain. CMM is based on Demings work (statistical process control) and Juran's (costs of quality), while the basis for the model is Crosby's quality management maturity grid (Humphrey, 1989). CMM uses Crosby's definition regarding quality: conformance to requirements (Humphrey, 1997). CMM distinguishes between product and process quality.

The cost of quality (Humphrey, 1997) is:

- Failure costs: the costs of diagnosing a failure, making necessary repairs, and getting back into operation.
- Appraisal costs: the costs of evaluating the product to determine its quality level.
- Prevention costs: the costs associated with identifying the causes of the defects and the actions taken to prevent them in the future.

The Software Process Improvement (SPI) cycle which is part of CMM that is based on Crosby, contains the following steps (Humphrey, 1989):

1. Understand the current status of their development process or processes.
2. Develop a vision of the desired process.
3. Establish a list of required process improvement actions in order of priority.
4. Produce a plan to accomplish the required actions.
5. Commit the resources to execute the plan.
6. Start over at step 1.

Crosby (1979) defines 5 maturity levels: Uncertainty, Awakening, Enlightenment, Wisdom, Certainty. In line with this, CMM presents its Process Maturity Levels (Humphrey, 1989, 1997):

1. Initial: undocumented and in a state of dynamic change, reactive.
2. Repeatable: some processes are repeatable, possibly with consistent results.
3. Defined: sets of defined and documented standard processes established and subject to some degree of improvement over time.
4. Managed: using process metrics, management can effectively control the software development process.
5. Optimizing: continually improving process performance.

CMM is focused on making things measurable, following consistent process definitions to coordinate the work and track the progress (Humphrey, 1997). It defines classes of quality measures, puts attention to a "Software Quality Program", for which even the structure is (IEEE) standardized (Humphrey, 1989).

Estimating software quality: for instance a graph (and a comparison is made with previous software programs): how many faults are gathered in each development phase? (The same could be true for standards: how many RFCs within each development phase of the standard?).

Capability Maturity Model Integration (CMMI) has been, since 2002, the follow up of CMM. It makes a distinction between development (of products and services), services (management and delivery) and acquisition[1]. The concept of CMM has been copied to maturity models for other subjects like the Maturity Model for Enterprise Interoperability (Guedria et al., 2009).

More than CMM

But software quality does not end with CMM or CMMI, there is more. There are many ISO standards for the software domain that cover quality issues as well. For instance the concept of usability has been addressed in the following ISO standards (Abran, Khelifi, & Suryn, 2003):

1. Product-oriented standards: ISO 9126, ISO 14598 (software product evaluation).
2. Process-oriented standards: ISO 9241, ISO 13407.

[1] (http://en.wikipedia.org/wiki/Capability_Maturity_Model_Integration)

The different standards are not coherent, which is shown by the different definitions of usability they use (Abran et al., 2003). Within ISO the JTC 1 (Information Technology) and then the SC7 (Software and Systems Engineering) are responsible for the release of a long list of standards, of which two are particularly interesting: 9126 and the latest 25000 family.

ISO 9126

This ISO standard consists of four parts related to a quality model, including metrics, for the software product. It actually consists of three quality models, making a distinction in (Castillo, Losavio, Matteo, & Boegh, 2010):

- Quality in use: Perceived quality by the end user in their context.
- Intrinsic: Static properties on the structure.
- Extrinsic: The product behavior in its environment.

Quality in use consists of a model consisting of attributes effectiveness, productivity, safety and satisfaction, as shown in the following figure. The metrics for quality in use have been defined within part four of this ISO standard (ISO/IEC, 2004). The same quality model is used for intrinsic and extrinsic, as shown in figure 17.

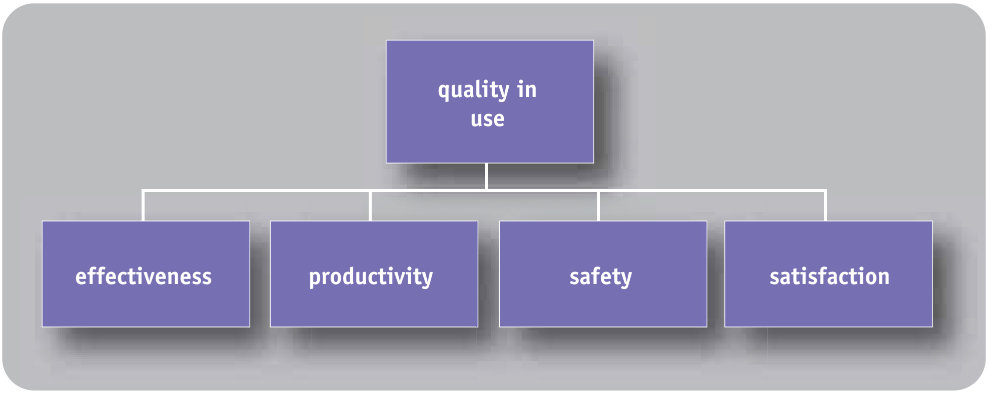


Figure 16 - Quality in Use model (ISO/IEC, 2001).

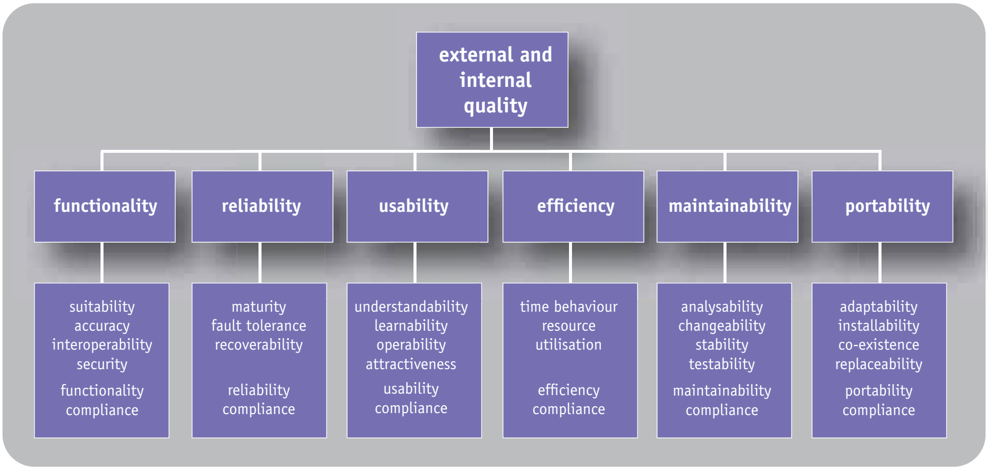


Figure 17 - External and internal quality model (ISO/IEC, 2001).

The external metric for this quality model are presented in ISO 9126 part 2 (ISO/IEC, 2003a), while the internal quality metrics are available within ISO 9126 part 3 (ISO/IEC, 2003b). ISO 9126 is the intended quality model, to be used in conjunction with ISO 14598 (ISO/IEC, 1999), which defines the process of software evaluation.

Figure 18 - ISO 14598: The process of software evaluation (simplified version).

ISO 25000 family

In recent years the ISO 9126 standard is often used, and work has been done to the follow-up of this standard. However the situation has become much more complex with the introduction of the ISO 25000 SQuaRE (Software product Quality Requirements and Evaluation) family.

ISO 25000 consists of 17 documents, which makes it quite difficult and expensive to understand, since all documents should be bought from ISO. The family of specifications is structured as follows:

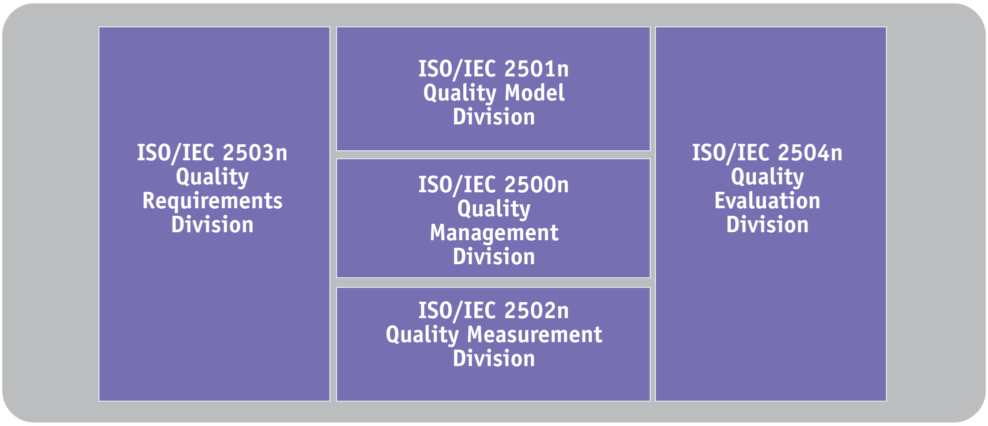


Figure 19 – Organization of the SQuaRE series of standards (Abran, Moore, Bourque, & Dupuis, 2004; Castillo et al., 2010).

ISO 9126-1 has been superseded by ISO 25010, the system and software quality model. The following figure contains the new quality attributes to which Information Quality has already been added in particular to evaluate Web applictions (Lew, Olsina, & Zhang, 2010). The second figure consists of the new quality in use model, also adapted by adding learnability of web applications. Overall it is a slight enhancement of the old 9126-1 model; a comparison is available within literature (Lew et al., 2010).

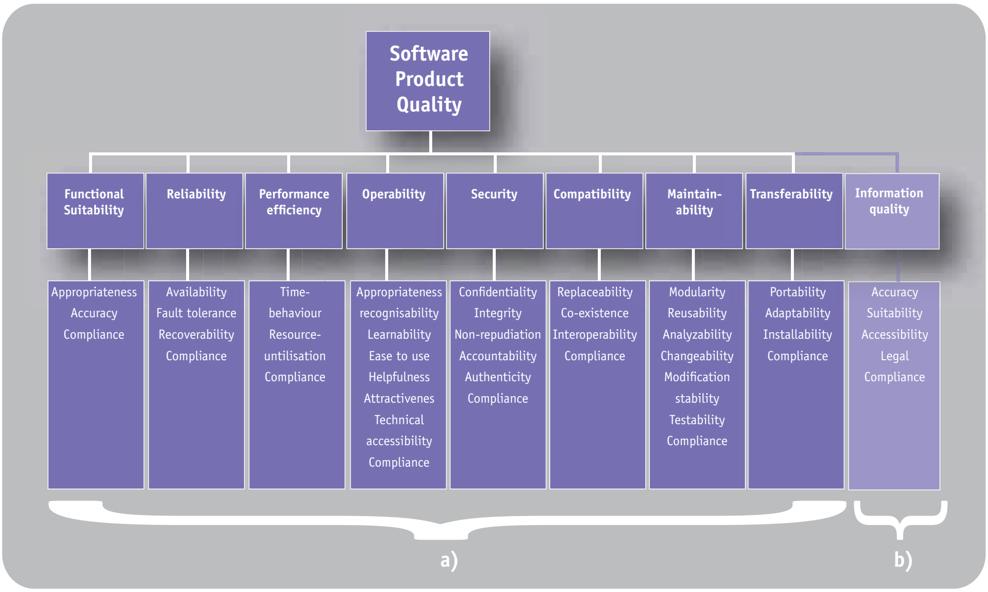


Figure 20 – Product Quality Model (a) with an extension for web applications (b) (Lew et al., 2010).

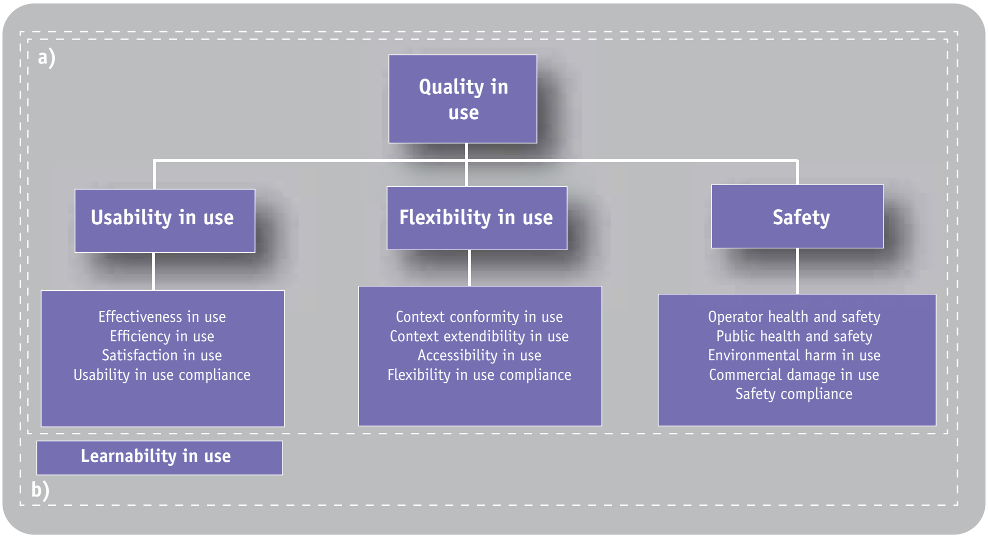


Figure 21 – Quality in Use model (a) with an extension for web applications (b) (Lew et al., 2010).

New within the family and intended to be used together with ISO 25010 is the ISO 25012: Data Quality Model. This data model distinguishes inherent and system data quality, according to the following definitions (ISO/IEC, 2008):

- Inherent data quality refers to the degree to which quality characteristics of data have the intrinsic potential to satisfy stated and implied needs when data is used under specified conditions.
- System dependent data quality refers to the degree to which data quality is reached and preserved within a computer system when data is used under specified conditions.

Characteristics	DATA QUALITY	
	Inherent	System dependent
Accuracy	X	
Completeness	X	
Consistency	X	
Credibility	X	
Currentness	X	
Accessibility	X	X
Complaince	X	X
Confidentiality	X	X
Efficiency	X	X
Precision	X	X
Traceability	X	X
Understandability	X	X
Availability		X
Portability		X
Recoverability		X

Table 19 – Data quality model from ISO 25012 (ISO/IEC, 2008).

Both ISO 25010 and 25012 have already been used or extended for specific purposes like web applications (Lew et al., 2010) or web portals (Moraga, Moraga, Calero, & Caro, 2009).

ISO 25030 is defined by a requirements engineering process in which quality requirements are included early in the life cycle of system development (Castillo et al., 2010). This standard is complementary to ISO 9126, since the software requirements (from ISO 9126) are a part within the larger categorization of elements that should be part of a requirements engineering study.

Arguably CMMi and ISO 9126 are currently the most commonly used quality concepts in software engineering practice. CMMi is most often used to organize the software development process. However a well-defined and structured developed process might still lead to undesired outcomes of the software engineering process. ISO 9126 is used to assess the outcome of the development process. CMMi and ISO 9126 together cover both the process and product quality for software engineering.

CMMi and the ISO standards are often used as foundations to build upon. For instance LaQuSo is a software product certification model that loosely builds on CMMi (Heck, Klabbers, & van Eekelen, 2010; Heck & Van Eekelen, 2008). For instance the Quint project has led to an extended ISO 9126 model (Van Zeist, Hendriks, Paulussen, & Trienekens, 1996; Van Zeist & Hendriks, 1996) which is a valuable extension of the ISO work. Also based on ISO 9126 is the developed instrument to measure the perceived quality, consisting of scoring 43 items (including functionality, reliability, etc.) on a 7-point Likert scale (Issac, Rajendran, & Anantharaman, 2006).

Certification of (adapted) models of ISO 9126 is also a possibility.

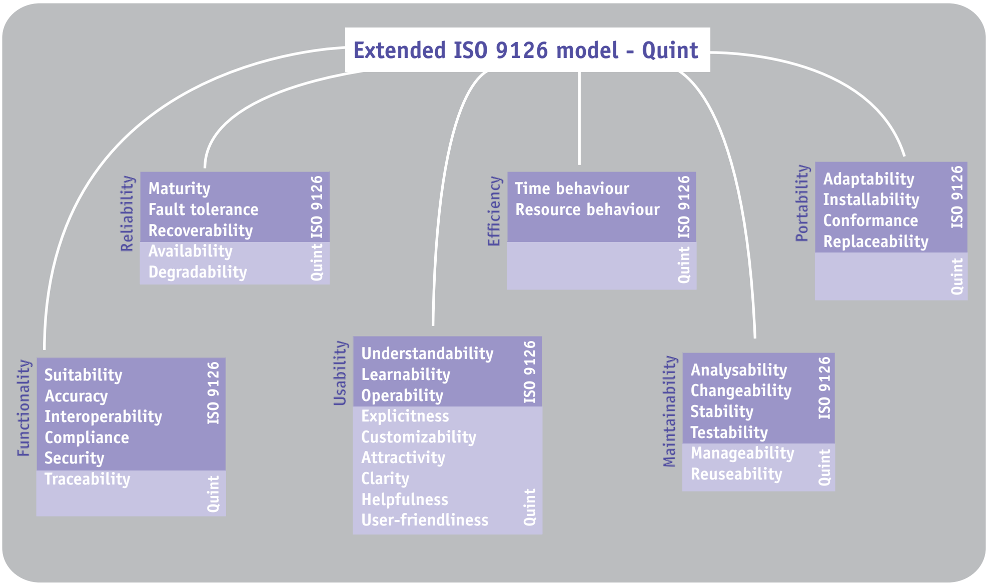


Figure 22 – Example of extended ISO model (Van Zeist & Hendriks, 1996).

The pre CMM and ISO era

The roots of CMM and ISO lie in former research studies on quality in software engineering. In particular ISO 9126 builds upon the work of Cavano and McCall (1978), McCall, Richards and Walters (1977), Boehm (1973); and Boehm, Brown and Lipow (1976).

The McCall quality model uses three major dimensions to define the quality of the software product: product revision (ability to undergo changes), product transition (adaptability to new environments) and product operations (its operation characteristics) (Milicic, 2005). Each contains the following quality factors:

- Product Revision: Maintainability, Flexibility and Testability.
- Product Transition: Portability, Reusability, Interoperability.
- Product Operations: Correctness, Efficiency, Reliability, Integrity, Usability.

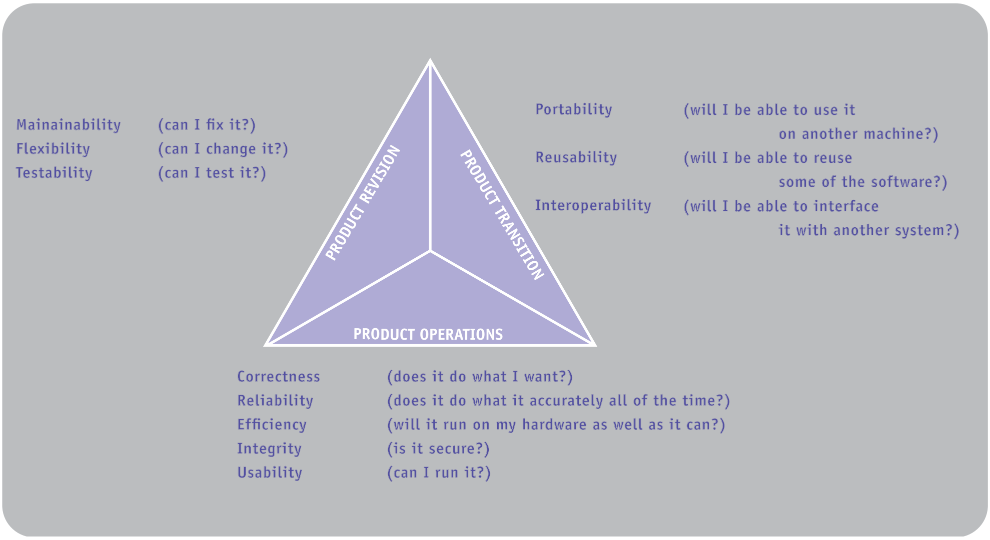


Figure 23 – McCall's quality model (Cavano & McCall, 1978).

As well as the three types of characteristics (major perspectives) and the eleven quality factors (to specify) the model hierarchy consists of twenty-three quality criteria (to build) and metrics (to control).

The Boehm quality model looks similar to the McCall quality model in the sense that there is a hierarchy of three layers called high-level, intermediate level, and primitive characteristics. The high-level characteristics address three main questions that a buyer of software has related to the general utility of software (Milicic, 2005):

- As-is utility: How well (easily, reliably, efficiently) can I use it as-is?
- Maintainability: How easy is it to understand, modify and retest?
- Portability: Can I still use it if I change my environment?

The intermediate level consists of 7 quality factors representing the qualities expected from software. The lowest level, the primitive characteristics, consists of 15 elements that provide the fundament for defining one or more metrics per primitive characteristic. Figure 20 shows the model.

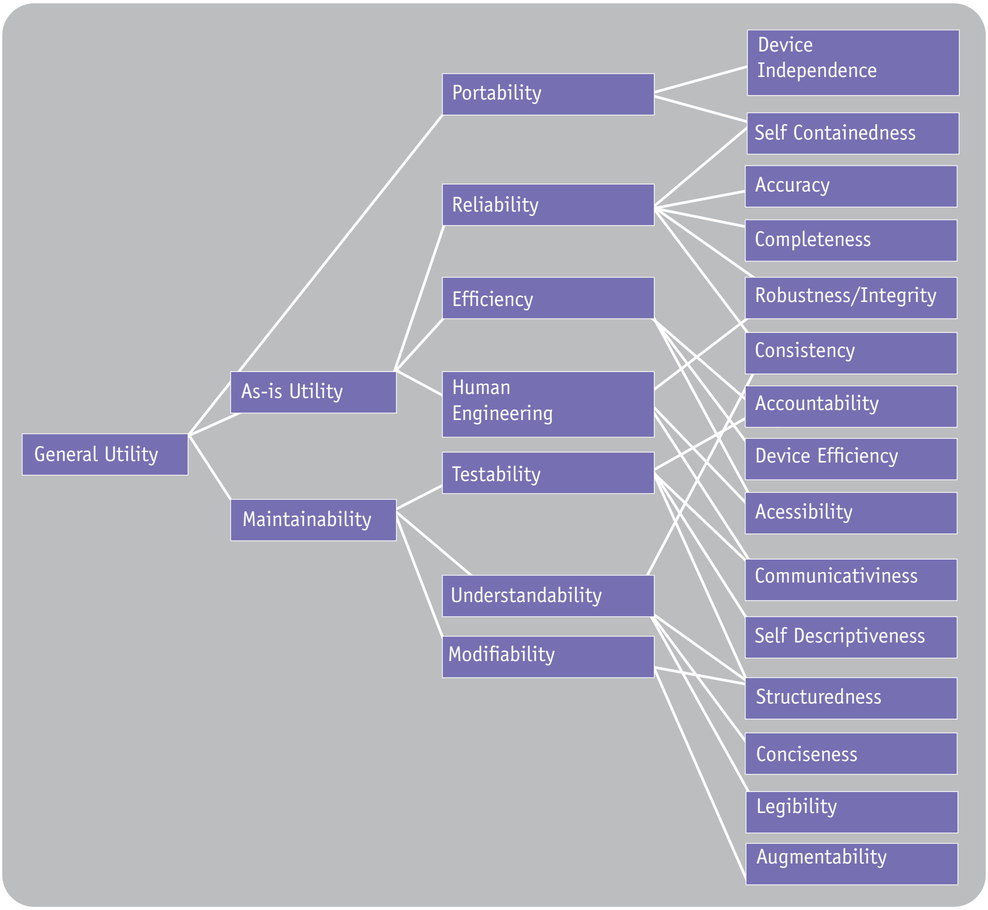


Figure 24 - Boehms quality model (Boehm, 1973; Milicic, 2005).

Although the similarities are clearly present, the major difference is that the McCall model primarily focuses on the precise measurement of the high-level characteristic (As-is utility) whereas Boehms model is much broader with more focus on maintainability.

But there are even more quality models for software engineering; worth mentioning are FURPS+, and Dromey's quality model. FURPS+ was developed by Robert Grady, and nowadays is part of the IBM Rational Software, and distinguishes functional (F) and non-functional (URPS) quality characteristics. FURPS stands for (Milicic, 2005):

- Functionality – which may include feature sets, capabilities and security.
- Usability - which may include human factors, aesthetics, consistency in the user interface, online and context-sensitive help, wizards and agents, user documentation and training materials.
- Reliability - which may include frequency and severity of failure, recoverability, predictability, accuracy and mean time between failure (MTBF).
- Performance - imposes conditions on functional requirements such as speed, efficiency, availability, accuracy, throughput, response time, recovery time and resource usage.
- Supportability - which may include testability, extensibility, adaptability, maintainability, compatibility, configurability, serviceability, installability and localizability (internationalization).

Dromey's quality model focuses on the relation between the quality attributes and the sub-attributes, as well as attempting to connect software product properties with software quality attributes. For easy usage, it includes a 5-step process model as well.

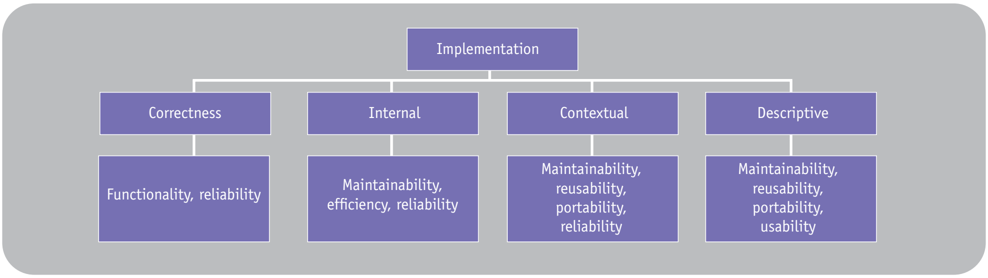


Figure 25 - Principles of Dromey's quality model (Milicic, 2005).

Although it seems that the software engineering domain has more than enough quality models, there are even more, created by specific consultancy companies, like the TMap quality approach by Sogeti. And not to forget the quality models for specific software languages, for instance for JavaBeans (Washizaki, Hiraguchi, & Fukazawa, 2008). However from a practical viewpoint it seems most obvious to concentrate on two models: CMMi and the ISO 25000 SQuaRE family.

A.3 Quality in information systems

Just as in the area of software quality, in the world of information systems the notion of quality is described by the introduction of 40 quality attributes (Delen & Rijsenbrij, 1992). It includes a process model called the quality loop for incorporating quality in the IS development process. This quality loop consists of three steps (quality requirements, quality engineering, and characteristics).

The quality notion is hierarchically decomposed into (4) dimensions, (21) aspects, and (40) quality attributes (Delen & Rijsenbrij, 1992).

	DIMENSION	Aspects / attributes			
	I PROCESS development and control of information systems Contribution by developer: IA by client: IB	1. Quality conditions a prof. skills b acount mgt. c project mgt. d system development	2. Quality control	3. Continuity	4. Completeness of services
			5. Delegation to third parties		
P R	II STATIC properties of the information system in mainenance & control	1. Flexibility	2. Maintainability	3. Testability	4. Portability
		5. Connectivity a external b internal	6. Reusability	7. Fitness of the infrastructure	
O D U C T	III DYNAMIC functioning of the system for the user	1. Reliability a correctness b completeness c authorizedness d timeliness	2. Continuity a uninterrupted b robustness c restorability d degradation possibility e diversion possibility	3. Efficiency a speed - internal - total b user-friendliness c economy d match with manual proc. e workability manual proc.	4. Effectiveness a coverage of bus. processes b availability - in time - on location c usability d decision support e end user support
	IV INFORMATION importance for company	1. Correctness		2. Completeness	5. Verifiability
		3. Up-to-dateness		4. Accuracy	

Figure 26 – Quality attributes (Delen & Rijsenbrij, 1992).

Although related to quality, but still different, the success of IS has been well studied and has resulted in outcomes like the Delone and McLean IS success model (DeLone & McLean, 1992). It divides the measures for MIS success into five categories: system quality, information quality, information use, user satisfaction, individual impact, organizational impact. By performing an extensive literature study they have come up with a list of measures.

The list of measures is a summary of the work done by many scholars, including the work of, for instance, King and Epstein (1982) who set up 10 attributes for information value: reporting cycle, sufficiency, understandability, freedom from bias, reporting-delay, reliability, decision relevance, cost efficiency, comparability and quantitativeness. Other included work is the study by Bailey and Pearson (1983) who, based on a study of 36 distinct factors of computer user satisfaction, identified the top 5: accuracy, reliability, timeliness, relevancy and confidence in a system.

The first figure is the IS success model. The second figure shows the summary of success measures.

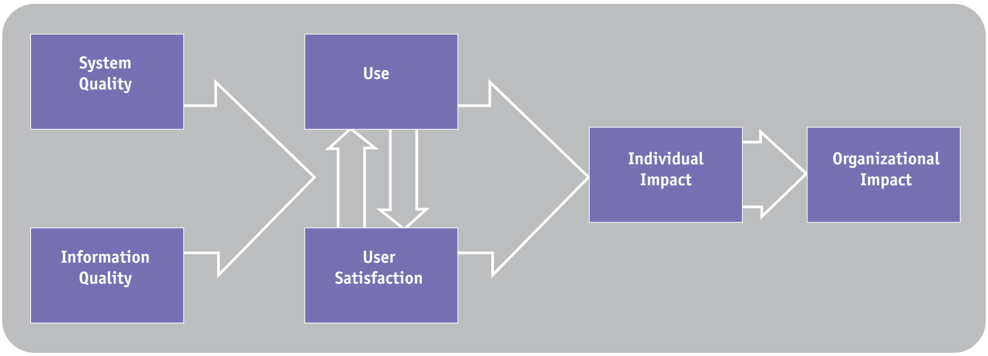


Figure 27 – Original IS success model (DeLone & McLean, 1992).

Important to stress here is that the main conclusion is that IS success is multidimensional and an interdependent construct. The list of measures should not be used as is but by combining measures to study interdependencies and to create a comprehensive measurement instrument (DeLone & McLean, 1992; Delone & McLean, 2003). When looking at the table the large number of quality attributes attracts attention.

System Quality	Information Quality	Information Use	User Satisfaction	Individual Impact	Organization Impact
Data accuracy Data currency Database contents Ease of use Ease of learning Convenience of access Human factors Realization of user requirements Usefulness of system features and functions System accuracy System flexibility System reliability System sophistication Integration of systems System efficiency Resource utilization Response time Turnaround time	Importance Relevance Usefulness Informativeness Usableness Understandability Readability Clarity Format Appearance Content Accuracy Precision Conciseness Sufficiency Completeness Rehability Currency Timeliness Uniqueness Comparability Quantitativeness Freedom from bias	Amount of use/ duration of use: Number of inquiries Number of functions used Number of records accessed Frequency of access Frequency of report requests Number of reports generated Charges for system use Regularity of use Use by whom? Direct vs. chauffeured use Binary use: Use vs. nonuse Actual vs. reported use Nature of use Use for intended purpose Appropriate use Type of information used Purpose of use Levels of use: General vs. specific Recurring use Institutionalization/ routinization of use Report acceptance Percentage use vs. opportunity for use Voluntariness of use Motivation to use	Satisfaction with specifics Overall satisfaction Single-item measure Multi-item measure Information satisfaction: Difference between information needed and received Enjoyment Software satisfaction Decision-making satisfaction	Information understanding Learning Accurate interpretation Information awareness Information recall Problem identification Decision effectiveness: Decision quality Improved decision analysis Correctness of decision Time to make decision Confidence in decision Decision-making participation Improved individual productivity Change in decision Causes management action Task performance Quality of plans Individual power or influence Personal valuation of I/S Willingness to pay for information	Application portfolio: Range and scope of application Number of critical applications Operating cost reductions Staff reduction Overall productivity gains Increased revenues Increased sales Increased market share Increased profits Return on investment Return on assets Ratio of net income to operating expenses Cost/benefit ratio Stock price Increased work volume Product quality Contribution to achieving goals Increased work volume Service effectiveness

Table 20 – Success Measures (DeLone & McLean, 1992).

Ten years later an update of the model was proposed by the same authors (Delone & McLean, 2003). The most distinctive changes in the new model are the addition of both service quality and net benefits. Service Quality is added to avoid too much focus on the product and on neglecting the service aspects. The 22-item SERVQUAL measurement instrument from marketing might be used as a fundament to measure this IS function. Net benefits have been included because the impact of the system goes beyond the individual user, but might have an impact on inter-organizational (industry), consumer or society aspects. Net benefits reflects the wide range of entities that might be affected by the IS function.

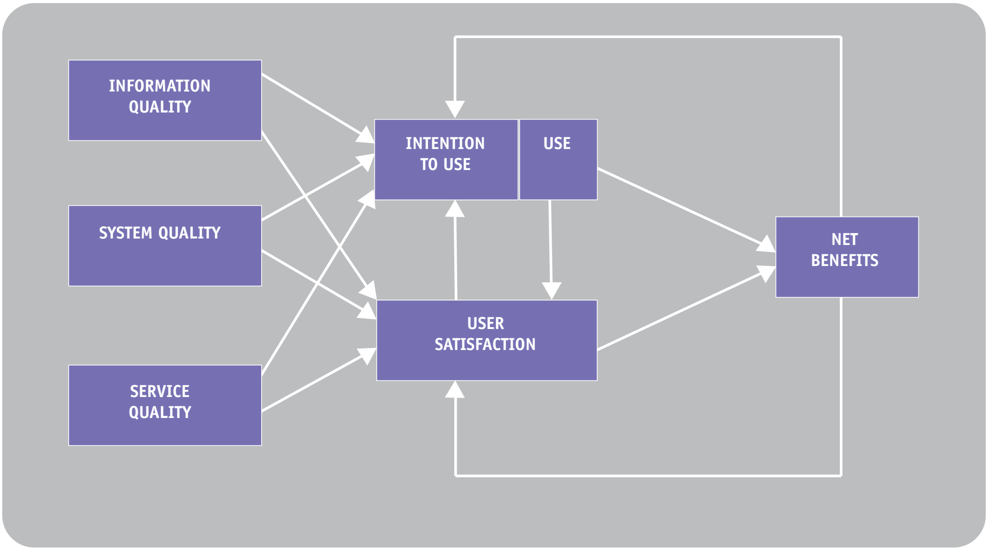


Figure 28 – Updated Delone & McLean IS Success Model (Delone & McLean, 2003).

By adding metrics to each of the six categories the model can be customized for specific applications. This is demonstrated for e-commerce in the following table:

Systems quality • Adaptability • Availability • Reliability • Response time • Usability	Information quality • Completeness • Ease of understanding • Personalization • Relevance • Security
Service quality • Assurance • Empathy • Responsiveness	Use • Nature of use • Navigation patterns • Number of site visits • Number of transactions executed
User satisfaction • Repeat pruchases • Repeat visits • User surveys	Net benefits • Cost savings • Expanded markets • Incremental additional sales • Reduced search costs • Time savings

Table 21 – Example of metrics (for E-Commerce success) within a model (Delone & McLean, 2003).

The Delone and McLean model is used by several researchers for validation or to propose other success models or IS quality models. An extensive summary of empirical studies used for the validation of the IS Success model has led to the search for supportive evidence, mainly at the individual level of analysis (Petter, Delone, & McLean, 2008).

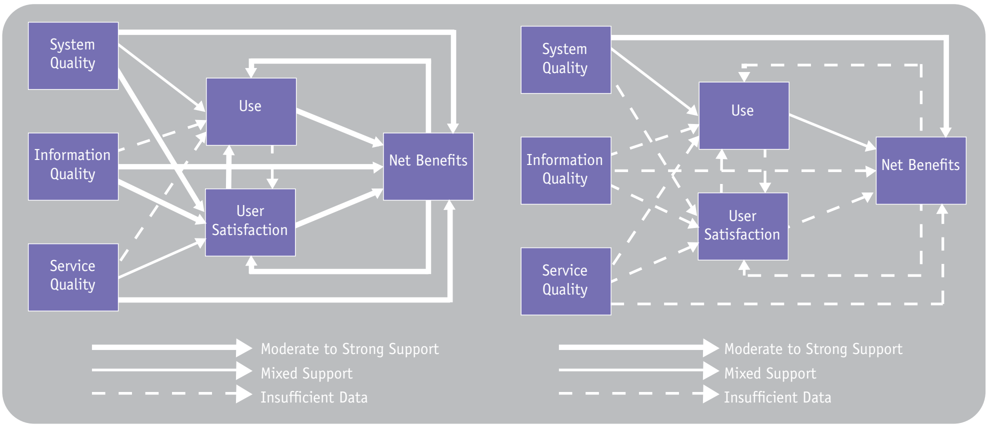


Figure 29 – Support for interrelationships between constructs. Left side at the individual level and right side at the organizational level of analysis (Petter et al., 2008).

Other research has focused on validating the measures to be used within the constructs. This has led to the validated Enterprise System Success model (Sedera & Gable, 2004) presented within figure 29. Also quality attributes have been researched for specific purposes like Knowledge Management (Owlia, 2010) and Service Oriented Architectures (O'Brien, Bass, & Merson, 2005). Recently a new IS quality model was presented that looks promising because of its focus on quality instead of success (Rodriguez & Casanovas, 2010). The hypotheses behind the model are not yet validated since it is research in progress.

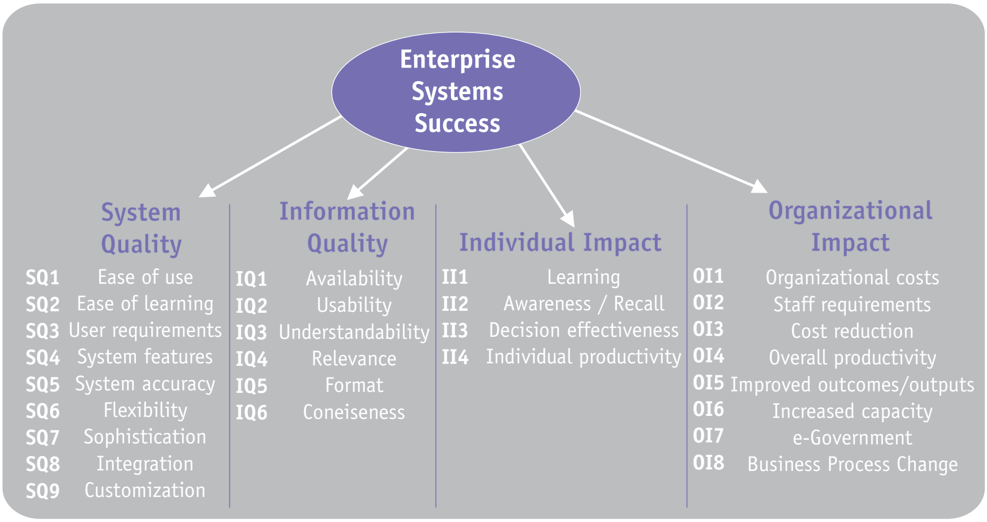


Figure 30 – Validated measures within the model for Enterprise System Success (Sedera & Gable, 2004).

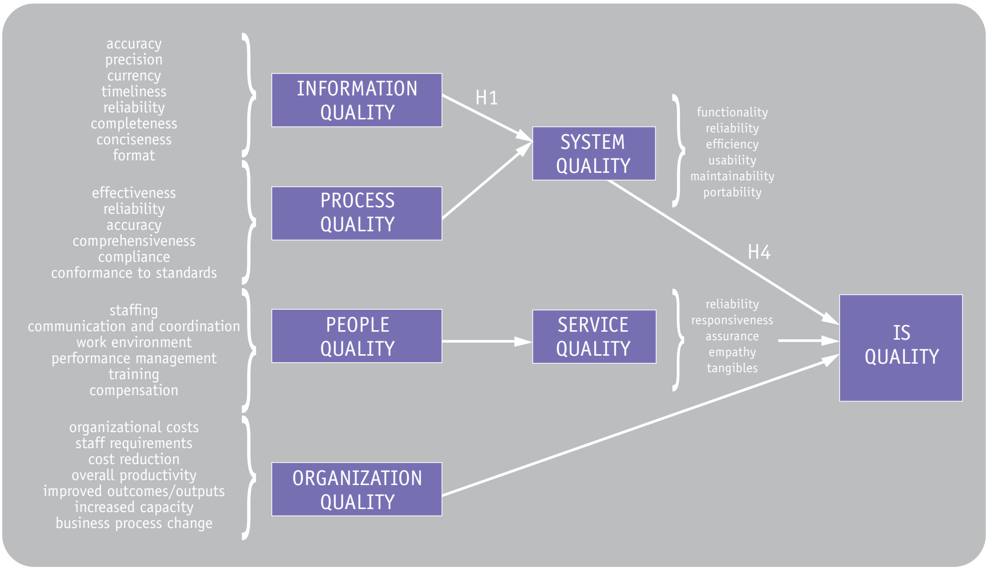


Figure 31 – Proposed IS quality model (Rodriguez & Casanovas, 2010).

The hypotheses suggest a positive relationship between the constructs. The suggested measures for each of the six qualities are as follows (Rodriguez & Casanovas, 2010):

- Information (or Data) Quality should be measured in terms of accuracy, precision, currency, timeliness, reliability, completeness, conciseness, format of input/output and relevance.
- System quality: proposed are the ISO 9126 measures: functionality, reliability, efficiency, usability, maintainability and portability.
- Service quality: proposed is SERVQUAL (from the marketing domain), which consists of five dimensions: reliability, responsiveness, assurance, empathy and tangibles.
- Process quality: proposed is to use CMMI-DEV for selecting terms like: effectiveness, reliability, accuracy, comprehensiveness, compliance and conformance to standards.
- Organization quality: measures proposed by Sedera et al: organizational costs, staff requirements, cost reduction, overall productivity, improved outcomes/outputs, increased capacity and business process change.
- People quality: measurements are proposed from the People Capability Maturity Model, level 2 (P-CMM); these are related to staffing, communication and coordination, work environment, performance management, training and development and compensation.

Ir. Erwin Folmer joined TNO in 2001 to lead the European OpenXchange project focused on ebXML. Since then he has been involved in standardization and interoperability research with a special interest in semantic standards (business transactions/vertical). He is involved in standards for the domains of temporary staffing industry and education, amongst others. As a standardization expert he has a role within the Netherlands Open in Connection team, a Dutch government program to improve the adoption of open standards (and open source software) in the Netherlands. From 2009 he joined the University of Twente part-time in order to start a PhD research project on standardization, while continuing his work for TNO. Erwin authored the freely available BOMOS book, a model for the development and management of semantic standards. A website dedicated to semantic standards, www.semanticstandards.org, is maintained by Erwin.

Dr. ir. Jack Verhoosel is Senior Business Consultant and Architect at TNO. He has a PhD in Computing Science. From 1994 he started working as a researcher and project manager at the Telematics Institute and Lucent Technologies Bell Labs. Since 2003, he works at TNO and is currently leading the group on Connected Business that focuses on the efficient and effective use of ICT for the cooperation between and coupling of organisations, i.e. interoperability. He specialises in interoperability, architecture and standardisation. Research topics include information standardisation, with a focus on standardisation processes, semantics and structuring of information and quality of standards and standardisation processes.

TNO innovation for life

NOV

UNIVERSITY OF TWENTE.

CTIT

This book contains a broad overview of relevant studies in the area of semantic IS standards. It includes an introduction in the general topic of standardization and introduces the concept of interoperability. The primary focus is however on semantic IS standards, their characteristics, and the quality of standards. Sidesteps are made to the economics of standards, the development & adoption of semantic IS standards, and the latest trends in the area of standardization.

The reader will get a basic understanding of a huge amount of literature in this area and is invited to look for the original sources for in-depth understanding. In addition, the audience can make the next step by building new research on these sources to advance the area of semantic IS standardization. It is also useful for practitioners or policy makers that are mainly interested in a quick overview of the state-of-the-art on semantic IS standards in the current scientific literature.