Rotterdam School of Management
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ICT Standardisation Management

A multidimensional perspective on company participation in standardisation committees

RSM - a force for positive change

ICT Standardisation Management
A multidimensional perspective on company participation in standardisation committees

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A multidimensional perspective on company participation in standardisation committees

Management van ICT-normalisatie
Een multidimensionaal perspectief op deelname van bedrijven in normalisatiecommissies

Thesis

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Acknowledgements

At long last ………

I just hate to admit it, but it took me something like 13 years to actually complete this thesis. And there's nobody to blame but me – I'm lazy, I can easily be distracted and I tend to try and take many things not too serious (a few too many, maybe). Another part of the explanation might be that I conveniently ignored the fact that I was supposed to do a PhD for the first couple of years. But be that as it may – here we are.

Over the years I've been lucky enough to meet a number of people who had quite a positive influence on my research (some still continue to have). Notably, these include Tineke Egyedi, Ken Krechmer and Mostafa Hashem Sherif. But there have been many others; too many to list them all here. Cheers, Folks.

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I'm probably one of the very few PhD candidates who can claim that work on the thesis didn't interfere with his private life to any extent worth mentioning. Even so, having a wife and a couple of friends does, of course, nevertheless help not to immerse yourself too deeply in work and to enjoy ample spare time and free weekends. Thanks to all of you who helped on that front.

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List of Acronyms

3GPP	3rd Generation Partnership Project
ANSI	American National Standards Institute
ATM	Asynchronous Transfer Mode
CCITT	International Telegraph and Telephone Consultative Committee
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CEPT	European Conference of Postal and Telecommunications Administrations
CPS	Cyber-Physical System
CSM	Corporate Standardisation Management
EPR	Electronic Patient Record
ESO	European Standards Organisation
ETSI	European Telecommunications Standards Institute
EWOS	European Workshop on Open Systems
FCC	Federal Communications Commission
FRAND	Fair, Reasonable and Non-Discriminatory
GDP	Gross Domestic Product
GSC	Global Standards Collaboration
GSM	Groupe Speciale Mobile
IAB	Internet Architecture Board
ICANN	Internet Corporation for Assigned Names and Numbers
ICT	Information and Communication Technologies
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IESG	Internet Engineering Steering Group
IETF	Internet Engineering Task Force
IFIP	International Federation or Information Processing
IMAP	Internet Message Access Protocol
IoT	Internet of Things
IPR	Intellectual Property Rights
ISO	International Organization for Standardization
ISO	International Organization for Standardization
ITS	Intelligent Transport Systems
ITU	International Telecommunication Union
JTC1	ISO/IEC Joint Technical Committee 1
LAN	Local Area Network
M2M	Machine-to-Machine
NGO	Non-Governmental Organisations
NIST	National Institute of Standards and Technology
NSO	National Standards Organisation
OMA	Object Management Group

OMA	Open Mobile Alliance
OSI	Open Systems Interconnection
OTA	Office of Technology Assessment
POP	Post Office Protocol
PTT	Post, Telegraph and Telephone administration
QoS	Quality of Service
R&D	Research and Development
R&D	Research and Development
RDT	Resource Dependence Theory
RF	Royalty Free
RFC	Request for Comments
RRI	Responsible Research and Innovation
S/MIME	Secure/Multipurpose Internet Mail Extensions
SA	Standards Association (IEEE)
SC	Smart City
SC	Sub-Committee
SDO	Standards Developing Organisation
SEP	Standard Essential Patent
SG	Smart Grid
SG	Study Group
SIO	Scientific or Industrial Organisation
SITA	Société Internationale de Télécommunications Aéronautiques,
SM	Smart Manufacturing
SME	Small and Medium-sized Enterprise
SMEs	Small and Medium-sized Enterprises,
SMTP	Simple Mail Transfer Protocol
SSM	Strategic Standardisation Management
SSO	Standards Setting Organisation
SST	Social Shaping of Technology
STS	Science and Technology Studies
TBT	Technical Barriers to Trade
TC	Technical Committee
TG	Task Group
TSG	Technical Specification Group
UA	Unit of Analysis
W3C	The World Wide Web Consortium
WAPI	Authentication and Privacy Infrastructure
WG	Working Group
WLAN	Wireless LAN
WSN	Wireless Sensor Network
WTO	World Trade Organisation
WWW	World Wide Web

Executive Summary

Today, virtually all Information and Communication Technologies (ICT) systems are based on international standards; they are the one major mechanism to ensure interoperability. Standards now under development will define future ICT systems' functionality. This gives those who actively contribute to standardisation the opportunity to shape these future systems to make them meet their respective (technical and/or economic) preferences. The level of a firm's involvement in the standardisation of a particular technology depends on the stakes it has in this technology or in the sector(s) within which it will be developed, made available and applied.

Very generally, a company's standardisation management function is tasked with the 'translation' of the firm's strategy in a given sector into a supporting and enabling standardisation strategy and its implementation. Typical decisions to be made and tasks to be performed to this end relate to, among others, the level of involvement in the process (possibly ranging from none at all to the foundation of a dedicated standards consortium), where to be involved (i.e. the selection of the most relevant Standards Setting Organisations (SSOs) or the creation of a new one), the establishment of a time line (to align standardisation with internal research and technical development, R&D) and the selection, briefing and monitoring of prospective delegates. Moreover, the identities, capabilities and strategies of the different stakeholders as well as their needs and requirements need to be known and understood (including those of potential customers and users), not least in order to identify potential allies and opponents and how to deal with them. These aspects are of critical managerial relevance. However, hardly any research is available in this field.

This thesis aims to contribute to a better understanding of the different facets that, taken together, make up standardisation management. To this end, it develops an initial framework that incorporates external and internal (to the firm) factors that exert an influence on corporate standardisation management. Some of these factors are discussed in detail.

In the following, the thesis' key findings (from a firm's perspective) will be listed, along with a brief explanation. They appear roughly in their order of importance, as perceived by the author.

- It is crucially important to align the (external) standards setting activities with corporate criteria and goals [Chapter 2].
  If standardisation does not serve to reach a firm's strategic goals in a particular market, it is little more than a waste of resources.
- Clear goals for a firm's involvement in a particular standardisation activity need to be defined up-front (and subsequently acted upon accordingly) [Chapter 2].
  All relevant corporate goals must be clearly identified and communicated for each individual standards setting activity.
- In almost all cases it will be necessary to form alliances in order to impact standards setting [Chapter 4, 5].
  This holds for both the corporate and the individual level.
- The availability of capable individuals and their social capital within a Working Group (WG) are essential for effective and efficient standardisation work [Chapter 3].
  This links to the above. Social capital is crucial in order to form alliances at the individual level and thus to influence votes (possibly even against an employer's interests).
- It is a good idea to try and learn from the past and to apply this knowledge to ongoing activities [Chapter 4].
  Not to repeat mistakes made in the past may make a huge difference.

- Multi-disciplinary standards setting will become increasingly important [Chapter 5].
  This may require an adapted standardisation process to better cater for multi-disciplinarity. Also, new alliances may need to be formed and individual standards setters will have to acquire new skills and knowledge.
- It may well pay to try and influence policy making [Chapter 5].
  European policy makers have a considerable influence on the European Standardisation Organisations (ESOs). Lobbying the European Commission may thus help indigenous corporate standardisation efforts.
- The alignment of standardisation activities with internal development capacities will be beneficial [Chapter 2].
  To be able to capitalise on a first-mover advantage it will be necessary to ensure that adequate production capacities are available in time. This may imply the need to defer the standards setting process.
- Different SSOs have different 'cultures' [Chapter 2, 3].
  These different cultures need to be taken into account when selecting the most suitable individual(s) for an assignment to a given SSO.
- A formal leadership role may be a double-edged sword [Chapter 2].
  Depending on an SSO's rules a chairperson may have to adopt a neutral position (and may not represent e.g. a company).
- Generally, it is important to monitor the standardisation environment to identify – at the strategic level – the most suitable SSO(s) for each potential activity [Chapter 5].
  The ICT standardisation landscape is rather dynamic. Any changes may well have an impact on ongoing activities as well as on those about to be initiated.

The thesis also postulates an almost inescapable development towards highly multi-disciplinary standardisation. This holds particularly for smart systems. In this sector, close co-operation both at the technical level and between representatives from both technology and society will become a necessity. This will pose a number of new challenges also for the standardisation environment. To this end, a new process has been proposed that should better meet the requirements of multi-disciplinary standardisation. However, not just the standardisation environment, but also firms, including their respective Corporate Standardisation Management (CSM) function as well as individual standards setters will have to adapt.

From a more theoretical perspective, the thesis identifies five factors (along with constituting elements) that exert influence on the CSM function and may, in turn, be influenced by it. Moreover, each factor may also exert a certain level of influence over others. The factors include the corporate characteristics, the standardisation context, competing/complementing activities, the individual and a range of external (to the company) elements.

These factors, the standardisation management function, the rough nature and the directions of the respective mutual influences are integrated into a framework that may serve as a basis for future, more detailed research, e.g. on the exact nature and, particularly, strength of the respective influences.

Samenvatting [Summary in Dutch language]

Internationale normen liggen tegenwoordig aan de basis van vrijwel alle systemen op het gebied van informatie -en communicatietechnologie (ICT). Ze maken interoperabiliteit mogelijk. Normen die nu worden ontwikkeld zijn bepalend voor de functionaliteit van toekomstige ICT-systemen. Wie bijdraagt aan de ontwikkeling van deze normen geeft dus mede vorm aan de toekomstige ICT-systemen, op basis van de eigen (technische en/of economische) voorkeuren. De mate van betrokkenheid van een bedrijf bij de normalisatie van een specifieke technologie hangt af van de belangen die het heeft bij deze technologie of de toepassing ervan in een of meer sectoren.

De taak van het "vertalen" van de ondernemingsstrategie in een bepaalde sector naar een ondersteunende en faciliterende normalisatiestrategie ligt bij de normalisatiemanagement-functie van het bedrijf. Besluiten en taken hiervan hebben betrekking op o.a. de mate van betrokkenheid in het normalisatieproces (uitersten zijn wegblijven of een heel nieuw normalisatieconsortium oprichten), wáár meedoen (keuze van de meeste relevante normalisatie-organisaties of het creëren van nieuwe), het uitzetten van een tijdpad (om normalisatie in de pas te laten lopen met onderzoek en ontwikkeling (R&D) van het bedrijf) en het selecteren en instrueren en van degenen die het bedrijf gaan vertegenwoordigen, en het contact houden met hen. Bovendien is het nodig andere belanghebbenden te kennen en begrijpen – wie zijn ze? Wat zijn hun bekwaamheden, strategieën, behoeften en eisen? Hoe met hen om te gaan? Het managementbelang is groot. Toch is er nauwelijks wetenschappelijk onderzoek hierover.

Dit proefschrift beoogt beter inzicht te geven in verschillende kanten van normalisatiemanagement. Daartoe wordt een model ontwikkeld van – gezien vanuit het bedrijf – externe en interne factoren die invloed hebben op het normalisatiemanagement van een bedrijf. Enkele van deze factoren worden uitgebreid besproken.

Enkele kernresultaten (vanuit bedrijfsperspectief) in volgorde van belangrijkheid (in de beleving van de auteur):

- Afstemming van (externe) normalisatie-activiteiten op de criteria en doelen van het bedrijf is cruciaal [Hoofdstuk 2]. Als de activiteiten los staan van strategische doelen in een bepaalde markt is het verspilde moeite.
- Voordat een bedrijf gaat meedoen in een bepaalde normalisatie-activiteit moeten heldere doelen worden gesteld (en vervolgens moet daarnaar worden gehandeld) [Hoofdstuk2].
- Voor het beïnvloeden van normontwikkeling is vrijwel altijd samenwerking met anderen nodig (Hoofdstukken 4 en 5]. Dit geldt zowel op organisatieals op individueel niveau.
- Capabele individuen met sociale vaardigheden maken het verschil binnen de werkgroepen (WG) die de normen opstellen [Hoofdstuk 3]. Zij bepalen effectiviteit en efficiency en dit hangt samen met het bovenstaande. Sociale vaardigheden zijn essentieel in de samenwerking met andere experts. Het beïnvloeden van stemgedrag kan er zelfs toe leiden dat sommigen stemmen tegen het belang van hun werkgever in.
- Wie niet leert uit het verleden maakt dezelfde fouten [Hoofdstuk 4].
- Multidisciplinaire normalisatie wordt steeds belangrijker [Hoofdstuk 5]. Hiervoor kunnen aanpassingen van het normalisatieproces nodig zijn. Ook kunnen nieuwe allianties nodig zijn, en deelnemers met nieuwe kennis en vaardigheden.
- Het kan lonen om beleid te beïnvloeden [Hoofdstuk 5]. Europese beleidsmakers hebben veel invloed op de Europese normalisatie-instellingen. Hun normalisatie-werk is dus soms te beïnvloeden via de Europese Commissie.

- Interne afstemming tussen normalisatie-activiteiten en ontwikkelcapaciteit levert voordeel op [Hoofdstukken 2 en 3]. Om als eerste met iets nieuws op de markt te kunnen komen moet er op tijd genoeg productiecapaciteit zijn. Lukt dat niet, dan kunnen vertragingstactieken in het normalisatieproces nodig zijn.
- Normalisatie-organisaties verschillen qua cultuur [Hoofdstukken 2 en 3]. Dit is iets om rekening mee te houden bij het selecteren van individuen voor normalisatiewerk binnen die organisatie.
- Een officiële leiderschapsrol kan een tweesnijdend zwaard zijn [Hoofdstuk 2]. De regels van de normalisatie-organisatie kunnen een neutrale positie voorschrijven waarbij de voorzitter geen specifieke belangen (bijvoorbeeld die van zijn bedrijf) mag inbrengen.
- Het is belangrijk om de normalisatie-omgeving in beeld te houden om voor potentiële normalisatie-activiteiten de meest geschikte normalisatie-organisaties te kunnen bepalen [Hoofdstuk 5]. Het ICT-normalisatielandschap is behoorlijk dynamisch. Elke verandering daarin kan gevolgen hebben voor zowel lopende als nieuw te starten activiteiten.

Dit proefschrift laat een vrijwel onafwendbare ontwikkeling zien naar een hoge mate van multidisciplinariteit in normalisatie. Dit geldt in het bijzonder voor slimme ("smart") systemen. Hiervoor is nauwe samenwerking nodig tussen technologie-leveranciers en de sectoren waar deze wordt toegepast. De deelnemers in normalisatie moeten dus uit beide geledingen komen. Deelname van maatschappelijke actoren vormt een uitdaging voor de normalisatiewereld. Dit proefschrift doet voorstellen voor procesvernieuwing om multidisciplinaire normalisatie mogelijk te maken. Ook de normalisatiefunctie binnen bedrijven en individuele deelnemers zullen zich moeten aanpassen.

Vanuit een meer theoretisch perspectief identificeert dit proefschrift vijf factoren (plus elementen waaruit deze zijn opgebouwd) die de normalisatiefunctie van een bedrijf beïnvloeden en/of daardoor beïnvloed kunnen worden. Die factoren kunnen elkaar eveneens beïnvloeden. De factoren zijn: karakteristieken van het bedrijf, normalisatie-context, concurrerende of complementaire activiteiten, de persoon die deelneemt, en externe elementen (bezien vanuit het bedrijf).

Deze factoren, de normalisatiemanagementfunctie en de beïnvloedingsrelaties ertussen zijn samengebracht in een model. Dit kan de basis vormen voor toekomstig meer gedetailleerd onderzoek, bijvoorbeeld over de aard en sterkte van de verschillende beïnvloedingsrelaties.

1 Introduction[1]

1.1 General Background and Motivation

The term 'standard' does not really lend itself to a useful definition. The Oxford Dictionaries[2], for example, define a standard as *"something used as a measure, norm, or model in comparative evaluations"*. According to Merriam-Webster[3], a standard is *"something established by authority, custom, or general consent as a model or example"*. ISO defines a standard as 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*" [ISO, 2012].

All these definitions are too generic to be readily applied to a specific domain like Information and Communication Technologies (ICT). However, when the term 'standard' appears throughout the remainder of this thesis it will be meant in the sense of the ISO definition. Specifically, this will exclude proprietary standards (like e.g. MS Windows) that emerged through sheer market power as opposed to some form of (consensus-based) committee process.

In the field of ICT international standards are the one major mechanism to ensure interoperability between systems. In fact, Biddle et al. [2010] found that "*251 technical interoperability standards [are] implemented in a modern laptop compute*r"; they reckon that the total number of standards relevant to such a device is much higher. There are standards for operating systems, programming languages, user interfaces, communication protocols, disk drives, cables and connectors, etc.

Close links between standardisation and innovation may be identified. The times when statements along the lines of 'standardisation hampers innovation' were believed to adequately describe these links are (mostly) gone by now. However, the unqualified 'standards foster innovation' does not fully reflect reality either. Swann & Lambert [2010] observe that standards do both – enable and constrain innovation – but that the enabling aspect is much more important. Specifically, they note that "… *standardization does constrain activities but in doing so creates an infrastructure to help trade and subsequent innovation. Standardization is not just about limiting variety by defining norms for given technologies in given markets. Standardization helps to achieve credibility, focus and critical mass in markets for new technologie*s". Blind [2009] argues that there are several ways in which standards can promote innovation[4]. This holds particularly for the ICT sector, where compatibility standards are a major basis for innovations. The GSM[5] platform standards, for example, have been the basis for the numerous mobile services we are offered today.

The debate about the precise nature of the link between standards, standardisation and innovation is still ongoing. Recently, [Foucart & Li, 2021] confirmed the ambivalent nature of the relation between standards and innovation for manufacturing firms in the UK, as do [Wen et al., 2020] for the Chinese automotive sector. Along a slightly different line, [Zhang et al, 2020] find that active contribution to standards setting is beneficial for a firm's innovativeness, its financial situation and the quality of its human capital.

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[1] Parts of this section have gone into my preface to the book 'Effective Standardization Management in Corporate Settings' [Jakobs, 2016].

[2] http://oxforddictionaries.com.

[3] http://www.merriam-webster.com/.

[4] One rather new way is the ISO 50500 series of standards on 'Innovation management – Fundamentals and vocabulary' that is currently under development (https://www.iso.org/committee/4587737/x/catalogue/p/0/u/1/w/0/d/0; see also [de Casanove et al., 2017].

[5] Global System for Mobile Communications, originally Groupe Spécial Mobile.

Thus, participation in standards setting in order to influence the process to one's own benefit has become a major strategic tool to influence the market, utilised especially by the large players (see e.g. [Bird, 1998], [Updegrove, 2006a]). But standardisation also has other characteristics that make it interesting for smaller companies as well. For example, like research consortia, standards Working Groups (WGs) are a place for pre-competitive co-operation and intelligence gathering. Moreover, standards are a valuable tool for knowledge and technology transfer, which makes them relevant also for e.g. academia, research institutions and corporate R&D departments.

Also, the macro-economic importance of standards is no longer questioned. Swann [2010] provides a thorough review of the relevant literature. The reported findings include, among many others, that e.g. "*Standards contribute at least as much as patents to economic growth*" (according to [DIN, 2000]). Studies from different parts of the world suggest that the contribution of standards to the growth rate of the Gross Domestic Product (GDP) is about 2.4% in the UK, 2.5% in Germany, 2.5% in the Nordic countries, 2.7% in Canada and 3.4% in France (see [Menon, 2018]. In absolute terms, this means that the economic benefit of the current body of standards for e.g. Germany amounts to almost 17 billion Euros a year [Blind et al., 2011]. In addition, numerous case studies exist that highlight the economic benefits of standards for both nation states and firms[6]. Standardisation's economic importance is nicely highlighted in a paper by Hurd & Isaak [2009] aptly entitled 'IT Standardization: The Billion Dollar Strategy'.

What's more, "*Standards are not only a technical question. They determine the technology that will implement the Information Society, and consequently the way in which industry, users, consumers and administrations will benefit from it*." [EC, 1996]. This quote (from twenty years ago, but still very valid) conveys two important insights that are overlooked all too often. The first one is that Information and Communication Technology (ICT) systems simply would not work without underlying standards. The second one is that today's ICT standards are tomorrow's technology. That is, those who lead the standardisation initiatives today are likely to also be in the driving seat when it comes to the actual technology development and implementation.

Finally, standards are also of considerable interest to policy makers. In Europe, for instance, harmonised standards contributed a great deal to the creation of the European single market (see e.g. [Fligstein & Mara-Drita, 1996]). Generally, they help remove technical barriers to trade and enable people, services, goods and capital to move more freely [WTO, 1995].

The above would seem to suggest that standards and standardisation are pretty popular topics for research. In fact, standardisation research is a comparably young field of study, and still a rather small one (albeit one with increasing importance). Most of the early literature – and much of today's – focuses largely on economic aspects. A broader perspective, incorporating elements form a vast array of disciplines (including, but not limited to, business studies, computer science, economics, information systems, legal studies, management studies and sociology) emerged on a somewhat wider scale only in the late 1990s. A special focus of standardisation research has always been on the ICT sector. This is for one due to the fact that developments in this sector are extremely fast, with accordingly short technology life cycles. This imposes special requirements particularly, but not exclusively, on the speed of standards development. Private standards consortia that are responsible for a majority of important standards are another phenomenon virtually unique to ICT. Accordingly, much of the non-economic literature on ICT standardisation addresses issues that relate to these characteristics. Specifically, what little literature there is that deals with the management of corporate standardisation focuses quite strongly on how a company can harmonise its internal systems and/or

[6] A collection of such studies may be found at http://www.iso.org/iso/home/standards/benefitsofstandards/benefits_repository.htm?type=EBS-MS (accessed 27 December 2017).

processes. The following section provides a brief overview of the current state-of-the-art in standardisation management literature.

The thesis' subtitle reads 'A multidimensional perspective on company participation in standardisation committees'. Standardisation management has many dimensions indeed. Table 1.1 lists these dimensions of standardisation management along with some sample aspects to be associated with each of them and with publications that address these aspects.

Table 1.1: Dimensions of standardisation management and sample aspects[7]
(The underlined dimensions will be discussed in the subsequent chapters; references in brackets indicate publications of a certain relevance to the topic that have, however, not really been written from a standardisation management perspective)

Dimension	Sample Aspects	Discussed in e.g.	Standardisation Management Perspective e.g.
Cultural (SSO)	• SSO 'culture' • Other delegates' ambitions, values, etc. • …..	Henrich-Franke, 2008 Isaak, 2006	(Cargill, 2015) (Updegrove, 2004)
Cultural (Firm)	• Corporate culture • National 'home culture' • Delegates' background • …..	Alvesson, 2012 Guiso et al. 2015 Newburry & Yakova, 2006 (and many, many others)	Foukaki, 2017 Chow et al., 2001
Distributive	• Co-operation, co-ordination, competition and co-opetition between SSOs, • Competing developments • …..	Leiponen, 2008 van Wegberg, 2004 Mione, 2018	Jakobs, 2008
Economic	• Market structure • Competition • Market vs. consensus • Standards adoption • …..	Blind, 2004, Swann, 2010 Foucart & Li, 2021 (and many, many others)	(ISO, 2011) (ISO, 2012)
Ethical	• Sustainability • Security, privacy and trust aspects • …..	Wickson & Forsberg, 2015 (Wijen, 2014)	n/a
External	• policies & regulation • legal aspects • popular beliefs, preferences, prejudices • general technical development • …..	Wiegmann, 2016	

[7] This list of dimensions emerged over the years. I presented a very early such list at the UKAIS 2004 conference; in a paper entitled 'Shaping Future ICT Systems Through Today's Standards Setting'. The first quotable reference would be [Jakobs, 2006]; I do not claim that this list is complete.

Dimension	Sample Aspects	Discussed in e.g.	Standardisation Management Perspective e.g.
Innovative	• Innovation through standards • Relation standards and innovation • …..	Shin et al., 2015 Grøtnes, 2009 Hawkins et al., 2017	Abdelkafi & Makhotin, 2016
IPR	• SEPs • …..	Bekkers et al., 2002 Kang & Motohashi, 2015	(Contreras & Updegrove, 2015) (Contreras, 2019)
<u>Procedural</u>	• SSO guidelines, bylaws, etc. • Credibility and legitimacy • IPR guidelines • …..	Krechmer, 2008, Werle, 2001, Iversen et al., 2004	(Updegrove, 2006a)
Purview	• company vs. national, regional, global • …..	De Vries, 2013 Kano, 2000	Foukaki, 2017
Spatial	• Developments in other countries/ regions • Links between regulation and standardisation in other countries/regions • National/regional cultures • …..	De Vries, 2013 Kennedy et al., 2008 Kwak et al., 2011 Hawkins, 1992 Manders, 2015	(Ang & Massingham, 2007) (Chung, 2003)
<u>Technical</u>	• Competitors' capabilities • Customer needs • Complementary products/services • Future trends • …..	Lemstra et al., 2010 Lemstra & Hayes, 2009 Von Burg, 2001	(Jakobs & Lenssen, 1994) (Lemstra & Hayes, 2009)
<u>Temporal</u>	• Learn from the past • Anticipate/trigger future developments • …..	Russell, 2005, Russell, 2014 Steinmueller, 2017 Egyedi & Sherif, 2008	((Perahia, 2008))
Type of origin	• SDO vs. consortium vs. proprietary • ….	Cargill, 2017 Wiegmann, 2017a	Cargill, 1998

As can be seen, all dimensions have been discussed in the literature. However, only few have been seriously discussed in relation to standardisation management. Of these, the 'cultural' and 'procedural' dimensions have been discussed almost exclusively from a practitioner's point of view[8]. And while both the 'temporal' and the 'technical' dimension have been covered rather extensively in relation to standards setting, they more or less remain a white spot for standardisation management.

All in all, (aspects of) corporate standardisation management have so far been discussed almost exclusively from different mono-disciplinary perspectives. The result is a rather scattered literature (and knowledge) base that does not (and, indeed cannot) provide the full picture. I do not claim that

[8] This is by no means meant derogatively.

this thesis does; others will build upon it and remove any remaining (or emerging) white spots. But it does provide a more complete picture.

That is, this thesis does not aim to fill a ‘classic’ research gap. Rather, it attempts to adequately reflect standardisation management’s highly multi-disciplinary nature and to provide a more holistic account of the associated problems and issues. In doing so, it adopts a multi-disciplinary approach, drawing upon insights from

- Standardisation Research,
- Technology Management,
- Strategic Management,
- Science and Technology Studies (STS),
- History,
- Economics,
- Computer Science / Telecommunication.

Figure 1.1 below shows how these individual disciplines contribute to the subsequent chapters and which chapter covers which dimension(s).

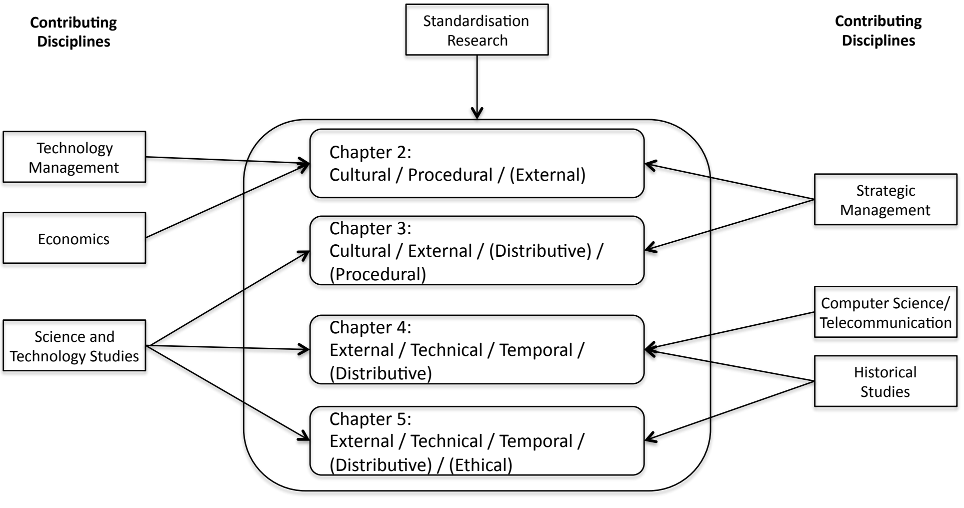

Figure 1.1: Dimensions discussed to the individual chapters and contributing disciplines

1.2 Standardisation Management – Setting the Scene

This section aims to give an initial fairly high-level overview of the state-of-the-art in a number of important company-internal aspects that directly relate to corporate standardisation management. Information about additional, more company-external aspects may be found in chapters 2 – 6.

1.2.1 Introduction

From a firm’s perspective, standardisation is perhaps not always a matter of life or death, but success in standards setting may well have a significant impact on the economic well-being of a company. This impact may materialise through different channels. Ennobling a proprietary specification by turning it into a standard[9] may imply increased revenues due to, for instance, a faster diffusion of that technology (see e.g. [Stoneman & Diederen, 1994]). Moreover, a standards-based technology supports the emergence of complementing products or services. This, in turn, increases the value of this technology (see e.g. [Andersen & Fjeldstad, 2003]) and opens up the opportunity to capitalise on Intellectual Property (IP).

Along similar lines, a company may use standards setting to change the rules of the game and to get a competitive advantage. Lemstra & Hayes [2009] report a case where NCR successfully did that by initiating the development of a wireless local are network standard (to become known as WiFi or IEEE 802.11) rather than emulating the market leader's (IBM's) technology.

Perhaps most importantly, standards may help extend existing markets or even open up new ones (see e.g. [den Uijl et al.; 2013]). The most prominent example here would be GSM. This standard was developed by the European Telecommunications Standards Institute (ETSI). It describes protocols for second generation (2G) digital cellular networks, as used by mobile phones. In 2018, GSM and its technical successors (including 5G) had a global market share of over 90%, GSM itself still holds around 28%. This has been forecast to go down to around 10% in 2023[10].

Unfortunately, there is a downside: Even more than two decades ago the costs for the development of an average IT standard amounted to about $ 10,000,000 [Spring & Weiss, 1995]. Another estimation put development costs for a 'major international telecommunications standard' to some 1,000 person-years of experience, twenty person-years of actual effort, plus $3 million [OTA, 1992]. Thus, a company's involvement in standardisation requires careful consideration to avoid costly and perhaps ruinous mistakes.

The observations above might lead to the assumption that companies take standardisation very serious and that it may even be considered as being as important as innovation. In other words, one might be tempted to assume that the ability to be successful in standards setting is about as important as the ability to innovate. One could also be led to assume that sophisticated management mechanisms are in place (at least in large companies) to help make sure that a company's interests are adequately represented in the international standardisation arena. Yet, at least anecdotal evidence – and the almost complete lack of (academic) literature on the topic – suggest that this is not necessarily the case.

In fact, some companies (e.g. Intel, Qualcomm, Ericsson) indeed seem to have well-defined standardisation strategies. Yet, apparently quite a few others seem to have adopted a laissez-faire approach. Some have a central standardisation department, for others it is more of an un-coordinated and distributed activity. While some manage, monitor, and track the standardisation activities of their staff, others do not have a clue of who is doing what in their name in which standards bodies. To make things worse, earlier research (see e.g. [Jakobs et al, 2001], [Jakobs, 2011a]) suggests that those active in standards working groups do not necessarily always represent their employers' interests. The vast majority of companies, however, especially SMEs, hardly participate at all in standards setting (see e.g. [Gupta, 2017] or [EC, 2022]). As a result, many of them miss out excellent opportunities to capitalise on their innovations.

1.2.2 (Corporate) Standardisation Management

The 1990s saw a bit of a hype surrounding 'Strategic Standardisation Management' (SSM). This is "*A management discipline and methodology that investigates all aspects of standardization across a business and/or industry, then defines, recommends, and implements appropriate strategies and*

[9] The specification of Ethernet (by DEC/Intel/Xerox), for instance, went on to become IEEE 802.3. More recently, Microsoft's OOXML specification became the ISO/IEC 29500 standard.

[10] According to https://www.statista.com/statistics/206655/forecast-of-the-distribution-of-global-mobile-broadband-subscriptions-by-technology-in-2016/ (accessed 7 January 2023).

policies to leverage standardization so that a firm can gain competitive advantage and avoid disadvantage" [Betancourt & Walsh, 1995, p. 119]. At that time, the American National Standards Institute (ANSI) ran the 'Center for Strategic Standardization Management' to assist companies to adopt this approach. These days, the interest in SSM seems to have all but vanished; yet, its underlying ideas remain valid.

Basically, SSM argues that standards may have a considerable impact on a company's business. Therefore, participation in their development should be seen as a strategic activity that needs to be carefully managed and to be aligned with the company's overall business strategy in the relevant sector (see also e.g. [Forselius, 1998] and Chapter 2). Accordingly, a dedicated central entity needs to be charged with standardisation management. Specifically, standardisation must not be considered just a technical issue. Neither is it a topic to be firmly located in the engineering domain. For example, management system standards like the ISO 9000 series affect all departments. Table 1.2 summarises the differences between the 'old' approach to standardisation management and SSM's postulate.

Table 1.2: The 'old' approach to standardisation ('little s') vs. Strategic Standardisation Management (SSM; 'BIG S'); (adapted from [Betancourt & Walsh, 1995])

Topic	'little s'	'BIG S'
Products	Manufactured goods	All products, goods and services
Processes	Directly related to goods manufacturing	All, including business processes
Industries	Manufacturing	All
Standards viewed as	Technical issues	Strategic business issues
How to think about standardisation	Based on internal departments	Based on a global perspective
Standardisation issues are included in	Manufacturing goals and specifications	A company's strategic business plan
Participation in standardisation activities is directed at	Product performance	Company performance, competitive advantage and market position
Evaluation of standardisation based on	Conformance and compliance	Long-term value to the company
Co-ordinated by	Departmental standards managers	A corporate office of SSM

Along similar lines, Bousquet [2003; p.52] notes that "*The 'standardization in the enterprise' function, like quality must clearly take place at a management level and the experts who will participate in the standardization work will be the true spokesmen for their firm's strategies*".

Apart from the tiny wave of papers and interest relating to SSM, the literature on (ICT) standardisation management is not just limited but also extremely fragmented across topics and disciplines. And, in most cases, it is not labelled as such. Some exceptions do exist, though.

Foukaki [2017] does not focus on the ICT sector (but on the automotive one), but her work is certainly of relevance for this field as well. Her in-depth comparative case study of two heavy-truck manufacturers finds at least two very different approaches to voluntary consensus-driven standardisation, the assertive one and the vigilant one. These approaches correspond with the 'leader' and the 'follower' approach identified in [Updegrove, 2006a] for the ICT sector (see also chapter 2).

The former aims to lead and to influence standardisation efforts, the latter aims primarily at intelligence gathering. The study's findings also indicate that active engagement in standardisation may serve as an effective way to manage an organisation's resource dependence and environmental uncertainties, thus linking standardisation to Resource Dependence Theory (RDT). Finally, and looking at corporate standardisation management from a co-opetitive angle the study reveals that to some degree inter-organisational tensions within standardisation may be resolved by demonstrating the possibilities of 'win-win strategies' (which is what co-opetition is all about).

De Casanove & Lambert [2015] give an overview of corporate standardisation activities in a major European multinational aerospace and defence corporation. They identify the main stakeholders and show how standardisation activities are internally linked to other corporate functions. They also show that these activities may lead to innovation, new products and the emergence of new markets. They show what a newly established standards department needs to do in order to become relevant. To this end, major tasks include the demonstration of the relevance of standardisation to the overall company strategy, and to enlist support from top management. The concrete level of a firm's involvement in standardisation activities needs to be aligned with the firm's strategic roadmap (which is what [Foukaki, 2017] found as well). Yet, at the same time, these activities must also be closely linked to the operational ones. This interconnectedness makes the corporate standardisation department central in multiple decision paths. All in all, the paper provides a toolbox for setting up a corporate standard function. However, and this is perhaps the most important message, one size does not fit all. All these activities need to be adapted to each individual company's culture.

Evidence from China, as reported in [Wu & de Vries, 2022], suggests that it will be beneficial for a company if its representatives adopt a leading position (e.g. editor or chairperson) in a WG[11]. They also highlight the importance of the standardisation process as a platform for knowledge acquisition and exchange[12], for which a long-term commitment is essential. The same holds for the collection of social capital[13]. This is of particular importance for SMEs (as reported in e.g. [Blind & Mangelsdorf, 2012]). The same holds for the observation that limited resources may suggest a focus on a comparably small number of valuable activities, to avoid dissipating energies. Like and [Foukaki, 2017] they also highlight the importance to align external developments and internal capabilities[14]

[Featherston et al., 2016] present a framework that should help identify if and when standardisation activities may be required to support innovations in emerging technologies. It is based on the strategic dimensions of 'time' (including sequencing of standards), 'type of innovation activity', the 'different types of stakeholders' that should contribute at the different stages of standards development and on 'different categories of standards[15]' (Terminology and semantic reference, Measurement and characterisation, Quality and reliability, Compatibility and interoperability, Configuration). They also show that standards help generate, structure and communicate information necessary for innovations. That is, standards may be used as a mechanism to align and to coordinate innovation activities. The framework should also be of help for standardisation management to determine what should be standardised when, and who should be involved.

Looking at standardisation management rather more from a policy perspective, Spring [2016] observes that so far it has been responsive rather than pro-active. This is inadequate in fast moving areas were many players are new to standardisation (like the ICT sector). Here, an over-arching guidance, like e.g. roadmaps, would be more important than even more technical standards. Especially considering the importance of a secure cyber-infrastructure he argues that it might well be

[11] See sect. 2.10.2 for a slightly different view. This may be down to regional differences, though.

[12] This is of particular importance for SMEs (as reported in e.g. [Blind & Mangelsdorf, 2012]).

[13] This is very much in line with findings reported in [Grundström & Wilkinson, 2004]; see also sect. 2.9.1.

[14] Which one should be aligned to which may depend; see also sect. 2.10.1.

[15] Based on [Blind & Gauch, 2009].

government's task to start and to find such initiatives. At a still higher level, he notes that standards may well become a "*new mechanism for controlling trade in a post tariff world of free trade*". The Chinese "Road and Belt" initiative would be a case in point (see also [Cai, 2017])[16].

1.2.3 Standards, Standardisation and Innovation (Management)

According to the OECD, "*An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations*"[17].

It has long been accepted that standards may both enable and constrain innovation (see e.g. [Swann, 2010] and [Swann & Lambert, 2010]). Whatever their exact impact may be, a close link exists between standards, standardisation and innovation. Accordingly, standards and standardisation are – or should be – of interest to innovation management. A bibliometric analysis of over 500 research papers published between 1995 and 2008 that discuss 'standardisation and innovation' [Choi et al., 2011] shows that these papers may be clustered into three group clusters with nine clusters (see Table 1.3; adapted from [Choi et al., 2011]).

Table 1.3: Research topics in standardisastion and innovation 1995 – 2008

Group Cluster A – function and role of standardization in innovation (165 papers)
- Cluster A1 – generic relationship of standardization and innovation (60 papers)
- Cluster A2 – technology and knowledge diffusion and transfer (26 papers)
- Cluster A3 – a regulation and integration tool (54 papers)
- Cluster A4 – IPR, patent, and legal issues (25 papers)

Group Cluster B – the impact/strategy of standardization in innovation (181 papers)
- Cluster B1 – impact and competitive strategy (88 papers)
- Cluster B2 – technology and business performance (92 papers)

Group Cluster C – standard-type oriented innovation research (182 papers)
- Cluster C1 – technology and product-oriented standards and innovation (86 papers)
- Cluster C2 – quality and management system standards and innovation (63 papers)
- Cluster C3 – service-oriented standards and innovation (33 papers)

Little changes may be assumed at least for the group cluster level if a similar study were performed today, while the 'popularity' of the individual Clusters would likely differ[18].

Choi et al. [2011] also show that the number of these papers increased by a factor of three between 1995 and 2008. One should have expected that this trend continues and that links between innovation management, standards and standardisation also play an important role in this context. However, recent books on innovation management ([Breuer & Lüdeke-Freund, 2017], [Chen et al., 2019], [Uzunidis et al., 2021], [Westland, 2017]) hardly touch upon the topic at all[19]. The same holds for the chapter on 'Innovation Management Principles' in [Hillner, 2021] and the recent papers on 'Innovation management challenges' [Tidd & Bessant, 2018] and 'Digital transformation and innovation management: A synthesis of existing research and an agenda for future studies' [Appio et

[16] Similar concerns also underpin the new European standardisation strategy [EC, 2022], which also aims to exert stronger policy impact on standards setting.

[17] See https://stats.oecd.org/glossary/detail.asp?ID=6865.

[18] For example, A4 may be assumed to be much more popular today as a research topic, as may be A2.

[19] The one exception here is [Ende, 2021].

al., 2021], which do not mention standardisation at all. The not quite-as-recent book by Afuah [2003] does explicitly address 'Dominant Designs and Standards', yet it does so rather superficially and in an Appendix. That said, the one aspect which relates standards to innovation management that does receive (quite considerable) attention is 'standards *for* innovation management'. This aspect, however, is way outside the scope of this thesis[20].

Wiegmann [2019b] is the one recent book that indeed discusses the management of standards, standardisation and innovation. Based on an in-depth case study on the micro Combined Heat and Power (mCHP[21]) technology development in Europe. He shows that awareness of the importance of applicable standards and regulations as well as expertise in this field and adequate (financial) resources are crucial prerequisites for a company that wishes to introduce a new technology into a highly regulated market. Such expertise, which would also enable active participation in standardisation and possibly also in the shaping of regulations, should preferably be available in-house. If it is, it will enable companies to actively participate in standards setting and ideally shape the ensuing standard to be in line (or at least not contradict) corporate interests. This, in turn, requires the formation of a supporting network comprising first and foremost other firms of the sector, but also e.g. industry associations, research institutions and possibly regulators (to improve legitimacy and credibility). Beyond that, it must be ensured that IPR issues do not complicate or even hinder co-operation.

Standards themselves may serve as a platform for innovation (see e.g. [APEC, 2010], [Egyedi & Koppenhol, 2009], [Egyedi & Widlak, 2019], [van Eecke et al., 2007]). Moreover, also the standardisation process may serve as such a platform (see e.g. [Ernst et al., 2014], [Jakobs, 2006]). Grøtnes [2009] shows that standardisation may be considered as a form of open innovation[22], where companies reveal technical information (outbound open innovation) and learn from others (inbound open innovation).

Pīlēna et al. [2021] identify a number of characteristics shared by standardisation on the one hand and open innovation as well responsible innovation on the other. These characteristics include, among others, the co-operation of different groups stakeholders based on mutual understanding and consensus, the principles of transparency and open participation and the accumulation and transfer of information and knowledge. Figure 1.3 visualises this. The closer one characteristic is to one of the corners, the more important it is for the associated process. But the three processes share all characteristics.

[20] See e.g. [Caetano, 2017], [Tidd, 2021], [Zarzycka et al., 2019] and many, many others in addition to the books mentioned above. Specifically, the ISO 56000 series of standards (Innovation Management) and its effects are widely discussed. This is not unlike the dichotomy 'research *about* standardisation' vs. 'research *for* standardisation'; this thesis is about the former, the vast majority of activities are about the later.

[21] Such devices produce electricity with the heat being a by-product of the electricity generation process. They are more efficient than conventional, separate systems.

[22] According to Chesborough [2003, p. xxiv], open innovation is "*a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology*".

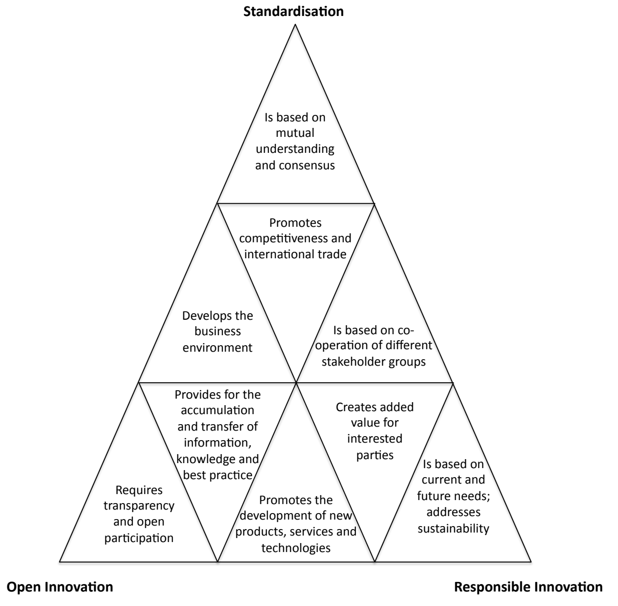

Figure 1.2: Shared characteristics of standardisation, open and responsible innovation (adapted from [Pilena et al., 2021])

In a globalised market, even the largest firms are no longer able to remain competitive relying exclusively on internal resources. In this environment, R&D alliances are a way to help improve a firm's knowledge and capabilities (see e.g. [Gupta & Wilemon,1996], [Rothaermel & Deeds, 2006]). In fact, firms increasingly consider such alliances as a strategic need (see e.g. [Cassiman & Veugelers, 2006]). This holds especially in technological sectors, notably including ICT (see e.g. [Bellini et al., 2019]), not least because ICT is increasingly instilled into 'traditional' technologies ('smart systems'; see also chapter 5); this requires additional know-how not normally available within ICT companies. In general, alliances may help, develop innovations that could not be done internally, reduce their time-to-market and facilitate the access to new markets (see e.g. [Narula, 2001]). Accordingly, studies on R&D alliances mostly focus on aspects like the reasons why firms engage in R&D alliances in the first place, with whom they engage and how partners are selected, which types of activities they perform and how such alliances impact firms' innovation and/or financial performance [Martínez-Noya & Narula, 2018].

Alliances have also been formed in the realm of standards setting. Perhaps most notably, alliances were crucial in some standards wars that were, however, fought in the market, not in SSOs' working groups. Examples here include VHS vs. BetaMax (where JVC's open strategy, also involving external stakeholders, eventually secured victory over Sony's BetaMax; see e.g. [Cusumano, et al., 1992]) and Blu-ray vs. HD-DVD (when Sony had learnt its lesson and applied a strategy that embraced external stakeholders to provide complementary products; see e. g. [Gallagher, 2012]). Inside an SSO's working group (IEEE 802.3), DEC, Intel and Xerox joint forces to push and promote Ethernet and secured victory over IBM's Token Ring not least through the creation of an open, innovative community around their technology ([von Burg, 2001]; see also sect. 4.2). More recently, Leiponen [2008] found intensive co-operation with a diversity of peers, to define and align technical preferences prior to any actual standardisation activities, to be helpful in influencing and setting standards in an SDO.

Links between IPR and standardisation have been studied extensively, most notably for the telecommunication industry. Bekkers et al. [2002], for example, discuss the standardisation of GSM. They show that Motorola, which held a the largest number of standards essential patents (SEPs), quite aggressively used its associated negotiation power during this process not only to dictate licensing terms, but also to structure the European market for mobile telephony through cross-licensing, thus effectively reducing the number of suppliers to these cross-licensees [Bekkers et al., 2002], [Iversen et al., 2004]. This behaviour subsequently triggered other firms' efforts to intensify their patenting activities (not least for cross-licensing purposes)[23]. Having learned their lesson, Nokia and Ericsson emerged as the largest SEP holders during the standardisation of GSM's successor, UMTS. Being also involved in the UMTS standardisation process, they "*used their knowledge of the standard's development for anticipatory patenting*" [Bekkers & West, 2009].

In general, patents and patenting may have multi-dimensional ramifications. Economically, royalties play a major role. Pohlmann et al. [2016] find that those companies which manage to incorporate their IPR into (technology) standards improve their financial performance. Once serious money is at stake, things will be taken to courts. The Apple vs. Samsung lawsuit (sum in dispute more then $ 1bn; see e.g. [Cusumano, 2013]) may not be a typical example. However, the calculation of licensing fees under the FRAND regime remains an issue, to be solved in court (see e.g. [Lemley & Shapiro, 2013]). In contrast, Besen [2016] argues that royalties should be established ex-ante, simply because courts are ill-equipped for such decisions, not least due to a lack of information.

'Patent thickets' and 'royalty stacking' have long been identified as problems associated with FRAND[24] licensing of standards essential patents (SEPs), the licensing approach adopted by most SSOs[25] (see e.g. [Lemley & Shapiro, 2006]). Patent pools have been discussed as a potential remedy (see e.g. [Lerner & Tirole, 2004], [Layne-Farrar & Lerner 2011]). Yet, their voluntary nature implies that in many cases not all IPR holders will join. This holds specifically for firms very active in R&D that, as a result, own a broad patent portfolio Accordingly, such patent pools may help reduce problems, but will not overcome them.

The denomination 'strategic patenting' refers to the fact that patents are not just legal or technical instruments. Rather, they are – or should be – a core component of a firm's strategy [Lang, 2001]. Strategic motivations for patenting may include, among others, patents' role as a bargaining chip in inter-company negotiations and to prevent patent infringement lawsuits by third parties [Blind et al., 2006]. Moreover, firms' IPR strategies need to take into consideration, and to be adapted to, the respective environment. Similarly, they will need to be adapted over time [Cohendet & Pénin, 2011]. Adaptation is also important in the realm of policy. Hall [2007], for example, argues that perceptions of the current system differ between sectors and that a one-size-fits-all policy approach is unlikely to emerge anytime soon.

A literature review on IPR in innovation management, published in 2012, found that IPR research "*is a stream that has just started to gain a foothold in journals focused on innovation management*" [Candelin-Palmqvist et al., 2012, p. 507]. They also found that "*The most frequently mentioned suggestions were as follows:*

- *IPR issues should be connected to other functions within the firm, such as marketing and HRM*
- *IPR issues should be compared in different countries, regions, and industries*
- *There is a need for longitudinal studies and studies on the firm level*

[23] In the wake of these events, ETSI modified it patent policy (see e.g. [Bekkers et al., 2002].

[24] Fair, Reasonable, and Non-Discriminatory.

[25] Royalty Free (RF) licensing, as adopted by e.g. the W3C, is an increasingly popular alternative (see e.g. [Contreras et al., 2022].

- *IPR issues should be connected to performance and success measures: e.g., success in individual careers, company performance, and return on innovation"* [p. 507].

Much of this still holds today.

1.2.4 Research, Development and Standardisation

Linking Research and Development (R&D) and standardisation is one of the major managerial tasks for each firm that is active in standards setting. Much of this task is internal to the company, including the establishment and maintenance of close links not just between R&D and standardisation, but also between standardisation and the legal department that manages, among other things, Intellectual Property Rights (IPR; see Figure 1.4).

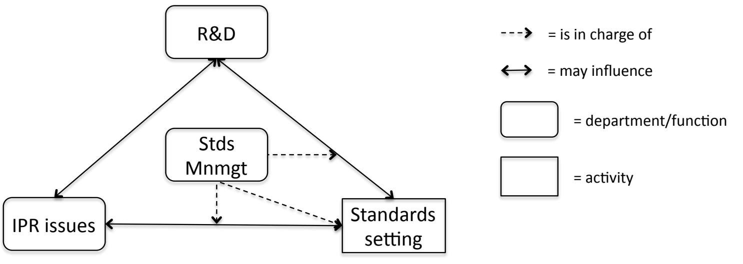

Figure 1.3: Bi-directional links between IPR, R&D and standardisation

Motivations for these linkages may differ, though, and will typically depend on the goals that guide a firm's participation in standards setting. On one end of the spectrum would be the goal to own as many Standard Essential Patents (SEPs)[26] as possible and to capitalise on the IP through royalties. To do so, firms may well go to great lengths; see e.g. [Kang & Bekkers, 2015]. On the other end, the desire to open up a new lucrative market may imply that SEPs are licensed on a Royalty Free (RF) basis in order to remove any barriers that might impede the widest possible implementation of the standard. Aligning the speed of the standards setting process with internal R&D is a perhaps more mundane, but nevertheless important task. Such alignment (that may well imply attempts to slow down or speed up the standardisation process) will help obtain a first-mover advantage upon completion of the standards work[27].

To reach either of these goals a company needs to transfer its technical expertise into standards setting. To do so, some of its employees need to actually attend the meetings of a relevant Working Group (WG)[28]. In fact, active contributions to a WG's activities are crucial (unless the corporate goal is just intelligence gathering); the subsequent chapters will focus on this level of standards setting. Yet, data compiled through different studies indicate that a number of barriers stand in the way of a broad participation of members of the research community in standards setting. This holds for both industrial and non-industrial researchers; the situation is particularly bad for the latter (see e.g. [Bridgit, 2014]). The findings of the 'Interest' project[29] suggest that three major barriers stand in the way of researchers' participation in standards setting. These include lack of financial resources, lack of time and lack of recognition; this is corroborated by the findings of the Bridgit project [Bridgit, 2014] and by [Blind et al., 2018]. All three barriers apply also for corporate R&D staff and need to be

[26] A patent is called 'standard essential' if a standard cannot be implemented without using it.

[27] For interesting and relevant accounts on the various links that exist between standards, standardisation and innovation see e.g. [Hargreaves et al., 2014], [Ho & O'Sullivan, 2015] and [Blind, 2013] and [Hawkins et al., 2017].

[28] A WG is a sub-unit of an SSO, where the actual technical work is being done.

[29] http://cordis.europa.eu/project/rcn/74192_en.html (accessed 27 December 2017).

addressed by standardisation management to actually enable knowledge transfer (and thus corporate interests) from R&D to standardisation.

Standardisation is a form of collaboration with customers, suppliers, competitors and other stakeholders. Against this background, Zhou et al. [2018] find that R&D's novelty (the degree to which firms incorporate technological innovation into products or processes) and openness (the level of knowledge flow across company boundaries) are preconditions for a firm's standardisation activities. These activities, in turn, may well help to improve a firms' innovation performance. This is because knowledge gained through participation in standardisation will stimulate innovative and creative thinking. Along similar lines, Yang et al. [2022] find that standardisation promotes innovation development and that firms should align the co-ordination of standardisation and innovation, respectively. However, reviewing the open innovation research landscape and trying to identify upcoming topics, [Bogers, et al. 2017] completely ignore standardisation, as do [West & Bogers, 2014] for the same field of research. Along similar lines, but looking at the literature on technology transfer channels between academia and industry, [Perkmann et al., 2013] also do not make any mention of standardisation. It would appear that Blind [2019] is correct to assume that "*patents and standards … have not yet been integrated into strategic (technology) management*" ([p. 1064]; see also [Großmann et al., 2016]).

1.2.5 Reasons for Companies' Participation in Standardisation

The decision whether or not to participate in a certain standards setting activity is one of the most important tasks of a standardisation management function. Accordingly, a number of papers look at the reasons that may trigger a firm's participation in standards setting. One such reason are international activities. National (of the country of firm's headquarter) standards adopted at the European/international level will improve trade opportunities, emerging foreign standards may create barriers to trade [Wakke et al., 2015]. Technological uncertainty may be another trigger for participation. Riillo et al. [2022] show that companies are more inclined to participate in standardisation activities in cases where competition in the market was characterised by uncertainty about future technology development. Standards may help to reduce such uncertainties. Riefler [2008] looks at industry specific standardisation activities in the automotive sector. He finds that companies decide whether or not to join a standardisation initiative based on both internal and external criteria. They aim to balance the functionality of the standard, any advantages to be gained by participation (e.g. influence on the design) and the participation costs to be expected. The composition of the working group is the main external criterion – participation of competitors may trigger own participation. Based on a survey of German firms that were either active in patenting or in formal standards setting at the national level, Blind et al. [2022] found that firms use patenting and participation in standardisation strategically. For one, they aim to incorporate patents into standards[30]. Moreover, however, both avenues are used to boost firm reputation and to foster co-operations. For a company's standardisation management function this suggests more aligned patenting and standardisation strategies and perhaps even an integration of both functions.

Looking at company characteristics that may influence its decision whether or not to become active in standards setting, [Blind, 2006] finds that its size is the most decisive factor – the larger the company, the more likely its participation in the standards setting process. This is supported by findings reported in [Wakke et al., 2015][31]. Similarly, R&D activities increase the probability of a firm's participation in

[30] Which appears a bit odd given that the most important motive to participate in standards setting was purely technical: "*Creation of a well-engineered standard*". In contrast, the least important motive (out of 20) was "*Integration of own intellectual property rights in standards*". A reason here may be that the surveyed firms came from many different sectors, whereas IPR is relevant mostly in the ICT sector.

[31] And somewhat challenged by [Riillo & Jakobs, 2022] who find that an econometric analysis does not support the hypothesis that engagement in standardisation is positively associated with measures of firms' growth.

standardisation, albeit only up to a point; companies with very high R&D activities are less likely to join standardisation processes. Along similar lines, Blind et al. [2020] argue that high-tech companies may exploit standardisation as a vehicle to push their technology to the mass market. Pohlmann et al. [2016] point out that companies should link their standardisation strategy and their patent strategy to maximise the value of Standard Essential Patents. A firm's performance as well as the industry sector it is active in also play a role. For the manufacturing sector, a positive and significant relation may be identified between a firm's performance and the level of its participation in standards setting. This does not hold for the service sector, though, where companies appear not to be able to reap any benefits from participation in standardisation [Wakke et al., 2016]. To weigh potential advantages of participation (e.g. royalties, accelerated market entry) against disadvantages (e.g. knowledge spillover) would a standardisation management task.

The reduction of both technological and legal[32] uncertainty through standards is discussed in [Wen et al., 2022]. They study the development of standards for enabling technologies (e.g. the Internet, IoT, 5G) which, in turn, allow the development of complementary innovations (e.g. smart applications). Their empirical study finds that the higher the number of standards in a certain field of technology the higher the likelihood that complementors create high-impact innovations. This suggests that complementors may want attend standardisation meetings, if only to learn about likely future developments and to arrange their internal activities accordingly.

Using the case of the Danish toy producer Lego as an example, Frankel & Højbjerg [2012] show how standardisation can be used to influence government policy in ways favourable for a company[33]. That is, the desire to shape legislation may also be a motivation to participate in standards setting, albeit not a very obvious one.

Looking at the effects that participation in standardisation may cause, Deng et al. [2022] adopt a different point of view. They show that participation in standards setting may lower the risk of investing in that company, as perceived by investors. This is due to the fact that standards, agreed upon by a wide range of players, serve as a platform for further innovation sand thus help reduce risks. This holds particularly for companies active in markets with high levels of (technological) uncertainty[34]. In remains unclear, though, if simple participation suffices in this context or if a firm's active contributions to the process need to be visible[35]. In any case, such perceptions by potential investors may have major implications for corporate strategic planning and may thus also (indirectly) impact standardisation management[36].

To inform companies and help them decide whether or not to participate in a given standards setting activity, Bhatt et al. [2021] develop a forward-looking decision model that is based on a market economics approach.

1.2.6 Selecting an SSO

For over a decade the web of SSOs that develop standards in the field of ICT has been large and highly complex; this complexity is still growing. Moreover, individual SSOs differ in many respects, including e.g. their membership base, their IPR regime, their governance structure, the links they maintain with other SSOs and their importance in a certain field. Accordingly, the selection of the

[32] This refers mostly to IPR-relates issues, i.e. to the question whether or not licensing fees may apply if a standard is to be implemented.

[33] Perhaps most notably in the case of European Harmonised Standards, which may explicitly be referenced by European legislation.

[34] Which, in turn, may be a trigger for participation in standards setting (see above).

[35] This also links to the use of participation in standardisation as a marketing tool; see sect. 2.9.6.

[36] Not so much so if simple membership in an SSO suffices to influence investors.

most appropriate SSO for a certain activity is an important and non-trivial task (see e.g. [Updegrove, 2006a] or [Jakobs & Kritzner, 2009]).

According to [Updegrove, 2003a], two major US-based ICT firms reported membership in around 150 SSOs each[37]. Both identified an SSO's IPR regime as crucial and a potential show stopper. Generally, Intellectual Property is the major aspect from the legal realm that is of relevance to standardisation management (at least in the ICT sector; see also e.g. [Bar & Leiponen, 2014] or [Simcoe, 2014]). Contreras & Updegrove [2015] provide a thorough discussion of the individual aspects relating to SSOs' IPR policies that corporate standardisation managers need to be aware of. They are particularly relevant for the decision which SSO to join or if a new one with a suitable IPR policy needs to be founded.

Hanseth et al. [2006] highlight the (potential) socio-technical complexity of standardisation efforts. Their study is based on a case of the standardisation of an electronic patient record (EPR) system. They show that a one-size-fits-all approach[38], which emphasises sound engineering (like consistency and completeness) over flexibility and adaptability, is bound to fail if the resulting technology is to be applied in different work practices. That is, a standard must not assume a specific work practice or environment within which it is supposed to function. Rather, it should be designed in a way that intrinsically supports such local adaptations[39]. Many modular standards (as opposed to one monolithic standard) are proposed as a potential solution[40]. Form a standardisation management perspective this suggests to try and make sure that flexibility and adaptability are incorporated into standards from the outset. It may also suggest that large firms should exert their influence (mostly in consortia) to make sure that processes (or traditions) leading to monolithic standards are modified accordingly.

Other aspects likely to be taken into account by companies that need to select the most appropriate SSO include the diversity of stakeholders (for learning aspects; see e.g. [Bar & Leiponen, 2014] and the openness to stakeholders [Rysman, 2009], e.g. for credibility aspects [Werle & Iversen, 2006], SSOs' funding models and costs of participation, the allocation of voting rights and the average time it takes to develop a standard (see e.g. [Wiegmann, 2017a)].

1.2.7 Adoption, Selection and Implementation of Standards

A substantial part of the literature tat addresses facets of standardisation management is devoted to the adoption and implementation of standards, mostly of management standards (e.g. ISO 9000, ISO 14000, ISO 26000 and ISO 27000).

A study of the adoption of the ISO 9000 series of standards by German firms in the mechanical engineering sector finds that forces external to the actual production departments are driving the decision to become ISO 9000 certified. Along similar lines, a firm's reliance on flexibility, e.g. in cases of small-batch production, reduces its likelihood adopting ISO 9000 [Beck & Walgenbach, 2005]. Said external forces may include government subsidies, customer pressure, an (overly?) strong administration and pressure by top-management (which may want to increase the proximity of the firm to its institutional environment). The latter holds particularly for large firms; in general, nature and strength of the influencing factors differs between small and large companies.

Benders et al. [2006] also report how external pressure (by important clients) and associated management decisions triggered the implementation of an Enterprise Resource Planning (ERP)

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[37] These figures seem to have increased since then. Recently, Intel reported membership in over 250 SSOs [Intel, 2018].

[38] Which is what standardisation is all about, really.

[39] This resonates with e.g. [Fleck, 1994], who notes that *"... the greater the configurational nature of the technology (i.e. the more it is composed of selections of components to meet local requirements) the greater the chances of failure*" [p. 647]. In his case, software had to be adapted to the local work environment, implying that this software had subsequently to be maintained locally, as future updates by the supplier could no longer easily be integrated.

[40] This very much resembles the 'pick & mix' approach, as discussed in e.g. [Williams, 1997b]

system. The case also shows that systems may well have characteristics (in this case national specifics) that render an implementation across countries (or other boundaries) very complex and time consuming. Moreover, care should be taken up-front to make sure that the system may be customised according to identified user requirements and expectations.

Against the background of inconsistent findings on the effects the implementation of ISO 9000, [Naveh & Marcus, 2005] analyse the effect such an implementation may have on a firm's business and operating performance, respectively. They (were among) the first to observe that the differences in the way companies implement and use the standard to be decisive. This resonates with [Tari et al., 2020] who report that implementations rooted in 'internal' motives (i.e. e.g. the wish to implement continuous improvement) tend to be more successful than those that are based on the (perceived) need to obtain a certification. Specifically, both papers find that in order to reap the benefits implementation and use need to be externally co-ordinated with suppliers and customers and internally integrated with existing practices and routines. ISO 9000 certification per se does not necessarily yield any competitive advantages. These may, however, be gained if the standard is also understood as a potential catalyst for change.

Although they may well be perceived as necessary evils (notably by SMEs) [Wiegmann, 2019a], [de Vries et al., 2009], the implementation especially (though not exclusively) of process standards is frequently required for certification and/or for compliance with regulations. Nevertheless, deviance from such standards may be observed even in highly regulated industries. This phenomenon is discussed in detail in [Fried, 2020]. Based on three case studies, Fried & Langer [2020] identify three types of organisational deviance from standards, termed 'attentive deviance', 'over-conformity' and 'non-regulated deviance', respectively. In the former two types, organisations acknowledge the value for and contributions of standards to their business. While 'over-conformity' will not result in any external sanctions, 'attentive deviance' may. The requirements of the standards on the one hand and those of the internal (production) processes on the other need to be carefully balanced to avoid regulatory sanctions. In the case of a 'non-regulated deviance', the (business) value if standards is questioned and deviations are accepted to accommodate internal specifics. Just like the motivations that underlie a process standard's implementation (see above), the way an organisation monitors deviations from standards has implications on its innovativeness and flexibility [Langer & Fried, 2020].

1.2.8 Managing Company-Internal Standardisation[41]

Recently, aspects relating to company-internal standards and standardisation as well as the implementation of standards also came into focus. Van Wessel [2010] develops a framework for Information technology (IT) standardisation management. This framework, however, focuses exclusively on company-internal standards, i.e. either those that have been developed in-house or that have been selected for internal use from a set of candidates. Yet, in general standardisation management covers a much broader range of tasks than that, most notably perhaps the selection of those Standards Setting Organisations (SSOs) in whose activities a firm wants to participate, the definition and application of the criteria by which SSOs are selected and the guidance of these activities. Specifically, van Wessel et al. [2015] highlight that good governance and management of each phase of a company-internal standard's life cycle (i.e. selection, implementation and use) is decisive for the success of a company-internal IT standardisation project. Adding the implementation aspect, Großmann et al. [2015] introduce and discuss a toolbox of possible strategies for the development and implementation of company standards. This should also help supply-chain partners to best deploy these standards. Similarly, de Vries & Slob [2006] develop a process-based model for company standardisation together with a best practice for the underlying processes.

[41] This topic is outside the scope of this thesis, really. Nevertheless, the section has been added fort the sake of completeness.

The internal implementation of a standard is not necessarily met with enthusiasm by those affected by it. Possible reasons underlying such resistance are studied from a rather more philosophical perspective by Haverkamp and de Vries [2015]. They also propose an approach how to overcome this resistance. More specifically, potential pitfalls of the attempt to impose a management system standard (ISO 9001 in this case) on a firm's division mostly comprising highly autonomous knowledge workers are discussed in [Sandholz, 2015]. He contrasts this with the development in another division where engineers had voluntarily internalised standard practices before being ordered to do so. As a result, they willingly adopted the processes.

1.2.9 Stakeholders in Standardisation

Adequate[42] representation of a variety of stakeholders in an SSO will be of interest for a number of reasons. For one, a wide representation of stakeholders may well improve the standard's legitimacy (see e.g. [Werle & Iversen, 2006]). Moreover, building an alliance, ideally comprising of customers, suppliers, complementors and users is important, not just in the market, but also during the standardisation process [Shapiro & Varian, 1999]. This is echoed in [Markus et al., 2006] who observe that in order to be successful in setting a standard ways need to be found to make sure that "*representative members of heterogeneous user groups (including IT vendors)*" [p. 461] will participate in the process.

On the other hand, the *general* need for wide stakeholder participation may be contested. Egyedi [2003], for example, argues that 'democratic' standardisation is not necessarily a value per se and that it depends on the type of standard at hand. For compatibility standards, for example, she states that "... *non- consensus consortium standards would seem preferable if seen from the 'democratic' viewpoint*" [Egyedi 2003, p. 33]. This is echoed in Jakobs [2005], who argues that for comparably short-lived, purely technical standards like e.g. those for PC interfaces (think USB) trying to bring in everyone at all costs is counter-productive. On the other hand, for other types of standards – Egyedi gives health and safety as examples; smart systems would be another one – democratic procedures (including adequate stakeholder representation) should strictly be followed and be monitored systematically.

SSOs, companies, administrations and individuals are stakeholders of the standards setting process. From a slightly different perspective (the one adopted by e.g. the EU; see [EU, 2012, p.21]) and referring more to standards than the standardisation process, "*SMEs (Small and Medium-sized Enterprises), consumer organisations and environmental and social stakeholders*" are also of importance. In fact, the importance assigned to "*appropriate representation and effective participation of all relevant stakeholders*" by the EU [EU, 2012, p.21] and the World Trade Organisation (WTO) [WTO, 2000] implies that means for a proper identification and classification of stakeholders and how to manage them are definitely an important policy aspect in the context of standards and standardisation.

The most popular stakeholder classification has been developed for the management discipline, in [Mitchell et al., 1997]. It was originally developed to help managers decide which stakeholders to listen to ('The Principle of Who or What Really Counts')[43]. Obviously, similar problems also occur in standards setting; this will be discussed below. This classification is based upon the three attributes 'power', 'urgency' and 'legitimacy'.

'Power' is ability "*to get things done effectively*" [Parsons, 1963]. And according to [Etzioni, 1964], power may exercised through force/threat ('coercive'), (material) incentives ('utilitarian') or via

[42] 'Adequate' is a tricky term, though. Numerically adequate representation would be one thing, adequate influence may be something entirely different. There is ample evidence that representatives' diplomatic, negotiation, rhetoric and similar, non-technical skills are important. Eventually, this may enable even a very small organisation to punch well above its weight in the process.

[43] De Vries et al. [2003] apply this principle to standardisation.

symbolic influence ('normative'). In standards setting, Microsoft has been alleged of using all three in the course of the standardisation of OOXML (see [Dolmans & Piana, 2011] and [Villarreal, 2016] for an account of this process and for further references).

'Urgency' is "*The degree to which stakeholder claims call for immediate attention*". Basically, the 'urgency' perceived by various stakeholders was the reason behind the emergence of standards consortia (see e.g. [Lehr, 1992]).

'Legitimacy' is "*A generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, definitions*" [Suchman, 1995]. It may be discussed at the three levels 'individual', 'organisational' and 'societal' (see e.g. [Werle & Iversen, 2006] for the latter two and [Jakobs, 2011a] for the former).

Combinations of these attributes yield seven categories of stakeholders. They are shown in Figure 1.5; Table 1.4 gives examples from standards setting for each category.

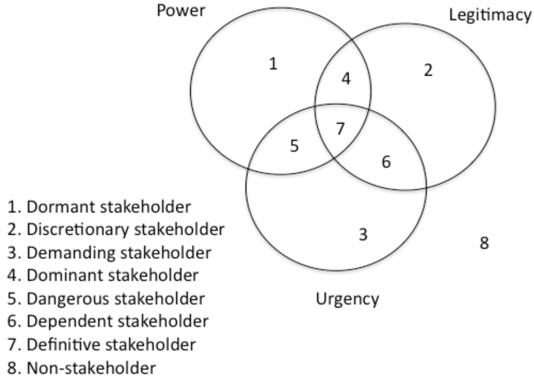

Figure 1.4: Types of stakeholders according to Mitchell [Mitchell et al., 1997]

Table 1.4: Stakeholder categories in ICT standardisation (adapted from [Dul et al., 2003])

Stakeholder Category	Examples
Dormant (P)	Research organisations, academia
Discretionary (L)	SME vendors
Demanding (U)	SME SEP holders
Dominant (P, L)	Other large vendors and manufacturers
Dangerous (P, U)	Other large SEP holders
Dependent (L, U)	Suppliers of complementary products/services
Definitive (P, L, U)	Large vendors and manufacturers holding SEPs

1.2.10 The Social Shaping of …

1.2.10.1 … Technology

Technological artefacts in general, and especially such powerful representatives as ICT systems, exert potentially strong impact on their environment. Yet, this is not a one-way phenomenon; complex interaction between technology and its environment may be observed, where technology may assume both an active and a passive role. That is, technological artefacts and their environment are mutually interdependent. The environment within which technology is used and employed has, among others, social, cultural, societal, and organisational aspects, rules and norms. Technology cannot emerge completely independent from such external influences. However, the impact ICT may have on organisations, or indeed society as a whole, has thus far attracted considerably more attention than the powers that shape this technology in the first place. Especially the impact of ICT within organisational settings (e.g. on a company's performance, or its role as an enabler of business process re-engineering) has been subject to a vast number of studies and analyses. Terms such as 'management of change' [Wilson, 1992], 'management of technology' [Burgelman et al., 2008] or 'organisational change' [Tidd & Bessant, 2009] may frequently be found in the literature, typically denoting studies on how the introduction and subsequent use of ICT have changed a particular organisational environment – for better or worse.

Two mutually exclusive schools dominated research on technology and organisations until the early eighties. Proponents of the 'organisational choice' model consider technology as a vehicle to both reflect and foster the interests of particular groups; the process of change can be, and indeed is, shaped entirely by policy makers or organisation's managers. *"Technology has no impact on people or performance in an organisation independent of the purposes of those who would use it, and the responses of those who have to work with it"* [Huczynski & Buchanan, 1985]. In contrast, 'technological determinism' in essence postulates that ICT determines the behaviour of organisations and that the consequences of manipulating a given technology will always be the same, independent of who manipulates it and within which context [Watad & Ospina, 1996]. It follows that, according to this view, organisations have little choice but to adapt to the requirements of technology; particular paths of technological development are inevitable; like organisations, society also has no other choice but to adapt.

Research into the social shaping of technology (SST) largely emerged as a response to technological determinism. SST adopts a middle course between the two older approaches; it acknowledges that technology indeed has an impact on its environment, but states that at the same time it is framed through technical, but rather more through e.g. organisational, societal, cultural and economic factors [Williams & Edge, 1996]. In particular, SST attempts to unveil the interactions between these technical and social factors. Abandoning the idea of inevitable technological developments implies that choices can be made regarding, for instance, acquisition, use and particularly design of technological artefacts. There may be a broad variety of reasons upon which these choices may be based. In an organisational context this may include purely technical reasons, as e.g. the need to integrate legacy systems, but decisions may also take into account company particularities, as for instance organisational or reporting structures. These choices, in turn, may lead to different impacts on the respective social or organisational environments. Thus, studying what shaped the particular technology offers a chance to proactively manipulate that very impact expected to result from this particular choice. At the same time this capability should also contribute to the prediction – and thus prevention – of undesirable side effects potentially resulting from a new technology. Technology tends to have other effects besides those actually intended, these effects need to be explored as well. On the other hand, the respective environment shapes technical artefacts and systems during design and also in use, i.e. at the site of the actual implementation.

1.2.10.2 … Standards

"*The shaping process begins with the earliest stages of research and development*" [Williams & Edge, 1996, p.874]. This observation points to a direct link between the shaping of technology and R&D activities. Research is not normally conducted with the aim to transform its results into a standard. However, this does not preclude research findings from being fed into standardisation processes. Plus, research that indeed aims at standardisation does exist, in the form of preand co-normative research, respectively. Such research is carried out with the specific goal of integrating its findings into future standards. Yet, 'conventional' research as well may be relevant to standardisation, sometimes even without the researchers and their organisations being aware of it. The relation between research and standardisation can be described by the knowledge and information flows between the two realms, as shown in Figure 1.6 [Interest, 2007a].

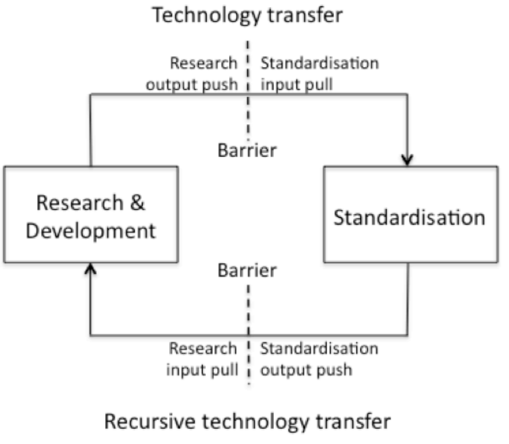

Figure 1.5: The relation between research and standardisation (from [Interest, 2007a])

Especially ICTs are in most cases based on international standards. Thus, while not necessarily representing the earliest stage of development, a standard clearly is an important early stage in the overall process that leads from R&D to products or services, and is thus also subject to a social shaping process.

SST considers the interaction of different players in the process of appropriation of a technology to a specific environment. The fact that choices may be made regarding development and use of a technology (see sect. 3.1) implies a level of uncertainty about its precise nature at the end of this process and about its actual future use. "*SST emphasises the negotiability of technologies – in the sense that artefacts typically emerge through a complex process of action and interaction between these heterogeneous players, rather than being determined by any one player*" [Williams, 1997a]. According to Williams [1997a], these players include technical specialists from supplier organisations, suppliers of complementary as well as competing products, consultants, policymakers, existing and potential users. They may have different understandings of a technology and, accordingly, attach different meanings to it [Pinch & Bijker, 1984]. Against this background, the alignment of the interests and expectations of the players (not to forget the business interests of their employers) may be considered one of the major tasks of the negotiations.

Standards emerge through the co-operation and joint efforts of different individuals in technical committees and working groups. They aim to develop a technology whose eventual nature, use, utility and applications are not normally known from the outset. That is, their work is characterised by a level of uncertainty that is comparable to that of the corporate environment that is typically studied by SST. Moreover, the list of players identified by Williams [1997a] bears a striking resemblance to the stakeholders typically represented in ICT standards setting. Specifically, it should be noted that the identified players are individuals (as opposed to organisations).

Most major SSOs have 'individual' membership. That is, WG members are supposed to act in a personal capacity (see e.g. [ISO, 2012]) and not, for example, as national or company representatives[44]. Their input to the process will be based on views, beliefs, and prejudices that have

[44] Major exceptions include the ITU and the European Telecommunication Standards Institute (ETSI).

to a considerable degree been shaped by their previous experiences. Specifically, the corporate environment of the group members' respective employer (including its economic and strategic views and preferences) will have a major impact on the different visions of how a technology should function and be used, and on the ideas of how this can be achieved. That is, various factors that shape technology in use are also likely be channelled into the SSOs' working groups, thus shaping the future standards.

To summarise, according to Gerst et al. [2005], standardisation is shaped by social factors. More precisely,

- a range of choices is possible at every stage of the standardisation process;
- these choices depend on technical factors but also on economic, social and organisational ones.

1.2.11 The Future and the Past

One does not need any clairvoyant abilities to recognise a major trend that is highly likely to have a significant impact on the standards setting environment and thus also on corporate standardisation management – 'smart' applications. The 'smartness' is the result of the integration of ICT into 'traditional' sectors like manufacturing or transport (see e.g. [Ho & O'Sullivan, 2017], [Folmer & Jakobs, 2020]). This merger of so far largely distinct technologies, and specifically of the underlying standardisation processes, carries a whole range of problems and issues[45]. The ICT sector has long stood out from the general standardisation environment, thanks to its particularly high dynamics with associated short product life cycles and the plethora of private standards consortia that are virtually unknown in almost all other sectors[46]. The standardisation of smart applications and also of a smart communication infrastructure will require co-operation between both SSOs and individuals from very different backgrounds. So far, a suitable and 'purpose-built' platform for such multi-disciplinary co-operation has not been created, although the need has frequently been recognised (see e.g. [EC, 2016b]). This need for a new approach towards setting standards in the field of smart infrastructure and applications (i.e. smart systems) has also been corroborated by experts (see e.g. [Caird & Hallett, 2019] or [Ligthart & Prasad, 2022]).

Such multi-disciplinary standardisation will also affect standardisation management. For example, firms active in the field will need to decide whether or not existing SSOs meet their needs or whether new ones with specific characteristics should be established. Moreover, inclusiveness would be of importance especially for smart applications, where many stakeholders will be involved that are typically absent from 'normal' ICT standardisation (e.g. city authorities or Non-Governmental Organisations, NGOs). This, in turn, will impose additional requirements on the skills of the individual representatives, since a common basis of knowledge and expertise may no longer be assumed [Jakobs, 2017f].

Asking "*What can we learn from history?*" [Mohammadi & Hammink, 2015, p.405] offer "*Technology development is influenced by a number of elements: the technology itself, the stakeholders and the social, cultural, economic, historical and societal context*" [p. 405] as part of their answer. The very same holds for the standards that underlie these technologies. And it will hold all the more if the time frame in question comprises only a few decades. In this case, it should be safe to assume that the context hasn't changed enough to make lessons from a few decades ago irrelevant today. And even if the 'context' changed over time, "*Those who cannot remember the past are condemned to repeat it*" [Santayana, 1920; p.284]; "cannot remember" being equivalent to "don't learn from".

[45] See also [Stuurman, 2017] for a discussion of the legal ramifications from a data protection point of view.

[46] The pharmaceutical industry would be one exception, see [West, 2016].

One such lesson, which will become increasingly important to be actually learned and, indeed, internalised is the necessity of a broad stakeholder participation in standards setting (most notably for smart systems; see above). Already in the early 1930s, it was "… *a fundamental principle in German standards work that all norms established shall be the product of the freely pooled labor of producer, consumer, and commercial interests, acting with the aid and cooperation of government and of science.*", according to the founder of the "Normenausschuß der deutschen Industrie", the predecessor of today's German NSO, DIN (quoted in [Yates & Murphy, 2019, p. 79]). This was not least meant to improve a standard's legitimacy. Even earlier than that, the IATM, the International Association for Testing Material, "… *asserted the need for representatives to come from both the manufacturers and consumers of materials*, …" (quoted in [Yates & Murphy, 2019, p. 42]). While (almost) all SDOs support such wide participation on paper, things often look different in practice[47]. At that time (late 19th century), participation of a broad range of stakeholders was a reality in the IATM and included engineers from very different disciplines, representatives from other disciplines (e.g. architects) as well as e.g. urban public works departments and even a police department in [Yates & Murphy, 2019].

The history of standards wars provides an instructive example of how a company did learn the lessons from history[48]. Sony's BetaMax video cassette formats lost out against JVC's VHS. Two generations of video recording technologies later, Sony's Blu-ray technology won against HD-DVD, not least thanks to the superior alliance Sony and Philips had formed (the lack of such an alliance was the main reasons for Sony's defeat in the video cassette case; see also [den Uijl & de Vries, 2013].

Even though standardisation management is a fairly new discipline with a short history lessons for the future of standardisation are to be learnt from past experiences, not least those from a failed major standardisation initiative. Most of these lessons are rather fundamental and, I would argue, virtually context independent. The reasons underlying some of the negative outcomes of the process are subject to proper standardisation management (timing, inadequate first implementations). Accordingly, they are still of relevance today.

The discussion above shows that

- corporate standardisation management is a highly complex issue;
- coverage of the topic in the academic literature is limited;
- its study requires a multi-disciplinary approach.

The literature review yields an initial conceptual model of the entities, factors and processes that influence the development of a standard (see Figure 1.6). Table 1.5 shows how the chapters of the thesis relate to the individual elements of the framework and which questions they try to address.

[47] The EU's new standardisation strategy (EC, 2022) is only one in a long list of policy documents that call for broader stakeholder participation, and for a reason.

[48] See also sect. 4.2.

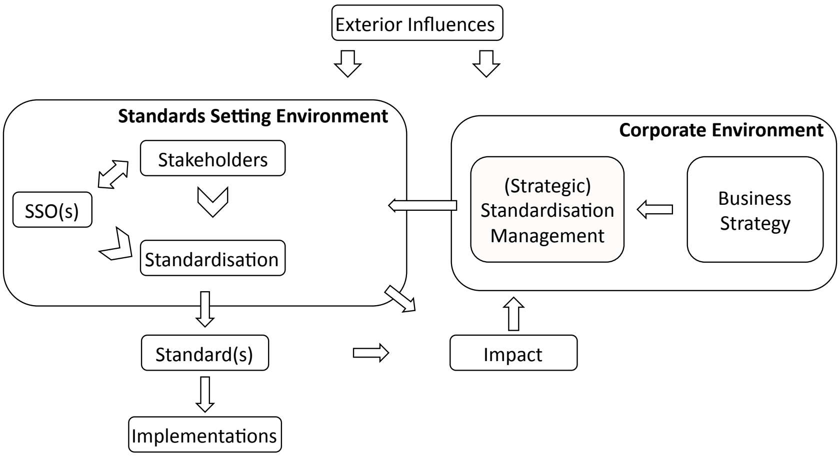

Figure 1.6: A conceptual model of the factors that influence the standards setting process and its relation to the individual chapters (adapted from [Jakobs, 2015])

Table 1.5: Relations between chapters and elements of the framework

Chapter	Framework Elements	Specific Questions
2	• Standards setting environment, • Corporate environment, • Link between environments.	How does an SSO environment influence standardisation work? Which aspects need to be considered for standardisation work? What establishes 'success'? How do companies manage ICT standardisation?
3	• Exterior factors, • Standards setting environment.	How do WG members act; what influences their conduct? How important are individual beliefs and values? What about coalitions ('individual' and 'corporate')? What influences decision making in a WG?
4	• Exterior factors, • Standardisation, • Standards, • Implementation.	How can and should SSOs react to ongoing competing / other relevant developments during standardisation? Which mistakes should SSOs avoid?
5	• Exterior factors, • Stakeholders, • Standardisation, • Standards, • Implementation.	When and how is co-ordination between standardisation activities necessary, and between which ones? Which external events/developments may impact the standardisation landscape? How can cross-sector interoperability be achieved? How should an environment for smart systems standardisation look like? How could societal stakeholders be integrated?

1.3 What this Thesis Aims to Achieve

The reader should now (hopefully) have a reasonably good general idea about the breadth and diversity of the aspects that link to (ICT) standardisation management and that, accordingly, a corporate standardisation management function needs to consider. It should also have shown that there is no such thing as a well-defined body of literature that researchers and practitioners could turn to. Rather, the literature on aspects relevant to standardisation management is spread across numerous and very diverse disciplines (ranging from Telecommunication to Philosophy). Moreover, it turned out that the topic 'standardisation' is not that overly high on the agenda of a number of relevant disciplines. Perhaps most notably, this holds for innovation management and strategic technology management (which is where most practitioner sand probably many researchers would look), but also for e.g. technology transfer and the Open Innovation community.

On top of the above it may realistically be assumed that the standardisation of smart systems will introduce new challenges, most notably a considerably widened range of stakeholders, many of whom without any technical background (i.e., e.g. societal stakeholders). This, in turn, will complicate standardisation management even further. Specifically, the function will have adapt: To a more complex web of SSOs, a broader variety of stakeholders and to a much higher level of multi-/inter-disciplinarity. It will, therefore, need to acquire new competencies, to co-operate more closely with other departments (e.g. R&D and the legal department) and to possibly also enter into new co-operations (both internal and external).

Against this background, this thesis' aim to:

- point scholars from other relevant disciplines to research gaps that need to be filled;
- serve as a point of reference for practitioners (from both companies and SSOs) and as a basis for further research activities into standardisation management;
- identify necessary characteristics of a more responsible standardisation process for smart systems (and other technologies with similarly potentially severe non-technical ramifications).

The overall goal thus is:

To unearth important, but frequently overlooked dimensions of standardisation management and incorporate them into a general framework.

1.4 Thesis Outline

This thesis looks at companies' activities relating to the management of standardisation in the ICT sector. This is a rather broad topic, encompassing a number of very diverse activities. Accordingly, the following chapters address a fairly wide variety of aspects.

Against this background, this brief, general introduction to the thesis and its structure is followed by a literature review that showcases said variety. It also shows that a fair amount of research has been done – and continues to be done – on aspects relating to corporate standardisation management. Yet, this research is typically fragmented and scattered across numerous disciplines[49]. Plus, research relevant for standardisation management is not necessarily labelled as such and, to make things still worse, scholars from different disciplines do not always know about potentially relevant work (for them) going on in other disciplines.

Aiming to catch the variety of approaches to ICT standardisation management, chapter 2 presents three case studies. These exploratory studies cover companies of different sizes (small, large and really large), from different geographical regions (to also capture the role of culture standards setting).

[49] Including, but by no means limited to (in alphabetical order): Business Studies, Computer Science, Economics, Engineering, History, Law, Management Studies, Philosophy, Sociology and Standardisation Research.

They are active in different but related fields of ICT and are active in different SSOs. Each study looks at both the company's internal management processes and some of the technical working groups within which it is active. That is, each study has two embedded units of analysis (UAs) – the company and the WG, yielding multiple cases with multiple units of analysis [Yin, 2009]. For each study, interviewees represent three groups: standardisation managers, WG members and WG members external to the company under study. Similar yet different open-ended questionnaires were used to capture information. The studies highlight differences and similarities of the approaches and provide recommendations at both the tactical and the strategic level. They cover a lot of ground with regard to corporate approaches and strategies (and also good practices), but they cannot go into all the details. So, some more specific aspects will be addressed in more depth in the subsequent chapters.

Standards are made by people. This simple truth tends to be widely ignored. But at the end of the day, individual members of a standards setting organisation's (SSO) WGs put together the specifications that may eventually become a standard. Accordingly, their backgrounds, views, convictions and prejudices are channelled into the process and likely to play a role there, as are their respective employers' strategies and business interests. Therefore, chapter 3 looks inside SSOs' working groups to study how these individuals impact ICT standardisation. To this end, a review of what little literature on the role of the individual in standards setting is available is complemented by a study of the process that lead to the family of standards associated with WiFi. That is, the IEEE 802.11 group is the study's unit of analysis. The study is based on information from this group's archive as well as on a survey of a number of its most experienced and longest-standing members. The survey, in turn, is based on a questionnaire with open-ended questions. A number of recommendations for corporate standardisation management functions are made on the basis of these studies.

I'm deeply convinced that we can learn from history[50]. Thus, chapter 4 discusses the 'historic'[51] case of the X.400 e-mail systems. Admittedly, this is a bit of a 'detour'. However, the events that prevented the wide implementation of X.400[52] (many of which were of a non-technical nature) and eventually led to the dramatic and initially entirely unexpected failure of a technically superior standard in the 1990s are certainly not unique to this case. Lessons for the future may well be drawn from them; these are spelled out. After all, it is a bit more complex than "the Internet won the 'religious war'"[53]. The chapter adopts a historiographical approach. It thus does not only look at past events, but also at other authors' interpretations of these events. As the bulk of the X.400 standardisation work was performed around 30 years prior to this chapter, this was deemed to be most suitable way[54].

Not unlike the previous chapter, parts of chapter 5 also look at the 'temporal' dimension. It first takes a look at past – in this case at the past 20+ years of the standardisation of different types of smart systems and their underlying (mobile) communication infrastructure. The outcome of this development, i.e. the current situation and a glimpse into the future, are covered via a survey targeting those that develop smart systems' standards today or whose research work may have an impact on future standardisation activities. Ultimately, the study aims to help answer the question how to best do multi-disciplinary standardisation. It was implemented as a qualitative survey based on questionnaires with open-ended questions; with SSOs' WGs and the relevant research world as the units of analysis.

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[50] This holds despite the fact that the one historian I know reasonably well is very sceptical about this, as different cultures, values and generally diverse boundary conditions making the transfer of insights at least very difficult. On the other hand, Sony seemed to have understood the lessons from the Betamax – VHS standards war when history repeated itself in the Blu-ray – HD-DVD war.

[51] By Internet standards – the events discussed took place mainly in the1980s.

[52] The International Telecommunication Union's (ITU) X.400 set of recommendation for e-mail systems.

[53] See e.g. [Russel, 2006] or [Drake, 1993].

[54] Other approaches like e.g. Science and Technology Studies (see e.g. [Sismondo, 2018]), may yield complementing findings.

Strict selection criteria made sure that only experienced individuals were invited[55]. It turns out that the (potential?) non-technical (e.g. legal, societal, environmental, ethical) implications of smart systems quite strongly suggest to also include these aspects into the standardisation process. After all, standardisation is a very early part of system development and it will be much easier to consider such aspects early on than it will be once the systems have been implemented. To this end, and now looking more into the future, a proposal is made how this could be achieved with minimal interference with the 'traditional' standards setting process.

Finally, chapter 6 puts everything together. It highlights the key findings and their implications for research and practice, at different levels. It also sketches a way forward and discusses the study's limitations.

Figure 1.2 visualises the thesis' structure. In a way, chapter 2 is the 'centre' of the work, as it introduces and discusses the overall problematic; chapters 3 – 5 contribute additional, mostly novel aspects. Eventually, everything is brought together and discussed in chapter 6.

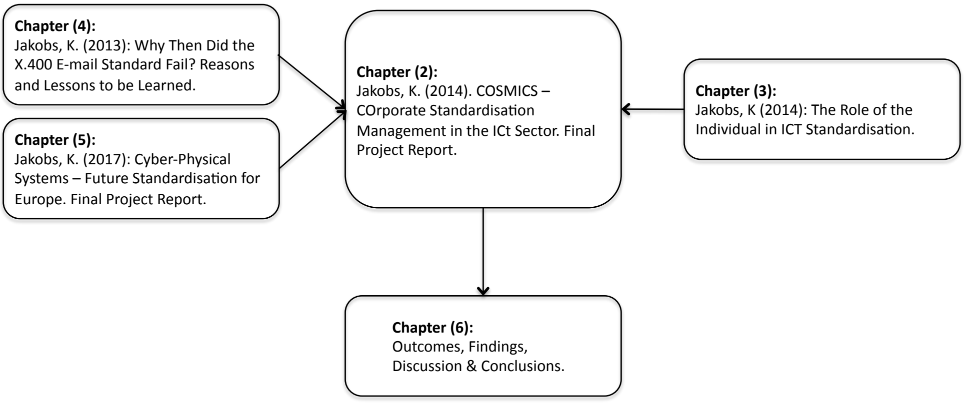

Figure 1.8: Structure of the thesis

The body of the thesis is based on two individual papers and two project reports. The reports have not been published, but ten papers (which have been published) present and discuss their main findings.

1. Jakobs, K.: *COSMICS – COrporate Standardisation Management in the ICt Sector.* Final Project Report (unpublished)[56]. 2014.
   - Jakobs, K.: *Managing Corporate Participation in International ICT Standards Setting*. Proc. International Conference on Engineering, Technology and Innovation, ICE 2014, pp. 1 – 9. IEEE, Bergamo. 2014.
   - Jakobs, K.: *Corporate Standardisation Management and Innovation*. In: Hawkins, R.; Blind, K.; Page, R. (eds.): Handbook of Standards and Innovation, pp. 377 – 397. Edward Elgar Publishers, Cheltenham, UK. 2017.
   - Jakobs, K.: *Managing Responsible Standardisation of Smart Infrastructures and Applications.* In: Jakobs, K. (ed.): Corporate Standardization Management and Innovation, pp. 193 – 202. IGI Global, Hershey, PA. 2019.

[55] See also sect. 5.7.2.

[56] This project was co-funded by Foundation CIGREF, (ISD) Programme – Wave C, Work Package 12.

- Jakobs, K.: *Responsibility by Design?! – On the Standardisation of 'Smart' Systems*. In: Gordon, J.S. (ed.): Smart Technologies and Fundamental Rights, pp. 285 – 315, Brill. 2020.

2. Jakobs, K.: *The Role of the Individual in ICT Standardisation*. In: Jakobs, K. (Ed.): Modern Trends Surrounding Information Technology Standards and Standardization within Organizations, pp. 244 – 261. IGI-Global. 2014.
3. Jakobs, K.: *Why Then Did the X.400 E-mail Standard Fail? Reasons and Lessons to be Learned*. Journal of Information Technology, vol. 28, no. 2, pp. 63 – 73. 2013.
4. Jakobs, K.: *Cyber-Physical Systems – Future Standardisation for Europe*. Final Project Report (unpublished)[57]. 2017.
   - Jakobs, K.: *Standardisation of E-Merging IoT Applications: Past, Present, and a Glimpse into the Future*. In Future Internet of Things and Cloud Workshops (FiCloudWS), pp. 342 – 347. IEEE, Vienna. 2016.
   - Jakobs, K.: *Emerging Smart Technologies and the European Standardisation System*. Proc. 30th Bled eConference: Digital Transformation – From Connecting Things to Transforming Our Lives, pp. 231 – 244. University of Maribor Press, Maribor. 2017.
   - Jakobs, K.: *Two Dimensions of Success in ICT Standardization – A Review*. ICT-Express, vol. 3, no. 2. Elsevier, Amsterdam. DOI: 10.1016/j.icte.2017.05.008. 2017.
   - Jakobs, K.: *Standardizing the IoT and its Applications – Learning from the Past?!* In: Hassan, Q. et al.: Internet of Things – Concepts, Technologies, Applications, and Implementations, pp. 191 – 217. Wiley/IEEE. 2018.
   - Jakobs, K.: '*Smart' Standardisation*. In: IEC Academy (ed.): Future Challenges in Standardization. Winning papers[58] from the IEC-IEEE-KATS Academic Challenge, pp. 19 – 26, Geneva. 2018.

I am the sole author of all papers listed above. In addition, two papers have been published with co-authors; their contributions to these papers are not part of the thesis.

- v.d. Brink, L.; Folmer, E.; Jakobs, K.: On *Multi-Disciplinary Standardisation – The Case of Spatial Data on the Web*. In: Puchar, A. et al. (eds.): Proc. 32nd Bled eConference: Humanizing Technology for a Sustainable Society, pp. 467 – 484. University of Maribor Press, Maribor. 2019.
- Folmer, E.; Jakobs, K.: *Standards Development for Smart Systems – A Potential Way Forward*. IEEE Transactions on Engineering Management, vol. 68, no. 1, pp. 75 – 86. 2020.

[57] This project was funded by the Excellence Initiative of the German federal and state governments.

[58] 2nd prize.

2 Managing Corporate Participation in International ICT Standards Setting

2.1 Introduction, Motivation And Background

Today, virtually all Information and Communication Technology (ICT) systems are based on standards.[59] Thus, standards now under development will be an integral part of future ICT systems and will define their functionality. In a way, this gives those who actively contribute to standardisation the opportunity to shape these future systems.

ICT systems have become more or less ubiquitous; this holds for most people's private lives as well as for the business environment. Regarding the latter, manufacturers of systems or components and service providers are among those with the highest interest in shaping ICT systems to make them meet their respective requirements. Depending on the stakes individual companies have in a new technology they will adopt different approaches to its standardisation. These may range from no participation at all to attempts to dominate the standards setting process to the greatest extent possible, with various levels of interest and involvement in between.

Success in standards setting (or the lack of it) may well have significant economic ramifications for a company. It may increase the 'credibility' of its standardised technology, improve the speed of its diffusions, encourage the development of complementing products and/or services, extend a market or even open up a new one for the technology and create revenues through licensing. On the other hand, backing the wrong horse by e.g. positioning a proprietary technology against a successful standard may lead to lost market shares and diminishing profits.

A standards setting process in the ICT domain does not necessarily lead to an optimal technical solution. This is due to several reasons that are not normally of a technical nature. For one, different players' potentially high stakes will often lead to some sort of compromise in order to accommodate all needs and thus prevent a stalemate situation. Other aspects that may play a role include, for example, the characteristics of potentially relevant Standards Setting Organisation[60] (SSOs), the identities, capabilities and strategies of the different stakeholders as well as their needs and requirements and those of potential customers and users. In addition, some of a firm's internal characteristics, including e.g. its envisaged role in a specific market or its research and development (R&D) and production capabilities, need to considered, for example, to align internal R&D and the standardisation process.

This chapter aims to identify both the external and internal (to the firm) factors that may influence am ICT standardisation process and that, therefore, need to be taken into account by a firm's standardisation management function.

The remainder of the chapter is organised as follows. Setting out from the very simple model developed in chapter 1, section 2.2 will successively introduce a number of factors and boundary conditions that have an impact on the standardisation process. Section 2.3 will then have a closer look at the major actors in ICT standardisation. Section 2.4 will try and put everything together to form a coherent framework. The initial findings from three case studies will be described in section 2.5 and briefly discussed in relation to the literature in section 2.6.

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[59] Biddle et al. [2010] identify "*251 technical interoperability standards implemented in a modern laptop computer, and estimate that the total number of standards relevant to such a device is much higher*".

[60] This term is used to denote both formal Standards Developing Organisations (SDOs; e.g. the International Organization for Standardization (ISO) and standards consortia).

2.2 Aspects Influencing Standardisation

Figure 1.3 shows a very rough model of the entities, factors and processes that eventually lead to a standard. The paper aims to develop a refinement of this model.

2.2.1 External Influences

External factors can hardly be influenced by SSOs or their members. However, they may have significant ramifications for the standards setting environment. This holds particularly for changes in policies or for new regulations that come in force. A recent new European regulation, for instance, stipulates that under certain conditions consortium standards may be considered as equivalent to European Standards in public procurement. This represents a U-turn from the European Commission's previously held position that pretty much ignored the existence of consortium standards. How these consortium standards are to be integrated into the existing European standards system remains to be seen.

Technical progress is another such external factor that may heavily impact standards setting. For example, nanotechnology received increased scientific, political and commercial attention in the early 2000s – the International Organization for Standardization's (ISO[61]) TC 229, 'Nanotechnologies' was established in 2005. And it is hardly coincidence that ETSI was founded in the same year (1988) when the Groupe Speciale Mobile completed the first set of detailed GSM specifications (in 1989, the group was transferred to an ETSI technical committee).

Society at large also influences technical development including standardisation through prevailing societal norms, which may change over time. In Victorian times, for example, the enthusiasm for science led to a huge number of inventions and innovations. More recently, increased environmental awareness helped trigger the development of the ISO 14000 family of standards. The impact of societal norms typically takes some time to be actually felt, but once it has materialised it may be quite strong and long lasting.

2.2.2 Standardisation

Standardisation is not a homogeneous process, carried out under one single set of guidelines, policies and by-laws. Especially in the ICT sector the standardisation work is distributed across a highly complex web of SSOs. This is primarily due to the enormous proliferation of standards consortia during the 1990s and 2000s. The links between these individual SSOs are not always easy to identify and understand. Some SSOs compete in very similar fields, some co-operate, and some just exist in parallel [Jakobs, 2008].

Not only is the web of SSOs complex, the individual organisations may also differ considerably. For instance, relevance, credibility, voting procedures, membership and membership levels, types of output documents, level of consensus required and IPR regime vary among SSOs. Updegrove [2006a] discusses these characteristics and their potential ramifications.

2.2.3 The Stakeholders – A First Overview

Like technology in general, technical standards are influenced by a very diverse set of stakeholders. Their influence is exerted through different processes with varying degrees of intensity and time-to-impact. Without any claim to completeness this list of stakeholders includes society at large, governments, institutions (firms, universities, R&D institutes, etc.), the SSOs and the individual standards setters.

At the highest and perhaps most abstract level society at large influences any technical development including standardisation through prevailing societal norms and changes thereof. For example,

[61] ISO' is not an acronym, but a word derived from the Greek word 'isos', meaning 'equal'. More information about ISO may be found at http://www.iso.org/.

increased environmental awareness helped trigger the development of the ISO 14000 family of standards. The impact of societal norms typically takes some time to be actually felt, but once it has materialised it may be quite strong and long lasting.

Governments are another – rather obvious – high-level initiator and influencer of standardisation. For example, under the New Approach the European Commission issues 'standardisation requests'[62] to the European Standards Organisations (ESOs) for harmonised standards in the support of European Directives. Influence may be exerted by political or legislative means and also through the procurement power of government agencies.

Companies are the most important and typically the most powerful stakeholders in (ICT) standards setting. They have different means to influence the standards setting process, most importantly including direct participation in the technical working groups. Another, complementing avenue is to become active in an SSO's policy making body. This approach may mostly be followed in private standards consortia, where in many cases money can buy a seat on the Board and thus influence on the strategic direction of a consortium.

Of course, the SSOs themselves also play an important role. An SSO offers a platform for standardisation activities. The characteristics of this platform will to a considerable extent shape the scope of its work and, particularly, its membership base.

Individuals are another important group. After all, they perform the actual technical work that shapes the final standard. They influence standards development not only through technical contributions, but also through non-technical skills like diplomacy, alliance formation or good rhetoric.

2.2.4 The Standards Setting Environment

Standards are developed by different SSOs. As the co-ordination between them is limited (see e.g. [Jakobs, 2008]) they may co-operate but they may also compete with each other. This has resulted in a highly complex maze of SSOs, with potentially dynamically changing links between individual organisations.

Private standards consortia have contributed much to this complexity. Another important contributing factor has been the merger of the – formerly rather separate – sectors of IT and Telecommunication, each of which had developed its own standardisation 'culture'. Figure 2.1 shows an excerpt of the ICT standardisation universe. The links between individual SSOs may represent very different forms of co-operation (using the term loosely). Figure 2.2 below shows some examples of the multitude of formal links that govern the relations between some SSOs. In addition, the Global Standards Collaboration (GSC) offers both vertical and horizontal co-ordination in the telecommunication sector (between regional standards bodies and the ITU).

[62] Until 2012 these were known as 'mandates'.

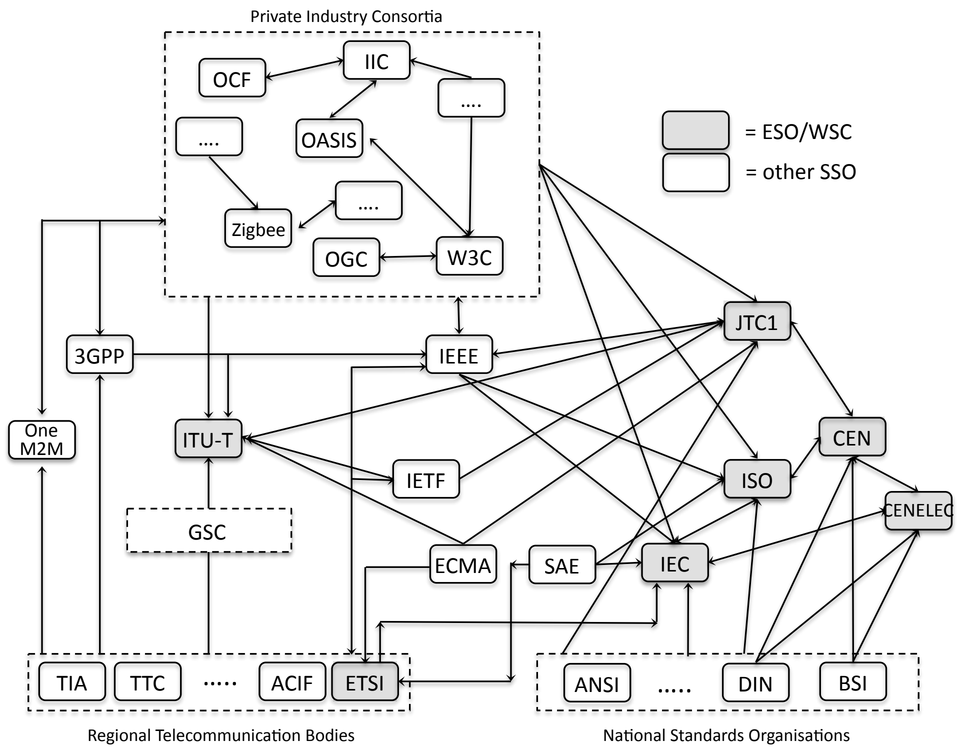

Figure 2.1: The ICT standardisation universe in 2017 (excerpt; adapted from [Jakobs, 2008])

From a management perspective, it is clearly helpful to have at least a rough idea of the – rather bewildering – types of co-operation agreements that may or may not exist not between individual SSOs. For instance, in some cases, such links may offer a welcome 'detour' for stakeholders who actively want to push a specification towards a standard. In Figure 2.2, the link between EPCglobal and JTC1 [63]would be a case in point. The EPCglobal consortium is widely considered as being largely driven by users. This is not normally the case for most, if not all, other SSOs, where users are dramatically under-represented. Utilising the co-operation between EPCglobal and ISO, a user may be able to influence the process within ISO by submitting their proposal via EPCglobal, as opposed to a direct contribution to the ISO process [Jakobs et al., 2010b].

[63] The ISO/IEC Joint Technical Committee 1 for information technology.

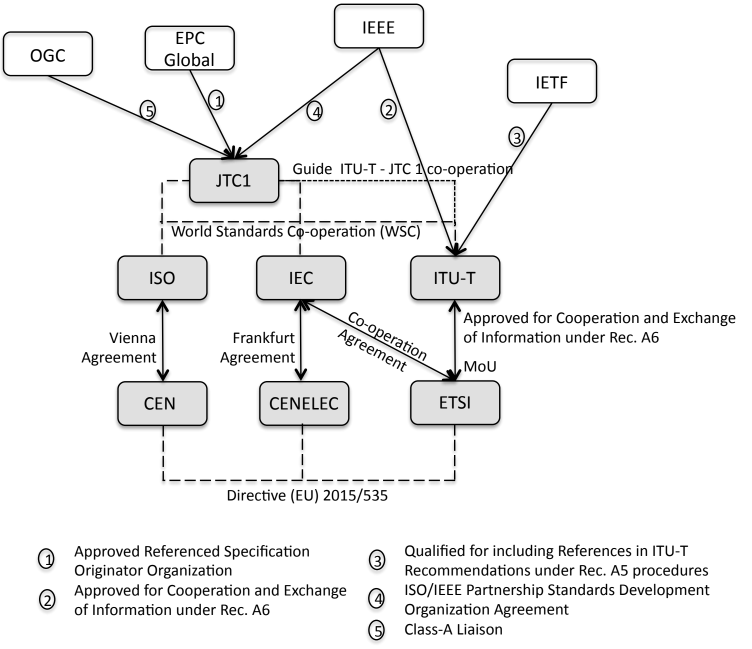

Figure 2.2: Different types of links between SSOs

2.3 The Stakeholders – Zooming in

This section provides some more details about three of the categories of stakeholders introduced above. The focus here will be on those aspects that are relevant for standardisation management; the categories 'society at large' and 'government' will not be considered.

2.3.1 Companies

2.3.1.1 Organisational Strategies

A categorisation of organisational strategies was introduced by [Miles & Snow, 1978]. They identify four types of organisations – 'Prospectors', 'Analysers', 'Defenders' and 'Reactors'.

- Prospector
  Innovative and growth oriented, searches for new markets and new products and services, prepared to take risks, relies on multiple technologies to stay flexible and adaptive.

- Analyser
  Tries to strike a balance between the search for new product/service opportunities and a stable set of offerings, technology deployed and organisational structure reflect this.

- Defender
  Aims to maintain its current markets and its limited set of products/services, only moderate emphasis on innovation, core technology is cost efficient, the organisational structure is centralised.

- Reactor
  Inconsistent or ill defined strategy, not really equipped to respond to environmental changes, may try to assume any role and to switch between them, albeit mostly unsuccessfully.

Each of these types can be characterised along three lines (see 32.4):

- Entrepreneurial
  Refers to the choice of the product/service – market domain and methods of competition.
- Engineering
  Refers to the choice of technology used to implement the methods of competition.
- Administrative
  Refers to the choice of organisational structure and processes to reduce internal uncertainty and to align the organisation with its environment.

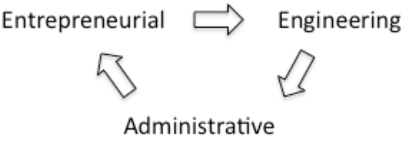

Figure 2.3: Corporate characteristics (adapted from [Miles & Snow, 1978])

2.3.1.2 Strategic Approaches to Standardisation

Firms' characteristics vary with respect to e.g. size, business sector or business strategy. Accordingly, their needs for, the perceived importance of and their ability to influence a standard will vary. Updergrove [2006] proposed a useful and applicable classification. He distinguishes three categories – 'Spectator', 'Follower' and' 'Leader', respectively. Jakobs et al. [2010a] added a fourth category, 'Contributor', placed between the latter two.

- Leader
  For companies in this category participation in a certain standards-setting activity is business critical. Accordingly, they are prepared to make a large investment in such an activity. Leaders aim to control the strategy of an SSO rather than merely participate in its activities. Large vendors, manufacturers and service providers are typical representatives of this category.
- Contributor
  A Contributor company is an active participant in the standardisation process and contributes to the development of the content of the standard. Yet, it is less interested in (or lacks the resources for) influencing the strategic direction of an SSO. Innovating companies and manufacturers typically constitute this category.
- Follower
  Organisations in this category want to enjoy full membership privileges and may occasionally want to influence the technical content of a standard (in addition to gathering intelligence). They are, however, not very much interested to influence the strategic direction of an SSO. Large users, SME vendors and manufacturers are typical members of this category.
- Spectator
  A Spectator's main motivation for participation is intelligence gathering. Spectators do not actively contribute to the creation of the standard. Rather, they want to be informed about the technical nuts and bolts of a future standard. Typically, this group comprises academics, consultants[64], and to some extent developers and system integrators. Spectators do not normally need voting rights.

[64] This is not to say that academia and consultancies are necessarily spectators. They may well assume any other role.

2.3.1.3 Linking the Classifications

An interesting link relates to the three 'lines' (domains) identified in [Miles & Snow, 1978] (see Figure 2.3) and the respective relevance of standardisation for them.

- Entrepreneurial
  Standardisation-related issues will be most prominent here. A firm wishing to introduce a new product or service in a certain market or to create a new market will in many cases rely on standards in one way or other. If adequate standards are already in place they may be used as a platform for an innovation. Otherwise, new ones will have to be developed. In this case, the focus may either be on developing *a* standard – i.e. its concrete technical specifications will be less important than the fact that a standard will exist in the first place. In contrast, if a concrete new product or service has already been specified the focus will shift towards influencing the technical content of a new standard. The typical roles assumed will be those of a 'Leader' or of a 'Contributor', respectively.
- Engineering
  This refers largely to internal (ICT) systems. In this problem area firms will typically assume the role of a 'Follower'. They will rarely develop requirements that are important and specific enough to be worth fighting for their incorporation into a new standard.
- Administrative
  While ICT standards will hardly play a role here, this problem does have clear links to standardisation. For one, it will need to address questions like where a standards department should be located in the organisational structure or if there should be a dedicated such department in the first place. Moreover, given the potentially crucial importance of standards for a firm, adequate communication channels need to be established to inform standards setters about relevant strategic issues associated with a new standard they are contributing to.

A straightforward mapping between the classifications is shown in Table 2.1. This mapping refers first and foremost to those technologies that are of vital interest to a firm. That is, different behaviours may well occur in cases where, for instance, the technology to be standardised is of undetermined interest or where participation is mostly prophylactic – they might at some point in time do some relevant work, so they'd better watch (according to [Updegrove, 2003b], back then both Sun and HP reported to be members of around 150 SSOs each). This implies that a 'Prospector' may also well be a 'Spectator' in certain cases.

Table 2.1: Linking organisational strategies and approaches to standardisation

	Leader	Contributor	Follower	Spectator
Prospector	++	+	-	--
Analyser	+	++	-	--
Defender	--	+	++	-
Reactor	?	?	?	?

++ = most likely; + = may well be; = rather unlikely; -= most unlikely; ? = unclear

2.3.2 Standards Setting Organisations

Updegrove [2006a] devised a very flexible approach to characterise SSOs, based on a number of attributes. An organisation wishing to become active in ICT standardisation can match its requirements on such a description and identify the SSO(s) that best meet its specific needs. These attributes can be sub-divided into four categories: 'General', 'Membership', 'Standards setting process' and 'Output'. The most important attributes associated with each of these categories will be briefly discussed below.

2.3.2.1 'General' Attributes

General attributes serve to provide some high-level information about an SSO. Information on its internal structure and on the way it is governed, which body makes the ultimate decisions will be especially important for those who would like to influence the strategy of an SSO. An SSOs structure and governance have ramifications for the openness of an SSO. The same holds for its liaisons with peer organisations; a good level of co-ordination reduces the risk of standardising on a technology that may eventually become irrelevant. Conversely, the level of competition a standard to be developed by a certain SSO faces from similar development going on elsewhere is an indicator of the risk to be associated with contributing to said standard. In contrast, a 'monopoly' situation suggests a reasonably safe bet.

Finally, its IPR policy has a significant impact on an SSO's attractiveness, most notably for holders of potentially relevant IPR[65]. According to [Updegrove, 2003b], for instance, two large IT vendors in a study check a consortium's IPR policy "very carefully" and "in excruciating detail", respectively, before deciding whether or not to join.

2.3.2.2 'Membership' Attributes

The overall number of members may be used as rough indicator of the success of an SSO's output. A broad membership base may well imply valuable market support for a standard. The prominence of members (in terms of e.g. market share) is also of importance. Support by large users, vendors and/or service providers will significantly improve a standard's chance to be successful in the market. More important still is the list of those important companies and institutions that actively contribute to the standardisation work in an SSO. Such active participation is a very good indicator of their support of the SSO's output.

2.3.2.3 'Standards Setting Process' Attributes

An SSO's standards setting process is decisive for its ability to quickly adapt to a changing environment and newly emerging requirements, to meet a opportunity or to support real-world implementations.

Moreover, the time it takes to develop a standard is an important factor. Obviously, this depends very much on, for example, the level of consensus sought, the degree of openness of a standards setting process, its transparency and the observation of due process. In many cases, it will be necessary to balance the requirement for speed and the need for a broad consensus (with an impact on the 'legitimacy' of a standard).

Other important aspects here include the requirement for interoperable implementations of a standard and proof of an implementation's conformance with the standard.

2.3.2.4 'Output' Attributes

The deliverables an SSO produces give an indication about its flexibility. For instance, full-blown formal standards indicate a more lengthy process, technical reports or similar types of deliverables suggest a faster, more adaptable process with a lower level of consensus. Information about the number of implementations shows the relative 'importance' of an SSO and may serve as one indicator of its 'credibility'. A standard that is maintained over time also says something about the SSO's willingness to adapt its deliverables to changing environments (as opposed to a 'fire and forget'

[65] The two most popular options include Fair, Reasonable and Non-Discriminatory (FRAND) and Royalty Free (RF). See e.g. [Simcoe, 2008] or [Lea & Hall, 2004] for in-depth discussions.

approach). A well-managed maintenance process is extremely helpful for longevity and adaptability of a standard.

2.3.2.5 Different Stakeholders' Perspectives

Different stakeholders will assign different levels of importance to the attributes outlined above. For example, a typical motivation for a large user company to participate in standards setting is to avoid eventually being stranded with a standard that doesn't succeed in the market. From its perspective (and apart from being technically adequate) the standard needs to be based on a broad consensus of all relevant stakeholders. It should adequately reflect its requirements and enjoy the support of many/all relevant major vendors and/or service providers. Ideally, no royalties should be attached but if licensing fees are to be paid they should be reasonable and not discriminate against individual firms.

On the other end of the spectrum, holders of a strong relevant patent portfolio (including potentially essential patents[66]) may well aim to make as much money as possible out of their IPR. To that end, they will primarily aim to assume a leadership position, either in the SSO or in the group that oversees the development of the standard in question. In addition, they will also send staff to the working group that does the actual technical specification work. Accordingly, they will look for a less democratic, hierarchical structure and processes that allow them to exert the desired influence.

The above, though over-simplifying, highlights that different stakeholders will look for different characteristics in an SSO, depending on their respective strategy (which may, of course, vary between standards).

2.3.3 Individual Standards Setters

The discussion above shows that different stakeholder will aim at exerting varying degrees of influence over an SSO's process, depending on their respective levels of interest in a new standard. Thus far, the focus has been on more strategic issues – e.g. how to select the best-suited SSO and how to arrive at standards that are in line with business interests.

However, at the end of the day, a standard's specification results from the efforts of the members of an SSO's working group (WG). Consequently, these individuals' motivations, attitudes and views are very likely to have an influence on the outcome of the standards setting process. A quote from a survey reported in [Jakobs et al., 2001] may serve to highlight this:

> *"Oddly enough, it's been my experience that _individuals_ dominate ISO. Sometimes the individual will have a powerful multinational corporation or government/national interest on their side, but the bully pulpit is controlled by individuals, and only those with a strong sense of purpose survive."*

This observation is echoed by Cargill [1997, p.8], who states that "*Very few standards decisions are made from a purely rational economic viewpoint—while it is pleasant to claim that standards are the fruit of quantitative economic roots, it is also highly suspect and more than a little naïve*"[67].

Even if one assumes that this is not necessarily always the case, the influence the strong-minded individual standards setter may have on the final outcome of the process should not be underestimated. [Umapathy et al., 2007] put it quite nicely: "*The human dimension of standards*

[66] An essential patent describes an invention that must be implemented to comply with a standard.

[67] Some 20 years later this appears to have changed. The same author observes "*The reality is that most professionals who are there* [at committee meeting] *are there to defend their corporate or business position. Consultants are there angling for business and an exploitable niche; market leaders are there to stop or mitigate the impact of adverse technology or craft barriers to entry; some companies are there to insert technology for the purpose of garnering royalties. Sometimes participants are there to "do the right thing", although this is rare*" [Cargill, 2019, p.10]. He continues: "*The most important 'thing' that a standards participant can possess when going to a standards meeting is a knowledge of their own corporate requirement for the standardization activity*".

setting is an important component of the consensus-based process employed by standards consortia". It should be added that the same holds for SDOs.

At least in the field of ICT (and specifically in mobile communication) the WGs are almost exclusively populated by engineers with a strong technical background (as opposed to e.g. strategy or marketing; see e.g. [Rosenkopf et al., 2001], or, albeit for a more historical account, [Henrich-Franke, 2008]). One should, therefore, assume that technical soundness, representing good engineering practice and going beyond the state-of-the-art are the most important individual success factors for a proposal to become the new standard. Yet, there is evidence that speaking out at meetings for or against a proposal is the most important single factor that influences technical decisions [Jakobs et al., 2010a]. That is, even good proposals will hardly be considered if nobody is available to explain or defend them at meetings. However, continuous active participation in standards setting in order to support proposals is a necessary condition, but not a sufficient one. Rather, a sustained participation by the same capable – and thus respected – representatives is the most promising approach. Over time, such individuals will have established extensive personal networks with their peers from both their own and other firms [Grundström & Wilkinson, 2004]; they will have amassed a wealth of social capital [Dokko & Rosenkopf, 2010]. Such social capital will make it much easier to either solve any identified problems up-front or to find solutions a rather more informal way.

The individual members of standards working groups act according to the role each of them assumes. These roles may be categorised along two dimensions. The first such dimension might be referred to as 'Task'. This refers to the actual type of activity in the WG an individual carries out. Such a Task may, for example, be to contribute fine-grained technical details ('Architect'), just observe ('Bystander'), guide the whole process ('Facilitator') or try and thwart it ('Obstructionist'; see e.g. [Umpathy et al., 2007] and [Spring et al., 1995]). The second dimension could be called 'Representation'. According to [Jakobs et al., 2001], WG members may see themselves as e.g. 'Company Representative', 'User Advocate' or 'Techie' (i.e. focus on technically clean and advanced solutions). These dimensions are not totally orthogonal to each other but in general each instance of 'Representation' may be associated with the best suited 'Task'.

In addition to the informal roles described above more formal roles also need to be filled in a standards WG. Depending on the SSO, such roles may include, for example, 'Editor', 'Rapporteur', or 'WG Chair'. These roles typically require a not inconsiderable amount of additional work to be done. The influence of those who are prepared to put in this extra work should not be under-estimated (see also e.g. [Spring et al., 1995]). Yet, a similar level of influence may be acquired through e.g. a combination of a strong personality and in-depth technical expertise. In fact, these two aspects are probably intertwined – those with strong views are more likely to invest time and effort to actually get their ideas incorporated into the standard.

2.4 Putting Things Together

This paper has identified and discussed a number of factors that may have an impact on a firm's success in ICT standardisation. Some of these factors link directly to a firm's business strategy, as exemplified by the rather close correlation between types of organisational strategies and approaches to standardisation, as identified by [Miles & Snow, 1978] and [Updegrove, 2006b], respectively. The importance of the skills and expertise of the individuals that do the actual standardisation work in the technical working groups of the SSOs have also been highlighted. An adequate consideration of these factors through a dedicated corporate standardisation management should help standardisation managers to perform their tasks more efficiently and effectively.

Thus far, the paper has looked at the actors 'SSOs', 'Companies' and 'Individuals' separately. Obviously, though, they are closely intertwined. Moreover, other influencing factors, not discussed in this paper, may be identified[68]. Plus, of course, a standard is not an end in itself. Rather, it needs to be diffused and, ultimately, adopted in order to be of any relevance for the market and, not least, its developers. Figure 2.4 shows the resulting initial conceptual model.

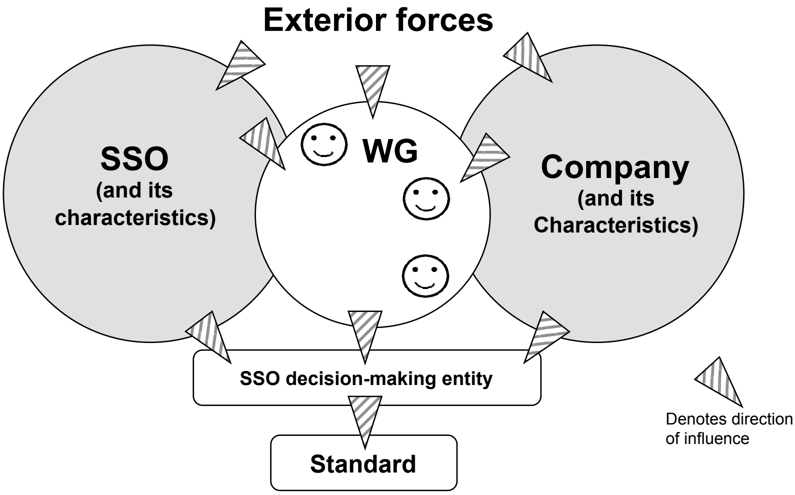

Figure 2.4: Initial conceptual model of influencing factors in standards development

The links between the individual entities are quite obvious. Corporate strategies and technical preferences, for example, should to a considerable degree shape the goals of the work of the firms' standards setters – provided that they are aware of them. Adequate internal structures, processes and information flows need to be in place to help actually provide the individual WG members with such relevant background knowledge. Moreover, firms might want to make sure that their representatives in an SSO actually promote their employer's interests (if applicable).

Both the technical and the non-technical (rhetoric, diplomatic etc.) capabilities and experiences of the individual representatives will have a considerable impact on the final standard. Which of these are more influential may vary between committees (ideally, WG members possess both, but such people are hard to come by). In any case, presence at meetings to defend one's own proposal or kill a competing one seems to be a sine-qua-non.

2.5 Methodology

2.5.1 Some Quick Explanatory Remarks

Project reports represent two chapters (this one and chapter 5) of the thesis. Both employed a very similar methodology that may appear a bit odd at first glance (as does the study presented in sect. 3.5). This holds especially for the solicitation of written responses to a set of open-ended questions, distributed via e-mail. This approach is not entirely unheard of, though; see e.g. [Koburtay et al., 2020], [Hanaki et al., 2007], [Canda et al., 2004] or [Fairman, et al., 2014]. There are, indeed, some very good reasons for this choice, which have been identified in the literature.

One such reason is the lack of realistic alternatives. Many if not most respondents were based outside Europe, which would have made travelling to a multitude of places a time-consuming and very costly

[68] See e.g. [Brons, 2007] for a thorough discussion of a multitude of factors that may impact effective participation in standardisation.

exercise (see also e.g. [James, 2007]). Likewise, a number of issues must be associated with telephone interviews. These include more 'technical' aspects (like e.g. noisy transmission lines, side noise and thus reduced understandability and time-zone related problems). More importantly (and probably not least due to these technical aspects), the telephone medium tends to generate less complex and shorter responses in interviews rather than the desired in-depth descriptive and reflective accounts, as e.g. Arksey and Knight [1999] note.

The asynchronous nature of written questionnaires and responses facilitates the participation of busy professionals who might otherwise not have been able to take part in the study and they are unobtrusive [Meho & Tibbo, 2003]. Moreover, being able to complete the questionnaire in their own time if and when it was convenient is believed to lead to richer stories (by e.g. [James & Busher, 2006]). Along similar lines, Henson et al. [2000] discovered that an asynchronous e-mail exchange allows participants to move back and forth through their responses and to revisit and possibly redraft them, thus also generating more content-rich responses. This is also emphasised by [Schiek & Ullrich, 2017, p.593], who observe that *"... in written communication the writer and the reader have far more space and resources (for example, consulting external knowledge) and time for statements and their decoding. Thus, written communication allows for homologous experience representation, even if it does not fulfil the criteria for synchronous communication and certain text genres. The experience may not be available narratively, or not even verbally*". Schieck [2014, p.387; own translation] echoes the latter by concluding that *"... written qualitative interviews may give access to information that may hardly be accessible via face-to-face interviews, or not at all*". On a different note, the asynchronous nature of written questionnaires and responses leads to *"... the absence of interviewer bias; such bias includes the tone of voice, speed of asking questions, interruptions made and may others ..."* [Woodside, 2016, p.277].

Two further arguments suggest the use of e-mailed questionnaires particular for the studies discussed in this thesis. For one, all interviewees had been actively involved in standards setting. This implies that they are very much used to producing concise, well-structured documents[69] as the outcome of their deliberations. After all, standards represent a means for knowledge transfer, making tacit knowledge explicit (see e.g. [de Vries & van Delden, 2011] or [Blind, 2013]); the same holds for such questionnaires.

Moreover, written answers leave less room for ambiguity (any remaining open issues could be clarified via follow-up e-mails) and readily provide quotable statements (i.e. no transcripts are necessary; see also [Meho & Tibbo, 2003]). Not least for these reasons, written responses at least reduce the need for explicit text categorisation (like e.g. coding). While leaving room for individual answers and comments, the questions were rather focussed, an attribute that was further supported by sub-questions if deemed necessary. In conjunction with the comparably low number of responses to be analysed (17 and 37 in total, respectively) this meant that the (sub)questions could be deployed for categorisation for the subsequent qualitative context analysis.

Previous and methodologically similar studies by the author have shown that most respondents indeed prefer the asynchronous completion of a questionnaire over a synchronous interview, which has to be scheduled well in advance and which may eventually collide with current, more pressing activities (this has also been noted by [Meho & Tibbo, 2003]). For a concise summary of the general pros and cons of the deployment of (e-)mailed questionnaires in qualitative research see [Bampton et al., 2013] and [Meho, 2006].

Independent of how exactly interviews are performed, empirical saturation represents an important aspect in qualitative research. In all studies, two types of empirical saturation have been considered, at different levels. At the overall study level, empirical saturation may very generally be defined as "*a*

[69] See also [ISO, 2017b] for an account of how much formal details matter when standards are written and [ISO, 2016a] for the level of detail that is associated with standards writing.

point beyond which few extra insights can be expected from further fieldwork" [Beuving; De Vries, 2020, p.52]. This was the case when the pool of potential interviewees was depleted[70]. In very pragmatic terms, this point was considered to be reached when a third reminder distributed to the set of potential interviewees did not yield any further responses. According to a meta-analysis, qualitative studies can reach saturation at relatively small sample sizes; 9 – 17 interviews may well suffice [Hennink & Kaiser, 2021]. These numbers could always be exceeded. According to [Legard et al., 2003, p.152], data saturation at the interview level is reached once "*the researcher feels they have … a full understanding of the participant's perspective*". In practical terms, this was the case when no further follow-up questions to a completed questionnaire were considered necessary.

2.5.2 And Why Case Studies?

Different approaches may be applied to collect and analyse empirical evidence. Similarly, research may have different purposes (and phases) – it may be exploratory, descriptive and explanatory. Common wisdom used to have it that case studies are useful for exploratory research, surveys and histories are appropriate for descriptive purposes and experiments are to be used for explanatory research. This view has frequently been challenged (see e.g. [Schell, 1992], [Yin, 1994]) and Yin [2009, p.8] observes that "*There may be exploratory case studies, descriptive case studies or explanatory case studies*".

Nevertheless, the present study is of an exploratory nature. Its goal is to identify factors that may influence the standardisation process and how they need to be taken into account by a firm's standardisation management. And standardisation management research is still in a fairly early stage, with a rather limited number of contributors and contributions. Specifically, whether or not theories from other, related fields (e.g. innovation management) may be applied remains unclear. This observation indeed suggests a case study approach as it is "*… particularly well-suited to new research areas or research areas for which existing theory seems inadequate …*" [Eisenhardt, 1989, pp.548-549]. Moreover, Yin [1981, p.98] notes that "*The need to use case studies arises whenever:*

- *an empirical inquiry must examine a contemporary phenomenon in its real-life context, especially when*
- *the boundaries between phenomenon and context are not clearly evident*".

Figure 2.4. above shows that both the standardisation process and the firm (with its various functions) cannot be separated from the context within which they exist (i.e. their environment) and which has considerable influence on both.

Yin [2009] links the choice of the most suitable research method to three conditions:

- The type of research question.
- The extent of the investigator's control over behavioural events.
- The time at which the events occurred (contemporary vs. historical).

Table 2.3 shows these conditions and the respective associated research method(s) of choice.

Table 2.2: Different research methods (adapted from [Yin, 2009])

Method	Form of research question	Requires control of behavioural events?	Focuses on contemporary events
Experiment	How, why?	Yes	Yes
Quantitative Survey	Who, what, where, how many, how much?	No	Yes

[70] Note that in all studies the overall number of respondents was (comparably) limited (with the number of WG members as theoretical maximum).

Method	Form of research question	Requires control of behavioural events?	Focuses on contemporary events
Qualitative Survey	How, why?	No	Yes
Archival Analysis	Who, what, where, how many, how much?	No	Yes/no
History	How, why?	No	No
Case Study	How, why?	No	Yes

For the task at hand, the research question (basically to identify the various influencing factors depicted in Figure 2.4) implies the need to take a closer look at two aspects[71]

- A company's management processes
  The key question to be asked here would be "How exactly do firms manage their external ICT standards setting activities?".
- The standardisation working groups
  Here, the main question would be along the lines of "How do standards working groups in the ICT sector function internally (i.e. beyond the formal rules and guidelines)?".

Both are 'how?' questions, which suggests 'experiment', 'history' or 'case study' as potential methods.

Part of the necessary information could have been compiled through a quantitative survey (e.g. "Do you have a central standards department?"), others through archival analysis (e.g. "How many people from company X attended the meetings of working group Y?"). While the responses to these questions are indeed relevant they yield only a very small part of the picture. Conducting experiments, on the other hand, would imply the ability to actually influence or manipulate the behaviour of the study subjects. Quite simply, this is not the case. And as the study is about contemporary or at least rather recent events there is no need to exclusively rely on e.g. written reports or other documents (if these are available in the first place). After all, most relevant actors will still be alive and may be talked to. In addition to the points discussed above this simple process of elimination as well points at case studies ad preferable research method.

2.5.3 Research Design

As mentioned above, the overall research question addressed in this chapter is "Which factors (may) influence the standardisation process and how should they be taken into account by a corporate standardisation management?".

ICT standardisation is a very heterogeneous environment. Its diversity extends to the major type of stakeholders (companies), the characteristics of the individual standards setting organisations (SSOs) that together establish a major part of this environment, and the individuals that populate the SSOs' working groups (WGs). To try and cover at least part of this heterogeneity, a multi-case study approach was chosen. While the number of cases that could realistically be done in a limited time will not cover the whole spectrum, the individual cases, put together, will yield a more complete picture than any single case study could.

[71] The formal characteristics of the SSOs (like e.g. Bylaws, composition of membership, fees and IPR rules) are of rather more limited interest in this context and therefore ignored. Softer aspects like an SSO's culture materialise also at WG level, they are discussed if relevant.

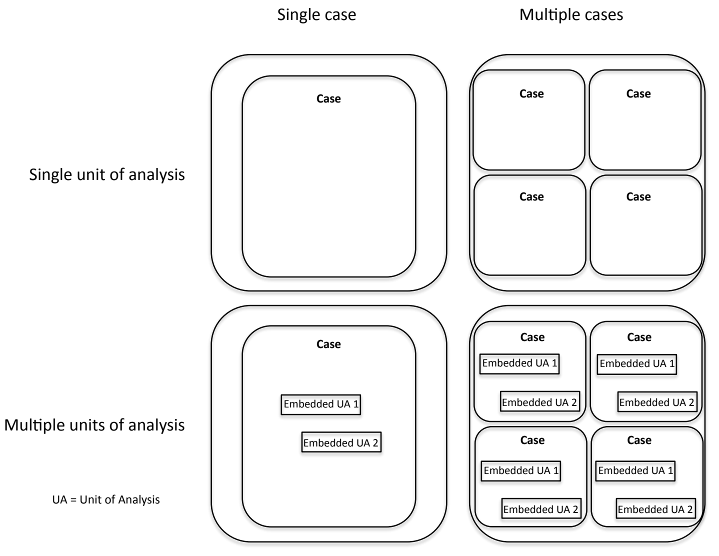

Figure 2.5: Types of basic case study designs (adapted from [Yin, 2009]).

Each case in this study is about one firm's involvement in standardisation. However, as can be seen from the bullets above, each study looks at a company's management processes as well as inside the technical working groups. Accordingly, each study has two embedded units of analysis (UAs) – the firm and the WG. Following Yin's [2009] classification of types of case study designs, the present study would be in the lower right quadrant – multiple cases with multiple units of analysis (see Figure 2.5).

One of the most popular criticisms of the case study method is its lack of generalisability (see e.g. [Morra & Friedlander, 1999]). However, the goal of an exploratory case study like the present one is not *"... to conclude a study but to develop ideas for further study"* [Yin, 2009, p.141]. Similarly, Streb [2009, p.372] notes that "*Identifying* [preliminary propositions and hypotheses] *very often is the actual purpose of the study instead of being its origin*". To this end, a number of propositions have been derived from the compiled information. These are presented and discussed in sect. 2.10.

2.5.4 Case Selection and Analysis

The idea underlying the eventual selection of case companies was to cover, on the one hand, a variety of different characteristics (e.g. size, origin) which, on the other hand, work in similar fields to allow for comparability. In addition, given the time available the number of cases could not be too high. Eventually, three companies were selected. They are of different sizes (SMEs face different problems than large companies do; see also sect. 1.2), come from different geographical areas (the role culture plays in standards setting should not be under-estimated; see also chapter 3), work in different yet related sectors (fields may well differ with respect to the way they do standards setting; see also sect. 2.2) and are active in a number of different SSOs (which may also have very different characteristics, see sect. 2.3.2). However, other, more mundane aspects were also crucial for the final selection. Most importantly, these included a firm's willingness to participate in the study (i.e. clearance by management) and the availability of knowledgeable and experienced staff members.

The author's professional network was used to initiate the process of finding companies that met the above requirements. Initially, corporate standardisation managers (i.e. individuals with job titles like 'Senior Standardisation Manager', 'Director of Standardisation' or similar) were contacted and asked whether or not they (or rather, their company) were prepared to participate in the study. In many cases this request was declined due to general confidentially aspects. Nine candidate companies did not decline participation up-front. Out of these,

- clearance by senior management (which was a rather lengthy process) could not be obtained in two cases[72];
- two companies could not be included due to an inadequate level of activities in ICT standardisation[73];
- one company that appeared suitable after a first interview had to be discarded due to unavailability or inactivity of staff members (despite promises to the contrary);
- two organisations that had originally been included due to their complementing, more horizontal activities were eventually excluded as the characteristics of their respective standardisation environments were too far removed from those of the ICT sector[74];
- two were retained.

Advice by (former) senior staff members of several SSOs (including CEN, IEEE, ISO, ITU-T) yielded six more candidate companies. In these cases

- three had to be discarded because their active involvement in ICT standardisation was too limited[75];
- in one case, the questionnaire was returned with very incomplete answers; the respondent could not be persuaded to provide more information;
- in another case, no staff members were available for additional information;
- one case was retained.

Three companies were retained – a very large Chinese multinational telecommunication equipment manufacturer and a large internationally operating British chip manufacturer; both share an interest in wireless communication. The third one is a small Dutch company active in the fields of compilers and operating systems.

Table 2.4 summarises the major characteristics of the companies under study.

Table 2.3: Characteristics of the organisations under study

'Type' of organisation	Characteristics	Main field of activity	Relevant standards bodies
The 'underdog' (OSC)	Small European SME	Compilers and operating systems	ISO
The 'high flyer' (CDD)	European chip manufacturer	Wireless communication	IEEE, Bluetooth SIG

72 Completing a (lengthy) questionnaire and/or doing an interview may well incur quite some costs (in terms of time spent) to the interviewee (and/or his/her employer). This holds all the more if a number of employees are involved and if the value of the exercise for the company is not necessarily immediately obvious (and may indeed be rather limited in some cases).

73 Both companies are major users of ICT systems but their standardisation activities are rather more geared towards engineering; this was not clear from the outset but established during an initial interview.

74 In one case, this was found out only after the analysis of the questionnaires completed by a standardisation manager and, in the other case, following a conversation with another WG member.

75 This could only be established after the analysis of the questionnaires completed by the standardisation managers; both companies are major ICT users.

'Type' of organisation	Characteristics	Main field of activity	Relevant standards bodies
The 'newcomer' (CTM)	Very large Chinese ICT equipment manufacturer	Telecommunication	ITU-T, 3GPP, IETF

The cases cover a pretty diverse set of companies. OSC represents one of the few cases in which a very small company was in a position to punch well above its weight thanks to an experienced and engaged individual. In that sense, it could be a role model for other small companies with an interest in active participation in standards setting. Something similar may be said about CTT, despite the fact that they are much bigger. They were well aware of the fact that standardisation is an important activity for their business and accordingly had a rather strong standardisation department (certainly in terms of expertise and experience). Finally, CTM is a really big player from a latecomer country; I feel this makes it particularly interesting. These companies are not necessarily representative for the ICT sector, but the proactive role each of them plays makes their practices and insights more informative than it would have been the case for companies with a low level of engagement. Moreover, their diversity enhances the potential for logic generalisations

The Sources of Information

The study deployed various sources of information (see below). Albeit desirable, it did not deploy direct observation or participant observation. For one, both would have been too time consuming. Direct observation would, in principle, have been possible for the 'working group' UA, but would have involved travels to typically frequent meetings of different working groups all over the world. Moreover, issues of multiple SSO memberships and accreditations would have imposed not inconsiderable logistical and financial burden. Plus, it would not have been possible for the 'company' UA. Participant observation could be ruled out for the same reasons, in combination with inadequate technical knowledge on the side of the author in almost all technical domains covered in the study. Thus, other sources of information had to be deployed.

Documentation

Perhaps a bit surprisingly, documentation was not a very major source of content information. Some types of documentation would have been extremely valuable, but could not be accessed for confidentiality reasons. These included primarily corporate standardisation strategies and individual WG members' meeting reports. Many companies rate all information about their standardisation activities as 'confidential'. Even the companies that did participate in the study (i.e. are more open) still would not make printed material available to outsiders.

The most important type of written information were SSOs' and WG's web sites and, particularly, meeting reports. In addition to occasionally providing a more detailed account of ongoing events and the development of a standard they were invaluable as sources of contact information.

Questionnaires

The bulk of the information was primarily compiled through questionnaires [76]. Different questionnaires were prepared for the different groups of interviewees (see below). All questionnaires were semi-structured and comprised open ended questions. In almost all cases these questionnaires

[76] Only one respondent represented in the study preferred to provide part of the information via an interview and part via a questionnaire. This interview was recorded and transcribed. During two other (initial) interviews (HoD Technical Regulation and Standardisation; HoD Corporate Standardization) it turned out that both companies were not suitable for the purpose of the study. Unfortunately, another (initial) interview with a Senior VP of a large Telco provider could eventually not be used Respodnetseither as no further information could be obtained from his – rather uncooperative – staff.

were distributed and collected via e-mail (including the clarification of any remaining open issues; see also sect. 1.3).

Given the overall purpose of the project, the information to be compiled through the questionnaire were manifold. At firm level they ranged from a firm's motivation for and ways of participation in standardisation via the internal organisation of its standardisation management and the way how the individual representatives are selected and trained to descriptions and evaluations of specific recent major activities. At the working group level the aspects covered included, for example, roles assumed by the individual and perceived success factors.

This diversity alone suggests the need for the compilation of information from different sources, specifically from different individuals within and outside the firm. This is in line with the general recommendation to use multiple sources in case study research. Darke et al. [1998] note that "*Multiple sources of evidence also assist in corroborating information provided by different participants where there are conflicting accounts of events and actions*". This triangulation of data also serves to counteract any potential bias on the researcher's side.

The Respondents

To reflect the different units of analysis (company and WG) and for triangulation purposes, different target groups have been identified and different questionnaires have been developed for each of these groups (see Appendix A). The target groups include:

- Corporate standardisation managers;
  Contact information came from the author's network or from senior SSO management staff. Theirs was the most complex questionnaire, comprising 32 questions, many of which had sub-questions.
- Corporate WG members (i.e. those who do the technical work);
  Here, contact information was obtained from management staff. The questionnaire for this category of respondents was much shorter, comprising 10 questions without sub-questions.
- External WG members (i.e. peers from other companies);
  Contact information were primarily obtained through official SSO documents (meeting minutes etc.). The questionnaire for this group was the shortest, with 7 questions. It mostly served to triangulate the responses from employees of the respective case company. Particularly this step comprised sending a not inconsiderable number of personalised e-mail messages (around 250 messages, including reminders).

All potential respondents were contacted by myself; sometimes upon recommendation (which was mentioned in the introductory e-mail message). In total, 17 completed questionnaires were used as a basis for analysis (two standardisation managers, two managers who also represented their respective company in WGs and twelve peers from the respective WGs). The respondents per case were:

- OSC: 1 corporate manager/member, 3 external
- CDD: 2 corporate managers, 1 corporate member, 4 external
- CTM: 1 corporate manager/member, 5 external

The Questionnaires

Dedicated questionnaires were developed for each group of respondents.

- Corporate standardisation managers;
  This was the most complex questionnaire, comprising 32 questions, many of which had sub-questions.

- Corporate WG members (i.e. those who do the technical work);
  The questionnaire for this category of respondents was much shorter, comprising 10 questions without sub-questions.
- External WG members (i.e. peers from other companies);
  The questionnaire for this group was the shortest, with 7 questions. It mostly served to triangulate the responses from employees of the respective case company. Particularly this step comprised sending a not inconsiderable number of personalised e-mail messages.

For standardisation managers the questionnaire comprised five parts:

A. General
   This asks for some background information about the company, the department and the job of the respondent (three questions).

B. Standardisation activities
   This covers the firm's goal(s) of its participation in ICT standards setting, the 'intensity' of participation deemed appropriate to achieve the goal(s) and the means of participation used to achieve the goal(s) (five questions).

C. Standardisation Strategy & Management
   This covers aspects like the organisational structure for standardisation management, number and training/education of the associated staff, communication channels and requirements to be met for any new standardisation activities (ten questions).

D. About People
   The standard setters are in focus here. This includes issues like the selection process, their training/education, and performance aspects (seven questions).

E. Specific Standardisation Activities
   This part addresses some recent major standardisation activities, the underlying goals, their evaluations and the general question about the meaning of 'success' in standards setting (seven questions).

The questionnaires for the corporate standards setters and the external WG members, respectively, are much shorter. Basically, the former asks about motivation for participation, information received, role assumed during the process, tasks to be performed, perceived important characteristics a successful standards setter should have and the perception whether the activity should be considered a success or a failure. The latter asks what actually steered the process, if any firms or individuals had (tried to) assume a leading role in the process and if so, how they tried to achieve this. Moreover, it asks for general approaches that firms should adopt and characteristics individuals should have in order to be successful in standardisation. These questionnaires were individualised in the sense that references were made to the respective specific WGs (which had previously been identified by the corporate standardisation managers).

The main part of the study was mostly conducted in the second half of 2013.

The Content Analysis

The analysis covered 17 completed questionnaires in total, the number of respondents per company varied between four and seven. Overall, this was a manageable number of questionnaires. In conjunction with the fact that a) the individual (sub)questions were quite focussed and with b) the observation that active standards setters are used to write precisely and concisely (see also sect. 1.3) this meant that the (sub)questions could be deployed for (implicit) categorisation[77] of the responses for the subsequent qualitative context analysis. To this end, for each category of respondents the full

[77] That is, I did not consider coding to be necessary.

responses per case were integrated into one document. For standardisation managers the responses amounted to 2 – 6 written pages per questionnaire (the others were much shorter); the resulting documents provided for a quick and convenient overview of the grouped responses. All responses were then read and re-read several times. Given the very manageable number of questionnaires per topic this already yielded a good general picture.

2.6 Case 1: OSC – Operating Systems and Compilers

2.6.1 Background

The Company

OSC is a small SME[78] headquartered in the Netherlands. They were founded in the mid-1970s. From the start OSC's activities focussed on operating systems (Unix, Linux, etc.) and on building compilation systems, for example, development systems and test and validation suites for compilers. Other areas of work include high-end graphics, software engineering tools, communications and networking, embedded systems, high performance and parallel processing systems and tools for VLSI design. In addition, IT consulting services are offered. The company has some 20 employees and a turnover in the seven figure range.

The Standards Body

ISO is a global, non-governmental federation of national standards bodies from about 160 countries. ISO was established in 1947. Membership in ISO is on a per-country basis, with one organisation – typically the respective national standards body – representing its country. There are full members, correspondent members (which do not actively participate, but are kept fully informed), and subscriber members which normally represent those countries that cannot afford one of the other categories. Depending on a full member country's interests its representative may decide to become a P(articipating) member or an O(bserving) member in a committee, or no member at all. P-members participate actively in the work, with an obligation to vote on all questions formally submitted for voting and, whenever possible, to participate in meetings. O-members receive committee documents and have the right to submit comments and to attend meetings, but not to vote. The actual standardisation work is almost fully decentralised and performed by over 280 Technical Committees (TCs), their respective Sub-committees (SC) and Working Groups (WG), with a total number of more than 3,000. All in all, ISO has produced over 22,000 standards and specifications (as of July 2019). Development and revision of standards are carried out as 'projects' within a committee. Typically, a project is assigned to a Working Group (WG) comprised of individually appointed experts. It should be noted that these experts act in a personal capacity and not as the official representatives of the organisation by which they have been appointed [ISO, 2017a]. ISO itself primarily provides a central administrative entity, provides guidance and strategic direction and maintains an overall schedule for each standardisation activity.

To adequately deal with all aspects of Information Technology (IT) ISO and the International Electrotechnical Commission (IEC) jointly established the Joint Technical Committee One (JTC1) in 1986. Today (July 2019), 35 countries actively participate in the work of JTC1 another 65 are observers. JTC 1 has developed its own set of procedures and guidelines [ISO, 2019], taking into account the special circumstances of, and requirements on IT standardisation. JTC1 comprises 22 active SCs.

The Working Group

In JTC1, SC 22 deals with 'Programming languages, their environments and system software interfaces'. SC22 has 7 active WGs; WG14 is in charge of the C programming language.

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[78] Small and Medium-Sized Enterprise.

The WG normally meets twice a year. Typically, 20+ people attend, with a core group of about 15 – 18 individuals. A Convenor is the official leader of the group. Geographically, the WG is clearly dominated by representatives from the US, with a few attendees from Canada and Europe. Throughout the period under study the group comprised almost exclusively of regulars, i.e. individuals that attended (almost) every meeting. Very few people showed up only occasionally. While companies like IBM, Intel, SUN and Cisco were represented, the majority of delegates (including the convenor) come from (very) small companies or are (self-funding) individuals without (disclosed) affiliation. Also, the vast majority of contributions (>90%) came from representatives of small companies[79].

The Standard

The standards setting activity under study aimed to extend the C-language for use in embedded systems. The initial scope of the activity was "*to define extensions to the syntax and semantics of the C language that allow the development of portable C programs that make optimal use of the characteristics of Digital Signal Processors used in embedded systems*"[80].

The justification of the activity read "*In the fast growing market of embedded systems there is an increasing need to write application programs in a high-level language such as C. Basically there are two reasons for this trend: programs for embedded systems get more complex (and hence are difficult to maintain in assembly language) and the different types of embedded systems processors have a decreasing lifespan (which implies more frequent re-adapting of the applications to the new instruction set)*"[81].

The 'official' development of the standard started in the wake of the WG's 1998 meeting in Santa Cruz[82]. This first document, ISO/IEC/JTC1/SC22/WG14/N854, was entitled 'DSP C – an extension to ISO/IEC IS 9899:1990' and was submitted in October 1998 as a 'New Work Item Proposal'. A ballot at SC22 level yielded no 'no' votes and one (somewhat critical) comment. Two 'no' votes with comments were issued in the subsequent ballot at JTC1 level. These issues could be resolved and the proposed Technical Report (TR) was approved as a New Work Item. The functionality described in the TR is not part of the C-language standard proper because it is relevant only for a subset of developers.

Almost exactly five years later, in Autumn 2003, SC22 voted on the Preliminary Draft version of the TR. Eight P-Members approved without comment, three with comments, two did not support approval and ten did not vote at all. The document was published as ISO/IEC TR 18037 in 2004. It was entitled 'Programming languages – C – Extensions to support embedded processors'. Following a number of defect resolutions the document was superseded in 2008 by ISO/IEC TR 18037:2008. This version is still in force.

OSC's representative was the editor of the TR.

The Corporate Respondent

The respondent joined OSC two years after its foundation. From 1980 – 1995 he was manager of the compiler department. Today, he is member of the management team and does consultancy work for customers in the areas of standardisation, software development and testing. He has extensive experiences in standardisation. Since 1986 he has been active in several ISO committees, mainly in the programming language area (ISO/IEC JTC1/SC22). He has been a member of WG2 (Pascal),

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[79] Based on information compiled via the WG's document register at http://www.open-std.org/jtc1/sc22/wg14/www/documents.

[80] http://www.iso.org/iso/home/store/catalogue_ics/catalogue_detail_ics.htm?csnumber=30822.

[81] http://www.open-std.org/JTC1/SC22/WG14/www/docs/n906.htm.

[82] http://www.open-std.org/jtc1/sc22/wg14/www/docs/post-Santa_Cruz.htm.

WG15 (POSIX), WG14 (programming language C) and WG11 (programming language independent specifications), chairing WG11 from 1991 – 2012. Since 1987 he represented the Netherlands at SC22 meetings. Moreover, from 1990 – 1997 he was active in Functional Standardisation at both European (EWOS) and ISO level, chairing ISO/IEC JTC1's Special Group on Functional Standardization from 1994 – 1997.

Information was mostly compiled through a questionnaire for standardisation managers (see sect. 2.5.2), the more sensitive information[83] through an additional interview.

The Respondents from the Working Group

The respondents from WG14 include three long-standing members with a vast experience in the field (out of eleven that had been contacted). They represented a large manufacturer (OSC direct competitor in the field covered by the TR) and two small US companies (one of the latter was also the WG convenor) and completed the questionnaire for external WG members[84].

The Market

The TR does not target a very large market. Its main users are companies that build C-compilers and chip manufacturers ('direct users', i.e. those that implement the standard). Accordingly, it is difficult to estimate the size of the market for TR18037[85]. Software that uses fixed-point is wide-spread, especially in signal processing and graphics applications (like in mobiles) but it could be that there are only a limited number of different compilers necessary for all these applications. The GNU Compiler Collection GCC), which covers a large deal of the market, has implemented TR 18037 in various versions. It is, however, less manifest which other compiler vendors have implemented it.

Motivations for Participation in Standards Setting

For a company like OSC, which is mostly active in field of compiler systems, the programming language standards are *the* defining specifications. OSC considers it important to not only adhere to those specifications but also to actively participate in, and contribute to, the development of those standards. Currently the company's main focus in this field is on the C programming language (and to a lesser extend to C++ language) and, accordingly, the focus of its participation in standards setting is ISO/IEC JTC1/SC22/WG14.

OSC's general conviction is that active contributions to standards setting is in the company's best interest. Specifically, the driving factors behind its standardisation activities include:

- to be there and know what is going on (this holds primarily for standards that are of lesser importance, like C++);
- to influence the standards directions (this is the goal if the standard is more important, like C);
- to be seen (by their customers) as knowledgeable and influential in the standards world.

Active participation in standards setting is very important for OSC – with an overall rating of 9 out of 10. In addition to the points identified above, pushing an own standard and the prevention of the emergence of a standard that is incompatible with their own technology or developments are additional potential reasons for participation. In contrast, exploitation of own IPR and the creation or extension of a market are not considered overly important.

The role of an 'observer' (who participates only to gather intelligence) is assumed only for less relevant standards, whereas both 'adopter' (who has strong interest in understanding the intricacies of

[83] Specifically parts D and E of the questionnaire for standardisation managers.

[84] One of the others wasn't involved in that particular activity, the remaining seven didn't reply at all.

[85] Here, the number of 'indirect users' would be relevant, i.e. those that use the compilers that implement the standard. V. Hagen [2006; p.215] speaks about "*a tremendous number of users*", without giving any figures.

the implementation of the standard, but does not make strong contributors to its content) and 'leader' (for whom participation is business critical and who aims to control the strategic direction of the process) roles are assumed in the case of standards that are of importance for the company. A 'leader' approach is also followed at a more strategic level, i.e. at the level of the Subcommittee within ISO (JTC1/SC22) and at the national level within NEN (the Dutch national standards body[86]).

OSC may also assume the role of an 'opponent'. Preferably, though, they would try to prevent another specification from becoming a standard by being the first to propose a standard in an area in which they have a sufficiently high interest. If that's not possible (and this is a hypothetic case; this situation has not occurred so far), the company would probably try to oppose such a standard at the management level (the idea behind this standards proposal is ill-conceived, not worth the effort, contradicting existing practice, does not help portability), not at the (detailed) technical level. This approach is largely based on the insight that a single company can do very little if people want to work on a project and have managed to get this project into the work programme.

Especially to be able to actually take on the role of a leader, OSC tries to occupy a formal leading role in the process (the respondent used to chair JTC1/SC22/WG11). Moreover, their representatives need to be both very good engineers and good communicators and diplomats. On the other hand, training or education are only provided on an 'if-needed' basis, as are information on any business goals underlying the standards setting activity.

Standardisation Strategy and Management

OSC does not have a written or explicit standards strategy. It has never been necessary and the company is small enough to handle any standardisation-related activities and issues informally on an ad-hoc basis. Any such activities are managed by OSC's management team. As resident expert the respondent is the focal point for any relating questions (e.g. on clarification and interpretation of standards) and proposals. The same holds for the internal dissemination of information about any new and potentially relevant standardisation activities that are compiled by the respondent from his activities in the national and international standardisation arena and from relevant internet fora.

This rather informal approach also extends to the link between internal R&D and standardisation (i.e. the respondent). A (potential) new standardisation activity (e.g. new additions to a standard) may emerge from internal development work, but is frequently triggered by input from customers. Any such proposals are first discussed internally and possibly with interested customers. If a proposal is considered credible, useful and implementable it will be brought into the relevant standards group either through a formal proposal or via informal discussions. Such activities are funded through a central budget item for standardisation.

OSC does not do any performance evaluation' of their standardisation activities. In fact, they consider it very difficult (if possible at all) to define meaningful specific performance evaluation criteria for standardisation activities. Generally, they would consider it a success if they were recognised as an important player (as both participant and contributor) in the standardisation work.

About People

Today, the respondent is the only OSC employee who actually goes to standards meetings (at both WG and SC level). This has changed over time; colleagues used to attend WG meetings as well. However, other employees are consulted if specific information or expertise is required. All OSC technical people come from academia and have a certain background in R&D.

No formal incentives would be offered to potential standards setters. However, in earlier times when more than one OSC employee had to go to meetings indirect incentives included being recognised internally as being the expert (as opposed to being an expert), thus conveying additional status.

[86] The respondent chaired NEN's TC NC 381 022 'Programming Languages' for 20 years.

Moreover, the opportunity for international travel (to WG meetings) helped attract especially younger employees.

Being the only OSC representative in standards setting (both nationally and internationally) today, having almost 30 years of experience in this field and being a member of the company's management team the respondent does not need either briefing nor monitoring. Yet, both were hardly necessary even when more (junior) people had been active in standards WGs. This is due to the fact that those who used to be sent to WG meetings were experts in their respective field and knew very well which functionality they wanted to have included in an emerging standard. Plus, programming languages are a highly technical domain with limited if any strategic or political ramifications.

The situation is different when it comes to meetings at the sub-committee (SC) level. Here, delegates act as national representatives. That is, they also need to align potentially diverging company positions. However, this never happened to the respondent. Rather, the most important aspect was that the Netherlands were represented at all in JTC1/SC22. Also, a small country like the Netherlands might well act as a mediator in case of differences between powerful countries or regions (e.g. between the UK, France and Germany at European level and between the US and Japan at the international one).

In order to be effective at either WG or SC level continuous participation by the same people is crucial. Initially, newcomers are typically lost and need to find their way round over time.

Primarily network building is crucial. Such a network is of utmost importance for informal information gathering and in cases where are favour needs to be asked. In such cases people need to know that any such favours will be returned if and when necessary. To make participation more effective, informal education used to be provided by the respondent. This covered aspects like the formal rules underlying standardisation processes as well as information about other companies' views and behaviour.

As OSC is a rather small company with limited and focussed standardisation activities and with a competent and experienced standards setter on their payroll they don't have a need for additional manpower or expertise in standardisation. On the contrary – the respondent has been hired by other companies to represent them in standards working groups.

An Important Standardisation Activity

The major not quite so recent standardisation activity into which OSC was involved aimed to extend the C-language for use in embedded systems. The activity resulted in the Technical Report ISO/IEC TR 18037:2008. Basically, the TR specifies a fixed-point extension to the C-language.

The original fixed-point extension to the C-language was done upon a request by an OSC customer. Accordingly, one of the company's goals underlying the standards setting activity was to make this customer happy. In fact, this is a frequent motivation behind OSC's standardisation activities. Another important motivation was to position the company and their product in the market. At some point in time it became clear that a large competitor was also planning to become active on this topic, albeit with an approach very different from that of OSC. If they had taken over and succeeded with their proposal the situation would have become very unpleasant for a small company like OSC. Stranded with a non-standard technology they would have lost most if not all investments in this field. That is, without this standard (or rather, with the incompatible one likely to have emerged without OSC's initiative) they would have had to throw their implementation away and to build something new; a costly and time-consuming exercise. Moreover, they had been convinced that their implementation was better than those of their competitors. Another motivation had been that the company wanted to be seen as expert standards setter by their customers. They wanted to demonstrate that they can take the lead in such a global environment, can make things happen and can achieve the desired results.

Accordingly, and in line with their general approach they aimed to pre-empt the competitor's initiative and submitted a proposal based on their proprietary technology.

In the course of the ensuing work some compromises had to be made and some parts of the original document had to be modified (which are said to have led to an improved document). Eventually, and after a number of revisions the final document was approved in 2004. A second, revised edition was published in 2008.

The TR is technically a good standard, but its actual relevance is not quite clear. That is not least due to the fact that information about numbers of implementations is not normally fed back into the originating WG; feedback typically only comes if a defect or an issue has been identified by an implementer.

OSC rates its level of success in this activity as 8 out of 10[87]. The final specification is not completely in line with their original proposal. This caused some efforts inside the company, but they consider it as close enough and as a success overall. This is not least due to the fact that their customers (including the one that triggered the whole activity) are happy with the outcome. Many of these customers are chip manufacturers who ship their chips bundled with a compiler. With the TR they can tell their customers that they have a standards compliant implementation.

WG members agree that the 'Leader' (OSC) got almost everything he wanted into the standard. Also, there have never been any attempts of actively delaying the process or otherwise hampering it. Nonetheless, the group's decision are based on consensus and nobody will get everything he or she may want.

A number of factors contributed to this outcome. Specifically, 'technical knowledge' is crucial. The group largely comprises active people who are very knowledgeable in the field; only very few have adopted the role of an observer (i.e. they did not actively contribute). In this particular WG success comes more from 'technology oriented' approaches. That is, proposals or contributions need to be sound and technically superior to get accepted; these proposals need to be presented by technically capable people. Rather more non-technical abilities may well help, but are of lower importance. Accordingly, in order to prevail and to be successful a WG member primarily needs in-depth technical knowledge.

However, many non-technical aspects may also play a crucial role. These include, for example, knowledge about the formal aspects of the respective standards setting process. That is, you have to know very well what needs to be done when (each standards body has its specific rules, by-laws and guidelines). You also need to know how exactly a proposal should be made, i.e. it needs to be clear how a proposal should look like and what it should contain. For example, a proposal for a standard is very different from a project proposal.

Yet, some less formal aspects are of importance as well. For one, it may help if you are a long-standing, reliable WG member. Likewise, knowing the important people (e.g. the convenor) and getting along with them well is very important. It is very helpful to talk to these people up-front about your plans, to align with them and to get their support. Once the work is under way, you need to be prepared (and to be known to be prepared) to actually contribute heavily and to make sure that the work gets done. And you need to be clear about the fact that the people in the WG do the work because they like it (this holds for the field of programming languages where corporate stakes are not normally very high and which takes place in more 'academic' environment; things may well look different in other areas). Nevertheless, opinions are a bit split about these aspects.

[87] The respondent reckons that getting '10 out of 10' is next to impossible, certainly for such a small player. He also reckons that it might be possible if you are with a powerful company which can push its proposal through by adopting a 'take it or leave it' approach.

It remains somewhat unclear who (or what) actually steers the work of the group. The importance of the role of the formal leader (i.e. the Convenor) has been mentioned (albeit primarily by the Convenor). Yet, once again the importance of the willingness to make major technical contributions and the ability to follow up on them and to defend them is highlighted here. Accordingly, the success of a company to actually get its proposal accepted without too many modifications does not so much depend on assuming the role of a formal leader, but on the technical qualities of both the proposal and its champion.

OSC has been successful in most cases in which they had proactively contributed to standards setting[88]. From their point of view of being part of the network is a decisive factor. This will get you the group's 'moral support' if you are perceived as an experienced and credible contributor who does not come up with stupid proposals and who is prepared to listen to others.

2.6.2 Discussion and Initial Findings

The case study is about a small firm's participation in standards setting in the highly technical field of programming languages. While programming languages may in principle be protected by both copyright and patent law (at least in the US) no patent declaration that relates to any standard under SC22 responsibility ('Programming languages, their environments and system software interfaces') has ever been filed with ISO[89]. This, in turn, helps explain why the exploitation of IPR was not a motivation for OSC to engage in the development of the TR. At first glance this may be a bit of a surprise as the ICT sector is typically (and with some justification) associated with IPR issues (the recent 'patent war' between Apple and Samsung is a popular example), as is ICT standardisation in particular ('standard essential patents'). In this case, however, the size of the market (in terms of the number of implementers) is comparably small and hardly any chances of extending it may be associated with the standard – an addition to a programming language will not extend the market to any degree worth mentioning. Accordingly, another frequent motivation for participation in standards setting – extending a market – does not apply either (see e.g. [Swann, 2010]). Moreover, the very technical nature of both the standard and the WG suggests that in such an environment any discrepancies between competing proposals (if there are any in the first place) will be reconciled on a technical – as opposed to e.g. a political – basis.

Despite the absence of these more 'strategic' motivations OSC take their standards setting activities serious.

> *"For compilers, the programming language standards are* ***the*** *defining specifications. And coming from an academic background ACE considers it important not only to follow those specifications but also to actively participate in and contribute to the development of those standards"*[90]. <OSC[91]>

In addition, suggestions for new fields of standardisation often come from their customers, and keeping customers happy is a priority for the company. Accordingly, such rather more non-strategic, down-to-earth motivations may suffice for comparably extensive standardisation activities (given the size of the firm).

The 'academic background' mentioned above, in conjunction with the absence of overly strong strategic needs seems to have led to some kind of 'free spirit' environment in the WG

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[88] However, he also admits that in general success is hard to measure.

[89] http://isotc.iso.org/livelink/livelink/13622347/Patents_database.xls?func=doc.Fetch&nodeId=13622347.

[90] Unless marked otherwise, all quotes were taken from the completed questionnaires without any corrections of typos or grammatical errors.

[91] This identifies the respondent as the OSC representative.

> *"The people work because they like it, not because they have to. So, you cannot steer, it's very difficult to steer the standardisation process. Sometimes you have a sub-committee or a technical committee level people say "ok, now we're going to steer and the WG should do this, that and the other and they should report back to us. And that doesn't work. Because, why should they do it; there's absolutely no reason to do it"*. <OSC>

It may be speculated here that such steering efforts from higher levels will be more successful if strong business (at the higher level) interests are at stake. Corporate financial stakes in this particular standard, however, have not been very high due to market characteristics.

Most likely, the above also helps explain an interesting finding from the case. While the group has indeed been dominated by SMEs (down to one-person consultancies) a number of 'heavyweights' were also significantly involved in the development of TR 18037 (albeit more in terms of attendance than of contributions, with one exception), including e.g. Intel, Cisco, SUN, IBM and Microsoft. Nevertheless, the study shows that even a small SME like OSC (26 employees) may punch well above its actual weight in ICT standards setting.

> *"They* [OSC] *got almost everything in the TR that they wanted"* <WG3[92]>.

In fact, today the basic technical approach from OSC, upon which TR18037 is based is more and more considered the 'natural' way of doing things. To be able to do so

> *"You really have to know the process, you have to know your technical stuff, you have to know the people and you have to be willing to put in the effort"*. <OSC>

That is, it takes expertise, credibility and the willingness to invest not inconsiderable resources (relatively speaking) into the activity.

The importance of in-depth knowledge of the technical aspects is highlighted by all:

> *"Sending technically capable representatives and making superior proposals/ contributions are IMO the best strategy for a Leader to prevail"* <WG2>.

In fact, all respondents agree that "*in-depth technical knowledge*" and "*a strong sense of purpose*" are most important characteristics for a WG member who wants to push a proposal or contribution. The same holds for the need of on-going work and dedication. Adding an additional angle, a WG member observes that

> *"A proposal that is not followed up by a champion usually will go no where"* <WG1>.

This is very much in line with observations from other standards bodies (see e.g. [Jakobs et al.; 2001] and [Jakobs et al.; 2010a]) where the presence of supporters and/or opponents is said to be of overriding importance. The OSC representative acted as editor of the TR, thus ensuring the company's continuous involvement and the presence of a champion. Going even one step further, the same WG member observes that even poor presentation skills are tolerable in this group since

> *"The ability to present a technical paper helps, but, this is a group of experts and mostly they know how to overlook a poor presentation if there are technical merits to the proposals"* <WG1>.

Once again, this (indirectly) also highlights the level of technical expertise of the WG members and the supreme importance assigned to the technical merits of a proposal.

On the other hand, the importance of knowledge about the process is challenged:

[92] <WGx> identifies the respondent as WG member x.

> *“Diplomatic skill and familiarity with the procedures are just not that important* [in WG 14]*, the leadership of the group (me) shoulders most if not all of the diplomatic issues that have to do with our parent organization”* <WG1>.

It should be noted, though, that this comment was made by the group’s Convenor. The comment also points to another phenomenon, albeit indirectly: ‘Diplomatic issues’ are said to occur only in relation with the WGs ‘parent organisation’ (i.e. SC 22). This, in turn, suggests that the convenor does not see any such diplomatic issues inside the WG (at least no major ones worth mentioning). This is seen differently by another WG member

> *“Where valid differences must be reconciled, being a good negotiator and alliance builder helps steer a group to consensus, but that should never be at the cost of obtaining a misinformed or coerced consensus”* <WG2>.

This comment once again also highlights the group members’ desire to reach a technical superior solution, not one that is based on “misinformed or coerced consensus”.

Moreover, representatives need to be well integrated into the respective WG. An example of someone who apparently hadn’t realised that:

> *“There had been a proposal from a Danish company in certain area on I/O for C. They had put it forward and the C-committee said “well, I don’t know”, they listened to the guy, and said “well, this is not clear to us, that is not clear to us, come back to us next time around with a better proposal”. And then of course, he came back next year, 6 months later. And there were different people around the table and they said “well, we’re not really interested” They sent him back again…. It all came down to the fact that he didn’t know properly what route to take and what kind of proposal to make”* <OSC>.

This is corroborated by another comment that rates the importance of a WG member’s standing in the group, his credibility and the fact that he’s been around for quite some time now as

> *“Very important. People with these credentials form the backbone of all the standards committees I’ve ever worked on”* <WG2>.

On the other hand, asked how important he would consider (in SC22/WG14) a WG member’s standing in the group, his credibility and the fact that he's been around for quite some time now, another response was

> *Very little* <WG3>.

In any case, continuous participation by the same people is essential:

> *“I think going to standards meetings you need a certain experience. If you come first time around you look around and think ‘what’s going on here and what are these people talking about and why are they allowed to talk in this way?’ You have to get the hang of it. So a certain continuity in this respect is important”* <OSC>.

Perhaps a bit surprisingly, to assume a formal leadership role (most notably, as Convenor) may even be counter-productive in some sense:

> *“As convener, my position has to be what is best for the C community, the Working Group and in general what is best for the C programming language. Other technical experts do bring issues raised by their companies, …”* <WG1>.

The technology that was standardised in this case has little bearing on any large companies’ strategies or business models. Accordingly, the financial stakes in this technology were comparably low (this holds despite the fact that for OSC the activity did have some economic relevance). The case very clearly demonstrates that in such an environment successful work first and foremost requires excellence on the technical side. This holds for both proposal and WG members (at least for those who are not just Observers). Along similar lines, it would appear that in such an environment the group aims to produce a technical superior standard that benefits the community at large. This standard should not be negatively influenced by misinformed consensus or company interest that go against the greater good.

However, even in such an environment the 'human factor' must not be under-estimated. The social capital[93] accumulated by the OSC representative may very well also play a decisive role (which could not be conclusively shown in this case, though). On top of that, corporate commitment to standardisation work is a sine-qua-non.

The case also sheds some light on the ambivalent role of a WG convenor. In ISO, the Convenor acts in a "*neutral and purely international capacity*" [ISO, 2016b]. This implies that, in theory, he must not represent any specific interests, including those of his employer/sponsor[94]. On the other hand, the Convenor does have some power to steer – and influence – the work of the WG (see also e.g. [Spring et al.; 1995]).

Likewise, the approach to pre-empt a competitor's (foreseeable) initiative by proposing a standard based on one's own technology may well work in 'low-stake' environment, but probably only there (the competitor was not even represented in the WG; this shows the relatively low importance assigned by them to this problem). It remains to be seen if social capital prevailed against a strong competitor with superior resources (assuming that competing proposals would be on roughly the same level of technical sophistication).

As OSC does not have a 'formal' standardisation management, only limited conclusions may be drawn here regarding a link between standardisation management and success in standards setting. One finding – that may be generalised to other SMEs as well – would be that it pays to invest in a technically experienced individual who knows his/her way round in the relevant standards setting organisations and who has a good reputation in these circles. Another one would be that even if such an expert is available success in a standards setting activity is also based on sustained participation in the group, possibly including the adoption of a leading role (that of the editor in this case). The adoption of the role of a Convenor (or equivalent) may be problematic at least for an SME with vested economic interests in a standard. Because of the neutrality requirement this would imply the need to send at least one more representative to the WG who's unofficial[95] task would be to present and defend the company position[96]

2.7 Case 2: CDD – A Chip Designer and Developer

2.7.1 Background

The Company

CDD designs and develops silicon and software for the consumer electronics market. Overall, they specialise in wireless connectivity, with a focus on five sectors: Voice and music (high definition wireless), Location (GPS-based systems), Automotive infotainment (integration of smartphones and in-vehicle systems, Bluetooth Smart and Imaging (cameras and printers).

[93] According to Bourdieu & Wacquant (1992), social capital is "the sum of the resources, actual or virtual, that accrue to an individual or a group by virtue of possessing a durable network of more or less institutionalized relationships of mutual acquaintance and recognition"

[94] According to the ISO Directive, "*experts act in a personal capacity and not as the official representative of the P-member or A-liaison organization*" [ISO, 2017a, p.13], i.e. particularly not as national representative. The 'neutrality' requirement doesn't apply here.

[95] In ISO, WG representatives are supposed to serve in their capacity as 'subject matter experts', not as national or company representatives. Practice may look different, though.

[96] In JTC1/SC22/WG14 a small, specialised company was represented by three people.

To this end, CDD develop semiconductors and software for a host of leading technology platforms and standards, including Bluetooth, GPS and other location technologies, FM radio, Wi-Fi, Near Field Communication and others.

The company was founded in 1999, with nine founding member. They broke even in 2003. Following some mergers and acquisitions the company now has 2,000+ employees, with offices in Europe, the US and Asia. In 2012, CDD had a turnover of slightly over USD 1 billion. The company was acquired by Qualcomm in 2015.

The Standards Body

The IEEE[97] Standards Association (SA) is the standards-developing arm of the IEEE. IEEE-SA is an ANSI[98]-accredited Standards Developing Organisation. They develop standards in a broad range of industries, including power and energy, biomedical and health care, information technology, telecommunication, transportation, nanotechnology, information assurance, and many more. These standards are developed in over 30 committees with more than 1,300 working groups.

IEEE Working Groups are open to anyone to attend – attendees do not have to be IEEE-SA members – i.e. any materially interested and affected parties can attend any standards development group meeting. However, usually a procedure for determining voting rights in the WG is established to control the process of participation. This can be as simple as 'anyone can vote anytime' to more elaborate rules that allow someone to vote after attending a certain number of meetings (and the right of voting to be contingent on continued attendance). However, none of these voting rules would preclude an individual's right to participate and comment at any meeting.

SA manages two types of standards development activities – one based on individual membership, the other on corporate membership. The vast majority of ongoing projects belong to the former category. This includes the IEEE 802 LAN/MAN Standards Committee.

The Working Group

IEEE-SA's Committee 802 develops and maintains networking standards and recommended practices for local, metropolitan and other area networks. The WG meets three times a year during the plenary sessions of the IEEE 802 Committee and holds additional interim meetings another three times per year. They work on the basis of individual membership. It has eleven committees. The most widely used standards include those for Ethernet (802.3), Wireless LAN (802.11), Wireless PAN (802.15) and Wireless Coexistence (802.19).

The 802.11 is the Working Group for WLAN Standards. It is made up of eight Task Groups and a number of other entities. A Task Group (TG) is in charge of authoring a standard or any subsequent amendments. Of these, TGmc (Task Group M, revision c) is in charge of the maintenance of the IEEE 802.11 standard. Between March and September 2013, for example, the group processed over 800 comments that were received in a Letter Ballot.

The Task Group comprises 20+ people. They come from companies of rather different sizes, ranging from around thousand (e.g. Lantiq) to several tens of thousands of employees (e.g. Intel). The majority of contributions come from those companies at the lower end of this scale. Figure 2.6a shows the contributions by individuals (where four people were responsible for over 60% of the contributions), Figure 2.6b those by company with CDD having submitted around 16% of the contributions (these figures relate to period before the letter ballot for the period from September 2012 – September 2013.

[97] Institute of Electrical and Electronics Engineers, a professional association dedicated to advancing technological innovation. It has about 425,000 members in about 160 countries.

[98] American National Standards Institute.

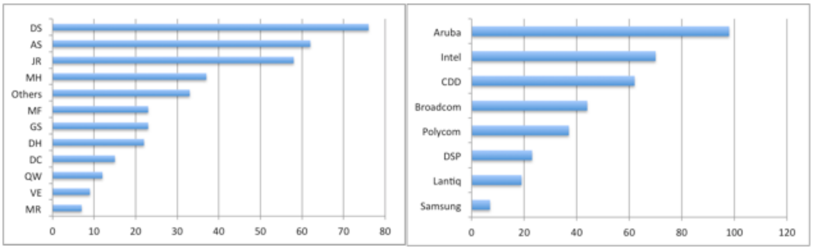

Figure 2.6: Number of contributions to TGmc
a) per individual[99] b) per company

The Standard

As mentioned above, this is not really about a standards setting activity, but about maintenance of the 802.11-2012 standard that was published in March 2012. Work on REVmc started in September 2012.

No essential IPR claims have been filed in conjunction with this activity.

The Corporate Respondents

Corporate respondent one <CDD1>, a standardisation manager, has considerable experience with standards, regulatory, and patent-related issues. This is not least based on earlier positions as CTO at three start-ups and senior technical positions at a couple of other companies. His role with CDD is to lead standards efforts, stay in contact with regulators, do some strategic business development, and lead some small research efforts. His formal title is that of a Fellow and Standards Architect at GSR's Global Standards Department, where he is responsible for Wi-Fi standards and the associated corporate strategy. He is heavily involved in a number of standardisation, trade group and regulatory activities; was formerly the co-chair of IEEE 802.15.3a (high speed UWB) as well as former chair of IEEE 802.19 (Wireless Coexistence Technical Advisory Group). He was also a significant contributor to 802.15.2 and 802.11g.

A second respondent is a standards architect and standardisation manager with the Global Standards Department; he completed the questionnaire for corporate WG members. He started attending the IEEE 802.11 Working Group meetings 20 years ago and became an active leader in the 802.11n project. He also was Chair of the REVmb activity (the predecessor to the standards activity to be discussed later) for a short time. In 2008 he was elected 802.11 First Vice-Chair and Treasurer. He is also Vice-Chair and Secretary of the 802.11 group.

In both cases information was compiled through a questionnaire for standardisation managers (see sect. 2.5.2),

Corporate respondent three <CDD3> is a technical expert with the company's Global Standards Department. The Department's staff are in charge of both standardisation management and of the actual standards setting work. Sometimes, people from either sales support, software or marketing will attend standards meetings, but they are no 'regulars'. They may show up only if there is something of importance to them. The department has a staff of around ten people.

The Respondents from the Working Group

Three external WG members, including the most active contributor, also completed the questionnaire for external WG members.

[99] The most active contributors are identified by their initials. The others are subsumed under 'others'.

The Market

By now, the IEEE 802.11 standard is almost ubiquitous. That is, the market size may be safely assumed to be substantial (billions of units). However, an improved and enhanced version of an existing standard – as produced by TGmc, will not have (financial) ramifications nearly as strong as those of a major new standard.

Motivation for Participation in Standards Setting

The standards bodies CDD are most active in relate to Bluetooth and IEEE 802.11 (aka Wi-Fi). They feel that having a leading position in these groups will help them to be early to market with new generations of chips and will instil confidence with their customers.

Being a fairly specialised company with focussed R&D activities standardisation is quite important to the company. Accordingly, on a scale from 1 – 10, standardisation activities get a seven or an eight.

The motivations for CDD's active participation in standards setting are varied. The most important aspects include the desire to influence an emerging standard and the compilation of technical intelligence. The former aims primarily at aligning the technical features of an emerging standard with those they have in mind for new internal chip developments. The latter, while considered equally important, is not pursued in itself. That is, intelligence gathering is more of a by-product of participation than it is an end in itself. To push their own standard and to create or extend a market through the development of a new standard are seen as relevant for the company, but do not have top priority (this is different in the Bluetooth sector where the extension of the market has top priority). They may also try to prevent emergence of another standard; this is, however, not done by being deliberately obstructive, but rather more through attempts to push their own proposals.

They have tried to actively oppose to other proposals in the past but have found this approach to be mostly counterproductive. However, if the company is behind in development of some new features that are going into a standard or they may think it would hurt their business in some other area, they may spend some extra effort to look for problems in the problematic proposed specification. They realise, however, that they can only get away with a limited amount of this before it backfires. In essence, it may happen that CDD thinks a new technology to be very important, but that they might want to slow it down nonetheless.

The exploitation of their own IPR through standards setting also has some – albeit limited –relevance (at least in IEEE 802.11).

In terms of the roles CDD typically assumes in standards setting, the above translates to being either a 'Contributor', i.e. an active participant that is less interested in influencing the direction of an activity or a 'Leader' if participation was business critical and they aimed to control the direction of the process. While both roles are assumed in both technical domains of interest in in the field of mobile communication (i.e. Bluetooth and IEE 802.11) the distribution of roles differs between the two. In the Bluetooth SIG, CDD aims to assume a leading role in 70% of the cases and acts as a 'Contributor' in the remaining 30% of the cases. In IEEE 802.11, both roles are assumed about equally often. As already noted, the role of an 'Opponent' is seen as problematic and assumed only if business needs dictate it.

To achieve these goals, CDD considers it most effective to have good communicators and diplomats represent them in the working groups. These people should also have very good technical knowledge, but the importance of this aspect is ranked slightly lower (8 out of 10). Moreover, the company believes that their representatives should be informed about the business goals underlying the a particular standardisation activity. This is, however, assigned only medium relevance (6/10). To assume a leading role in the process (e.g. as WG leader) is assigned an even lower importance, followed by the perceived need to train or educate active standards setters and to monitor them.

Standardisation Strategy and Management

CDD does not have a formal standardisation strategy. They conduct monthly conference calls where they aim to align standards setting activities with the development and marketing departments. Specifically, they want to make sure that the company's standardisation activities are consistent with customer needs and product roadmaps.

The company's central global standards department has a staff of about nine people. The respondent is a fellow with the department; its Director reports to the VP of Strategy. All staff have an engineering background, typically with advanced degrees, no business or management people may be found there.

Direct involvement in standardisation is the company's major way of staying informed about any relevant new activities. In addition, customers occasionally suggest activities in which CDD should get involved; Near Field Communication being a case in point. Similar suggestions may also come from the engineering department. Potentially interested internal stakeholders are kept informed about any new or ongoing developments via dedicated internal e-mail reflectors, wiki pages and document archives.

The link between innovation (R&D) and standardisation is institutionalised and done at the VP and CTO level. It has been implemented through monthly coordination calls between the standardisation department on the one hand and engineering, business development and marketing on the other. Generally, there is more information flow towards R&D from standards than the reverse.

A new standardisation activity is typically initiated by the central standardisation department. Yet, it may also happen that customers or the engineering department ask them to get involved. Before such an activity will actually be started it needs the approval of the CTO and VP of Strategy. The department has its own budget for its activities.

The company performs an evaluation of their standardisation activities against their annual goals. However, they also realise that due to the political nature of standards these goals cannot be set in stone.

About People

The about 8-10 people in the central standardisation department actively contribute to technical standardisation. All of them have a strong R&D background; this is very much a pre-requisite for membership in the standards group. Accordingly, they are generally expected to be subject matter experts from day one. If any briefings are done, they are done by other members of the standards group members. Nevertheless, no incentives are offered for prospective standards setters. In particular, this is not a dedicated career path. Moreover, to keep track of its standardisation activities the company maintains a master document that lists all groups in all standards bodies for which the group is responsible, as well as the person who owns the responsibility to monitor that group. This also helps to ensure continuous participation by the same people; this is achieved by making one person the owner of an activity, with a designated backup if that person is unable to attend.

Dedicated training for the members of the standards group is occasionally provided. Such training (which is done by external coaches) serves primarily to help hone the group members' political skills. That said, members of the group are expected up front to be subject matter experts with reasonably good interpersonal/political skills.

CDD may hire certain specialists for standardisation-related activities. Most of these people have an advanced degree and are experts on either Bluetooth or WiFi. Typically, they are supposed to do analysis and simulation in support of standards activities. They do not necessarily attend meetings, though.

An Important Recent Standardisation Activity

Given CDD 's major business areas it does not really come as a surprise that they have been involved in multiple activities in the Bluetooth SIG, the Wi-Fi Alliance and in IEEE 802.11. In the Bluetooth SIG, activities have focussed on the transmission of audio information and on Bluetooth Low Energy (LE). In the field of Wi-Fi, an example of a recent/ongoing major activity would be the revision process, the then version of which was REVmc (in October 2013). This case focuses on the latter.

The case covers the maintenance of a standard, not the development of a new one. Such an activity is more inviting to 'altruistic' behaviour as it is more about quality assurance than about the development of a new standard with a potentially high market relevance and associated vested corporate interests. However, the importance of this maintenance process must not be under-estimated. Task Group M is in charge of producing the unifying document that incorporates the amendments agreed upon by other TGs. The group has to very carefully make sure that these amendments are incorporated correctly into the new version of the IEEE 802.11 standard.

Generally, the company has specific features in mind for future versions of their chips according to their internal roadmap. They try to align the technical features and timing in the standards bodies to this internal roadmap. Occasionally, other companies will propose things that they have not thought of. In such cases, the company will have to decide whether or not to support them and include these features in their product roadmap. Bluetooth Low Energy would be an example of a case where the company decided to support the proposal and to incorporate it into their products. However, the company may also aim to contribute to a standard that is of high quality and benefits the whole industry (and thus also the users). In the case of REVmc, they adopted a 'contributor' and 'leader' role.

CDD's goal is to have 'Day 1' features – they identify the parts of the standard they have to have ready for certification on the day certification testing is opened. Yet, have lagged behind in the implementation of WiFi standards because they do not have enough R&D engineers to keep up with their competitors who could launch chips ahead of them. Thus, success in standards setting could not always be translated into success in the market.

The company applies a fairly 'down-to-earth' criterion to measure their success in standardisation by asking themselves the question "Are we providing features our customers want when they want them?". They feel that their success specifically in the field of Bluetooth is down to the fact that they could do exactly that.

CDD are quite satisfied though not overly enthusiastic about their overall success rate in standards setting. They feel that they are pretty good at compiling intelligence (which is one of their major goals; eight out of ten) and almost as successful at influencing an emerging standard (the second major goal; seven out of ten). They see medium success rates for them in their attempts at pushing their own standard and the creation or extension of a market through the development of a new standard (both are also of medium relevance to them). Their lowest priorities – to prevent the emergence of another standard and the exploitation of IPR through a standard – also have the lowest rate of success.

However, things look slightly different for the Bluetooth LE and Bluetooth audio activities. Here, the company has been very successful in its leading role, with a success rating of 9 out of 10 in both cases. REVmc is still a work in progress, so they do not yet know how it will turn out. However, they feel that indications are that it will be reasonably successful, at least a 7 out of 10.

2.7.2 Discussion and Initial Findings

Overall, CDD does not really view standardisation as a highly strategic tool. Rather, they aim to make sure that standardisation in relevant fields is aligned with both their internal development schedule and with their technical roadmap (or rather, vice versa). Moreover, they aim to improve the overall quality of the standards, for the benefit of the technology, the users and whole market.

> *"When I worked for CDD, the CTO told me that I should do what was best for industry when considering proposals (even those from internal sources). His mantra was "when the ocean rises, all boats float". We were to make the better boats"* <CDD3>.

One might say that this is an example of the altruistic approach to standards setting mentioned above. This corporate attitude is also reflected in the role assumed by the representative in the REVmc process:

> *"I see myself as a Member of the IEEE 802.11 Committee, and that I should act as a professional engineer with providing my experience in facilitating the creation of a good standard in a timely fashion"* <CDD3>.

Yet, as mentioned above, maintenance is an important activity in every SSO (see also [Egyedi, 2009]; the individual approaches may differ, though). This importance is not just assigned by the SSOs that want to offer technically up-to-date and error-free standards, but also by the individual in the groups and by their employers:

> *"I participate in different Task Groups (TGs) of IEEE and TGmc being the unified specification of all the Task Groups it is imperative that all merging is done properly without altering the meaning of original Specification and the new specifications generated by new TGs"* <WG3[100]>.

However, CDD's altruistic approach seems to extend beyond standards maintenance, albeit only to a point; the adoption of their own proposals is another priority of their standards setting activities:

> *"We strive to improve the standard in all groups, and to promote and encourage adoption of internal proposed proposals"* <CDD3>.

Those in charge at CDD pretty much agree that in-depth technical knowledge and diplomatic skills are the two most important capabilities that WG members must possess if they are not just acting as observers but want to make meaningful contributions.

> *"To be successful, you need to understand the technology that you are advocating to be standardized, and how that will be included in the market place. A well rounded person that can be cordial and firm in negotiations and leadership is also needed. You have to be able to keep your composure while debating the technical merits of various proposals"* <CDD3>.

This view is seconded by a WG member who notes that

> *"Performance [of individuals who tried to lead the process on a specific topic] was very important, both in tone (reasonable technical proposal that is optional and informative, intending to build on existing material) patient and persevering in answering technical questions and objections"* <WG2>.

And by another one:

> *"It is important that they* [the company representatives] *know the standard very well and they understand their contribution (i.e. they don't read something that somebody else have written). Here also come negotiation skills and good relationship with other standard participants"* <WG1>.

[100] <WGx> identifies the respondent as WG member x.

This holds specifically for the work in TGmc where input from different sources has to be integrated into one coherent document. However, a slightly different, yet complementing view highlights the need to really care about what you are doing in the group:

> *"I think that it if a person does not really care about what he is doing in the standard, it will not work"* <WG1>.
>
> *"Participants share a sense of responsibility for maintaining and improving the standard"* <WG3>.
>
> *"My interest is to see a 'rolled-up' version of the standard in better condition than the last revision. .... Being in REVmc is just a continuation of my desire to try to improve the final Base Standard document"* <CDD3>.

Quite in contrast to the literature (see e.g. [Kennedy et al.; 2008] or [Jakobs & Blind, 2011]) rhetoric capabilities and, more notably, proficiency in English do not seem to play a major role:

> *"Rhetoric capabilities are not really important. Two of my dear colleagues have made a successful career in the 802.11 while not being able to get a single paragraph in English without a major mistake"* <WG1>.

Another point worth mentioning in this context is that apparently much of the work is done outside the standards group:

> *"These issues* [compromises, time to market] *have caused most of the 'real' standardization work to be performed outside the 802.11 meetings by SIGs such as EWC (11n), ACCORD (11ac) WiGiG (11ad), Extend (11ah)"* <WG1>.

It is well know from the literature that negotiations will take place also outside the formal environment of a standards WG. Many deals will be struck and compromises reached in hallways and perhaps over a beer (see e.g. [Schoechle, 2009], [Dokko & Rosenkopf, 2010]). In a way, the approach reported here – to take work outside a standards WG into a similar body (e.g. a trade association like the Wireless Gigabit Alliance) – is a variation of this move of discussions and negotiations to a more informal setting[101].

The importance of occupying the formal role of the WG Chair in the process remains a bit unclear. In principle, the editor's major task is to incorporate changes that have been approved by the group; not a very influential job per se. However, the editor nevertheless seems to be influential, according to two WG members who agreed that

> *"The processes I was involved in were mostly driven by the editor"* <WG1>.

The Chair, on the one hand, can exert a certain influence on the work, primarily by speeding up the process or by delaying it. On the other hand, IEEE 802 policies require the Chair to be neutral [IEEE, 2012]:

> *"Yes, having a formal role to give more credibility to the proposal helps. However, as the Chair, you are supposed to be neutral, so this is a very fine line. Some TG Chairs have been more effective at being 'neutral' but still seeing that their company position is addressed while others it was a very big problem, and their bias was not well received"* <CDD3>.

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[101] To illustrate this approach: [Agilent Technologies, 2013, p.9] reports "*In response to the TGad call for proposals (IEEE document 09/1206r0) issued in November 2009, a proposal based on the WGA MAC and PHY version 1.0 Specification was contributed to IEEE 802.11 Task Group 'ad' (TGad) as a complete proposal specification (IEEE document 10/433r2) and was approved as TGad D0.1 on 20 May 2010*".

> *"I don't think that being an editor or chairperson helps getting your contributions accepted – at least not in the 802.11 amendments that I am aware of. On the other hand, an editor and a chairperson can speed up the process by getting the work done and assigning work to people. They can also delay the process by keeping a hands off approach. This can mean pushing or delaying the publication of an amendments by up to a year"* <WG1>.

In any case, the ability (of the WG Chair) to appear neutral while at the same time trying to support a proposal is a nice example of the potential relevance of diplomatic skills. Another aspect worth considering here is the fact that a company appears more credible and committed if they sponsor a role like Chairman, Editor or Secretary.

Being in a position to speed-up or delay the process may have significant ramifications for a company. After all, from a company's perspective the 'success' of a standardisation activity is not only related to the performance of its representatives in the actual standards setting activity or to the quality of the final standard. Rather, the ability to actually implement the standard ahead of competitors is an important aspect. That is, a major success factor would be

> *"Getting development teams on board with adequate resources at least a year ahead of the completion of the standard, so we can have prototypes ready to do testing"* <CDD1>.

Given this dependency, a delay of "up to a year" (see above) may have very significant ramification for a company's success in a standardisation activity.

Some initial findings may be derived from this case. For one, the observed importance of really caring about the work in standardisation complements the well-known relevance of being technically competent and having at least adequate diplomatic skills. For a company, this would imply that the criteria for the selection of the people who are sent to standards meetings should include an aspect like being enthusiastic about high-quality technology in general and standardisation in particular. This should, however, not be overdone. Earlier studies have shown that WG members may well adopt an (unofficial) role other than 'company representative' during the standards setting process. Specifically, they may see themselves as e.g. promoters of technically superior solutions or as user advocates (see e.g. [Jakobs et al.; 2001] or [Jakobs et al.; 2010a]) which may or may not be in the best interest of their respective employer. This risk (from a company perspective) will be particularly high with technology enthusiasts. This holds despite the fact that in this particular case the company as such adopted a similar attitude (albeit with a qualification). Things may well look different in cases where serious money is at stake.

The perceived importance of the editor is also worth mentioning. While in theory the editor' task is just to compile the work done by the WG members into one document, in practice the role seems to be rather influential. This is pretty much in line with earlier findings reported in [Spring et al.; 1995] where interviewees highlighted that "*A good editor or editorial group greatly enhances the standards process ...*".

The other two findings are related (although this may appear odd at first glance). One refers to the ambivalence of the role of the Chairperson. Even if the neutrality requirement (and the watchful eyes of the WG members) make it more difficult to (mis)use the role to support specific proposals, there will likely still be some room for manoeuvring. Moreover, as noted above, the opportunity to delay the process may have potentially severe consequences for a company. This refers mostly to the 'timing' aspect – internal developments need to be aligned with ongoing standardisation activities (or vice versa) if a company wants to be (among) the first to ship a product based on this standard. That is, a company needs to weigh the benefits of a potentially improved alignment between internal development and standardisation against the disadvantage of 'wasting' a Chairperson's technical and diplomatic abilities.

In any case, the ‘tangible’ aspect of the success of a standards setting activity ultimately manifests itself in the form of commercial success. This, in turn, does not only require a good alignment of development and standardisation (as discussed above) but also the ability to actually perform development work within the given timeframe. As a consequence – e.g. in the case of a lack of development staff, as experienced by CDD – a delay of a standardisation activity may well be in a company’s commercial interest.

2.8 Case 3: CTM – A Chinese Telecommunication Equipment Manufacturer

2.8.1 Background

The Company

CTM is a Chinese multinational producing networking and telecommunications equipment. The company was founded in the 1980s. In early 2018, CTM had over 140,000 employees, almost 50% of whom were active in research and development (R&D). CTM had filed over 64,000 patent applications in China and more than 48,000 outside China. Form these, over 74,000 patents have been granted.

The company participates in more than 150 international standardisation bodies (both formal SDOs as well as industry fora and consortia), including 3GPP, IETF, IEEE, ITU, ETSI, ATIS, CCSA and OMA. By the end of 2012[102], CTM had submitted more than 5,000 proposals to these organisations. In total, the company holds more than 180 positions in international standards organisations.

The Standards Bodies

- The International Telecommunication Union
  The International Telecommunication Union (ITU) is the United Nations’ specialised agency for information and communication technologies. It’s predecessor, the International Telegraph Union, was set up as a treaty organisation in 1865 by twenty European countries. In 1934, the Union’s name was changed into ‘International Telecommunication Union’; it became a UN specialised agency in 1947.
  In late 2013, the ITU comprised of 193 Member States, over 550 members, more than 150 associates and over 50 members from academia. However, the right to vote is restricted to one representative per Member State, i.e. almost exclusively to the respective national PTTs[103]. Other companies, notably those referred to as Scientific or Industrial Organisations (SIOs), need to be approved by their respective governments and only have a right to participate and to contribute to the technical work, but are not allowed to vote.
  Within ITU-T the technical work is done in Study Groups (SGs). During the 2013 – 2016 study period thirteen Study Groups (SGs) had been active. Representatives of both member countries and other organisational members (e.g. from SIOs) may participate in the technical work at SG level and submit contributions. Every SG is headed by a chairman and a (possibly several) vice-chairman, who are appointed by the WTSC[104], based on their technical and management skills. The work programme is structured into ‘Questions’ with a number of such Questions assigned to each SG.

- The Internet Engineering Task Force (IETF)
  The IETF started off as the standards setting organisation for the Internet in 1986. Today, it is a community of those concerned with the evolution of the Internet architecture and its smooth operation. It is open to any interested individual.

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[102] The latest official number (from this link). It is safe to say that today’s number is much higher.

[103] Post, Telegraph and Telephone administration.

[104] World Telecommunication Standardization Conference.

The IETF's overall work is organised into several Areas, each of which is managed by an Area Director. The actual standardisation work is done in Working Groups (WGs). At the time of writing (July 2018), there are seven Areas with more than 120 WGs.
'Membership' in WGs is open to all interested individuals, e-mail distribution lists being the major communication medium. In fact, an IETF 'member' is someone whose address appears on one of the IETF's distribution lists. In addition, there are three annual IETF meetings. A 'rough consensus' of all WG members is required before a specification can proceed on the standards track (as opposed to 'consensus', required by ISO and ITU). In particular, there is no formal voting procedure.
The major output of the WGs are Requests for Comments (RFCs). Not all RFCs are standards, but all Internet standards are RFCs. Thus far, over 7,000 RFCs have been produced, 97 of which are designated as 'Internet Standard'.

- Third Generation Partnership Project
  The 3rd Generation Partnership Project (3GPP) is a collaboration agreement that was established in 1998. It brings together six (national/regional) telecommunications standards development organisations[105], which are referred to as 'Organizational Partners'. They determine the general policy and strategy of 3GPP.
  The work is structured into four areas, each of which is covered by a Technical Specification Group (TSG). Each TSG, in turn, has three to five Working Groups which perform the actual standardisation work. They produce Technical Specifications, to be transposed into standards by the Organizational Partners.

The Working Groups

- ITU-T SG16 Q3
  Study Group (SG) 16 leads ITU's standardisation work on multimedia coding, systems and applications. It is also the lead SG on Internet of Things applications; ICT accessibility for persons with disabilities; communication in intelligent transport system; and Internet Protocol television.
  Question 3[106] considers multimedia gateway architectures and the development of multimedia gateway control protocols. Specific study items include the addition of new functionality to the H.248.x sub-series to enable existing and new network nodes to work as a split media gateway controller and media gateway.
  Publicly available information on membership in ITU-T SGs is limited to the members of the respective management team, the Rapporteurs and the Editors.

- IETF Megaco (WG closed)
  The group was established in 2001 with the mandate cooperate with the ITU-T in the continuing refinement and evolution of the H.248 protocol. This specifically includes participation in the development of H.248v2 and subsequent versions, creation of packages of general usefulness to users of the protocol, and creation of documents providing additional information to the development community on specific aspects of the protocol[107]. Members of the group met at three face-to-face meeting in the context of the IETF Meetings 51 – 53 (95, 45 and 40 people attended,

[105] ARIB: Association of Radio Industries and Businesses, Japan
ATIS: Alliance for Telecommunications Industry Solutions, USA
CCSA: China Communications Standards Association, China
ETSI: European Telecommunications Standards Institute, Europe
TTA: Telecommunications Technology Association, Korea
TTC: Telecommunication Technology Committee, Japan

[106] The work of ITU-T's individual Study Groups is structured into 'Questions', which are further subdivided into Work Items.

[107] http://www.ietf.org/wg/concluded/megaco.html.

respectively). As work on the topic is still going on within ITU-T, the group's mailing list is still alive, albeit with very limited traffic.

- 3GPP CT4
  WG4 of the TSG 'Core Network and Terminals' focuses on supplementary services, basic call processing, mobility management within the Core Network, bearer independent architecture, GPRS between network entities, transcoder free operation, CAMEL, generic user profile, wireless LAN – UMTS[108] interworking and descriptions of the IP multimedia subsystem within the mobile Core Network[109].
  The WG meets four to six times a year. Typically, WG meetings are attended by around 100 people. That is, CT is a rather large group with a broad mandate. It is responsible for 16 Work Items and has so far produced around 200 specifications. Not every meeting discusses every specification, so most members do not show up at each meeting. Typically, the vast majority of WG members attend between 30% and 50% of the meetings. The group is clearly dominated by the large vendors and service providers.

The Standards

- ITU-T H.248.82 – Gateway control protocol: Explicit congestion notification support
  Recommendation ITU-T H.248.82 defines a package to allow H.248 controlled media gateways to support explicit congestion notification (ECN). ECN is a mechanism to provide indications of incipient congestion affecting a Real-Time Protocol (RTP) stream to a receiver and, usually, to a sender. ECN when used with an RTP stream over UDP uses the RTP control protocol to provide feedback of ECN congestion markings to an RTP sender. The mechanism allows senders and/or receivers to react in order to reduce congestion in real-time communications. This Recommendation only describes the use of ECN in RTP over UDP streams.
  The work on this work item was triggered by a contribution from Alcatel in 2011; it was registered with SG16/WP1 in March 2011. The final recommendation was approved two years later, in March 2013.
  No patent statement and licensing declaration form have been registered by ITU-T so far for this item.

- 3GPP TS 29.238 – Interconnection Border Control Functions (IBCF) – Transition Gateway (TrGW) interface, Ix interface
  The document is a protocol profile specification. It describes the protocol to be used on the Interconnection Border Control Function (IBCF) – Transition Gateway (TrGW) interface. The basis for this protocol is the H.248 protocol as specified in ITU-T. Required extensions use the H.248 standard extension mechanism. In addition certain aspects of the base protocol H.248 are not needed for this interface and thus excluded by this profile.
  An initial first draft version of the standard was published in 2008. The version under study is release 12[110].
  No essential IPR has been declared for or the previous version 11.2.

- IETF RFCs
  The Megaco media gateway control protocol, RFC 3015 (also published as ITU-T Recommendation H.248), was developed in close cooperation with ITU-T Study Group 16. The group produced RFC 3015 'Megaco Protocol Version 1.0' (a 'Proposed Standard') that was

[108] Universal Mobile Telecommunications System, the standard for the third generation of mobile telephony.

[109] http://www.3gpp.org/specifications-groups/ct/ct4-map-camel-gtp-bch-ss-trfo-ims-gup-wlan.

[110] "3GPP uses a system of parallel 'releases' to provide developers with a stable platform for implementation and to allow for the addition of new features required by the market".

superseded in 2003 by RFC 3525 'Gateway Control Protocol Version 1' (also a 'Proposed Standard'). This RFC was re-classified as 'historic' in 2008.

The Corporate Respondent

The company has a central corporate R&D / Standards department. Individual product/ business areas also have their own standards delegates.

The respondent is director of an SME that provides, among others, consulting services to assist businesses to develop and implement successful standardisation strategies. Among others, he has been working for both a business unit and the central standards department of CTM. He has been active in telecommunication standardisation for 15 years. He started attending ITU-T in 1998 and has since then also been active in the IETF and in ETSI. In ITU-T, he has been active in various leading roles (Chairman, Rapporteur, Editor). His recent focus has been the development of the decomposed signalling architecture which decoupled call and bearer control signalling. His responsibilities are to ensure the desired standards outcome for the customer/employer. To this end he tries to focus on the technical and procedural aspects of the standardisation process rather than the political facets. He completed the questionnaire for standardisation managers.

The Respondents from the Working Group

Two members of the IETF's Megaco group and three members of 3GPP's CT4, who had worked on IBCF, completed a questionnaire for external WG members. Unfortunately, no information was received form any of the ITU-T SG 16 office holders (chairpersons, rapporteurs, etc.; out of the ten people from the ITU-T two claimed inadequate experience and eight did not reply.).

The Market

The three specifications relate to both the UMTS Terrestrial Radio Access Network and the GSM EDGE Radio Access Network. As these are still heavily used systems, the market size is considerable.

Motivations for Participation in Standards Setting

CTM is active in a wide range of SDOs, fora and consortia. This broad participation reflects the company's wide range of products. Participation in fora and consortia (as opposed to formal SDOs) is based on concrete business needs. These may include development of a technical standard (e.g. a communication protocol), establishment of a common view amongst industry (e.g. interoperability agreements), or the need to satisfy operators/customers (e.g. certification fora). Other reasons for participation include governmental, political and marketing reasons. CTM has recognised that participation is crucial for several reasons:

- Intellectual Property Rights (IPR)
  As a relative newcomer CTM has been forced into paying for licenses to use other companies' IPR. Obviously, this has put CTM at a disadvantage. Especially in the ICT sector, the desire to incorporate own IP into standards has been a key driver behind active participation in standards setting (this holds not just for CTM, but for most companies). In order to establish an IPR portfolio it is important for CTM to be part of relevant new standards activities. A strong IPR portfolio increases a company's bargaining power; for example, licenses may be swapped rather than bought.

- Appearance
  Again, as a newcomer there has been the perception that CTM does not have the adequate experience and technical skills. Also, being a Chinese company there are perceptions in the West of inferior Chinese products. Through participation in standards setting CTM wants to demonstrate that they do have adequate expertise and experience, even if it had to be hired, and that they can work in a multinational environment. They also try to be proactive and positive in order to show that they are good to work with.

- Transparency
  CTM feels that governments perceive them as a threat. Working in, and contributing to, open forums like formal standards bodies and industry consortia they aim at demonstrating the transparency of their processes.

For CTM the importance of active participation in standardisation depends on the overall company strategy. Overall, standardisation is considered important; on scale from 1 – 10 the assigned importance typically ranges from 7 – 9 over time. However, this does not necessarily hold for each activity – the work in some fora may be considered to be of lower relevance as the main purpose of participation is just to monitor. Alternatively, a forum may be important but the developed standards are mature now.

The company may assume different roles in standards setting, which may also change over time. The company prefers to adopt a positive role in standards setting, as opposed to trying to slow things down or to kill activities; but blocking an activity for the sake of blocking it is considered a waste of everyone's resources. Accordingly, the company typically makes active contributions to a standardisation process, albeit with different degrees of commitment the roles of 'Adopter', 'Contributor' and 'Leader' are assumed almost equally across the different activities. The role of an 'Observer' may also be assumed, albeit less frequently. In line with the more positive approach towards standardisation, the 'Opponent' role is assumed very rarely.

As the company's goals in standards setting differ between activities so do the means by which they aim to achieve the respective goal. That is, different business objectives and assumed roles entail different means. For instance, if the role of an 'observer' is assumed, there is no need to send the best person. On the other hand, if the company wants to drive the work, they will send a good communicator with excellent technical skills.

CTM considers the option of taking over a formal leading role in the process (e.g. as WG Chair) as a bit of a double-edged sword if they want to actually drive the process. This is due to the fact that the leader generally has to be impartial. Thus, in this case someone on the floor of a meeting is also needed to drive the work. In fact, the perhaps most important motivation behind assuming a formal leading role is if the company wants to be seen as the leader (e.g. by customers or partners). Accordingly, no overly high importance is assigned to this option to reach a specific goal. To actually lead the process they consider it more important to influence the selection of the leader. A wise choice will subsequently ensure that the leader is competent and can be worked with.

To send excellent technical people is considered slightly more important than to have a formal leading role. 'Excellent' refers to the person's ability to understand system aspects, to see how a change can influence the whole system and to quickly understand the impacts of a proposal.

Having good communicators and diplomats represent the company in standards setting is seen as being more important than the above (including technical savviness). In this context, an adequate command of English is almost a sine-qua-non. This is of special importance for a Chinese company like CTM (there are differences between standards bodies with regard to their support of non-native English speakers; the ITU, for instance, does a better job here than the IETF). Another aspect is whether the person is personable. Someone who has e.g. lunch and dinners with colleagues and generally has a reasonable level of social interaction will most likely be able to have more 'opportunity' and 'friends' in the standards bodies to work through issues. Again this can be a cultural issue.

Being 'diplomatic' in the sense of being polite and respectful is essential to move forward in standards. This does not apply, however, in case of an 'Observer' role (i.e. the representative does not talk) or that of an 'Opponent' (when it does not matter whom the representative upset).

Provision of general training and education for the standardisers is considered equally important. According to the interviewee it is very important to have some sort of process for bringing people into a standards activity. Having someone turn up at a meeting without an understanding of how a standards organisation works can lead to problems. It is also important to understand how to prepare effective contributions. If possible delegates should attend one or two meetings as an observer before they start pushing something.

Likewise, it is seen as equally important to discuss with delegates the business goals underlying the standardisation activity (as opposed to just inform them). As some such goals may be unobtainable at a certain point in time because of the prevailing situation (political, technical, time etc.) discussions about relevant business goals with standards people early in the process should identify any potential issues and help to save time and resources.

Monitoring of the delegates' activities is also considered very important, ranked between 'technical excellence' and 'good communicators and diplomats'.

The activities of the delegates should be sensibly planned and monitored. However, this should not mean that they are micro-managed. Contributions should be planned early to give time for drafting and internal discussion and review. Once the meeting is finished there should be a report outlining the discussions, results, competitor intelligence etc. and outlining what needs to be done for the next meeting. This needs to be communicated to the various people involved with the work. Delegates need to have some authority and level of trust to be able to make decisions at the meeting.

Standardisation Strategy and Management

CTM typically has a 'business direction' or 'business focus', which is communicated by the senior management. This broad goal is then disseminated by the various business units to develop their own goals. From these goals the business units derive their individual standards strategies. The CTO office has a dedicated standards department that also keep track of the company's high level standards strategy. The detailed strategy is largely developed by the standards people in the business units. That is, the company employs dedicated standardisation management staff both centrally and at business unit level. The latter need to show and explain to the CTO how the overall business strategy is being applied in their areas. This may involve, for instance, the planning, meetings attendance, talking to customers etc. Being a Chinese company there is a fairly strict hierarchical structure – ultimately, the CTO is in charge.

Regarding their backgrounds, standardisation management staff tend to come more from the technical side (e.g. engineers, physicists etc.) than from pure business/management. This is probably due to the technical nature of most standards.

CTM stays informed through a multitude of sources. Participation in a multitude of SDOs implies that the company stays abreast of standards activities. The delegates will see liaisons between organisations. People involved in an SDO's management will likely learn of proposals for new work items in off-line discussions before meetings. Often customers will discuss with vendors potential new activities or forums. Competitors may also contact CTM about co-operation on a new activity. These things should be / are communicated via reports to the CTM business units. Within these units internal mailing lists are used to report about such activities and about standards activities in general.

The company is aware of the importance of a link between R&D and standardisation. However, a formal such link is not always implemented. While in some areas there is basic research work which actually involves fundamental innovative research most areas focus more on the 'development' side. Yet, there has often been input from standards people to R&D, identifying innovation for the R&D department (as opposed to have R&D trigger standardisation activities).

CEO, CTO, standards department, R&D, other departments / business units and customers may all propose a new standardisation activity. Whilst the CEO and CTO may not actually propose a simple standards activity they may propose a new business focus or technology area. The business units and central standards organisation follow up on this and look at what needs to be done. More down to earth, people involved in the standards work are likely to propose new items. Customers and other vendors may also provide a stimulus for this.

The formal requirements a proposal for a new standardisation activity needs to meet depend on the level the activity is located at. For instance, setting up a new consortium will need higher level approval than a new work item in an existing technology area in an existing standards body. If the activity can be financed through the normal budget and with people that are readily available the proposal does not need to go very high. There is a formal process for estimating the number of people needed, to which standards body to go, etc.

CTM does ‘performance evaluation’ of standardisation activities. They track the number of contributions submitted to standards bodies and the success rate of those contributions. IPR is also monitored. Some people have a performance bonus linked to these activities.

The standardisation budget is tracked at both business unit level and centrally.

About People

CTM employs a couple of hundred people that actively contribute to technical standardisation activities. They typically come from the R&D areas of the business units and the central CTO department. Some come from management or marketing but this would be more for those fora where customer relationship is the most important aspect. The people are selected according to internal business unit processes. The selection is linked to the performance/appraisal process.

No direct incentives are offered for those active in standardisation. The lure of overseas travel may be seen as one (but this quickly wears off). Standardisation is also perceived as being more important than a ‘simple’ design job.

The scope of the work is discussed with those who join the standards team. This information is provided by the people already working in the area. There is a document available that outlines the general standards process and strategy. The interviewee may act as an unofficial mentor to bring newbies up to speed.

Standards setters are monitored. There is a plan of participation that is approved each year and that is updated as the year progresses. It is also expected that delegates provide reports of meeting activities and a monthly progress report. Anything that is interesting or urgent should be reported immediately.

CTM generally tries to ensure continuous participation by the same people in a standardisation activity. This has been recognised as a very important aspect of standards work. The longer a person participates the more experience he/she has, along with a better background for discussions and generally more and better relationships with the other delegates. There is, however, no formal method to ensure such continuous participation. High performers whom the company wants to keep are generally ‘accommodated’ more than others, e.g. through flexible work locations, additional payments or interesting work.

No formal training is provided for standards setters. The respondent occasionally runs a ‘standards practice’ course. Training in inter-cultural relations would be a very important topic for training.

CTM has employed many people for specific standard related jobs. CTM has been very astute and hired these experts to work on particular areas. This has given the company an edge in the standards bodies because of the extensive background and good reputation of these people. It is also generally cost effective (they are employed on an hourly basis). It is also used for marketing advantage (e.g. they can use the expert’s reputation) and shows they can work with people from overseas (e.g. the experts are from European, USA etc.).

Important Recent Standardisation Activities

One focus for the past several years has been gateway standardisation in ITU-T SG16, Question 3, IETF Megaco and 3GPP CT3 and CT4. This standards area is reasonably mature but still evolving due to new IP technologies that impact decomposed media gateway architectures. That is, in this standardisation area activities are still on-going. One work item that involved a major effort was the standardisation of 'Explicit Congestion Notification' (ECN), ITU-T H.248.82 and 3GPP TS 29.238. These standards relate to the same functionality.

There were several goals related to this activity. Firstly, the goal was to ensure that ITU-T SG16 Question 3 remained responsible for the development of updates to H.248 'Packages'. There were attempts via some companies to have 3GPP produce their own updates to H.248. These updates would have been narrowly focussed to ensure that they met these companies' design schedule. One of these companies was very dominant at the time so this was also an effort to make sure they didn't dominate.

Secondly, it was about getting an optimal solution that was in line with the IETF standard for Explicit Congestion Notification (ECN). Said companies wanted a more narrowly focussed implementation that would have required further work at a second stage.

Thirdly it was an exercise in working positively with a potential customer; to get CTM people and this customer's people to work together to reach a positive outcome for ECN.

The success of the gateway standardisation activity was rated 8 out of 10. This rating is based on the observations that the co-ordination between the CTM delegates to the ITU and 3GPP was very good and that there was good support from the customer management people. Likewise, the company got support from some regulators as well as from other vendors. With all these different people working on the issue CTM was able to ensure that 3GPP continue to refer H.248 related work to ITU-T SG16 where CTM has more influence. It was also good because CTM was seen as a 'positive' player which, in turn, generated goodwill. Some good relationships between CTM people and other delegates were also built. This success was all the more important since the issue was discussed at quite a high level at both CTM and other companies.

However, a bit in contrast to the above, CTM measures success in standards setting almost exclusively in terms of quantitative values, such as the number of (successful) contributions, the number of leadership positions and of approved work items. Apparently, there is no criterion related to the rather more 'soft' aspects of 'success' in standards, i.e.; for example, relationship building, support of business goals or other strategic issues.

The most important factors that contributed to the activity's success included the effective communication between the CTM delegates, good technical arguments and a positive attitude.

In cases where CTM wanted to influence an emerging standard the company's overall success rate may be rated as 'medium'. The reasons for this include the company's occasionally rather long reaction time; which is said to be largely due to its cultural background. As a result, a standardisation activity can be quite mature before CTM has decided on a direction that it wants to take. And once the work is mature it can be quite hard to have a major influence. This aspect, however, is improving as CTM delegates are now more present and active when the work item is in initial phases.

The same rating applies to cases where CTM wanted to push an own standard. The company is a comparably new player with about seven years of experience in international standardisation. They've had to build the capacity and confidence to develop and push own new areas. They are now more successful in this regards. The same holds for those cases where intelligence gathering was the main goal of participation. Given the company's generally 'positive' attitude in standardisation the company does hardly if every try to prevent the emergence of a standard. The exploitation of IPR has been a focus of CTM to ensure inclusion of IPR in standards. This has in many cases been a success.

CTM has also been very successful in using a new standard to extend or even create a market. In a short time the company has become one of the leading telecommunication equipment vendors. They have increased their market by being involved in new technologies and standards in markets outside their Chinese home market. This is in part of the strategy to be seen as experts and committed to open standards.

The interviewee feels that less time should be spent on reporting and authorisation. This takes away too much time from doing research, writing contributions, etc. Due to internal structures and for cultural reasons there are many levels of hierarchy each of which has to get approval for and report about standardisation work. This also holds for on-going work. Semi-formal standards co-ordination meetings where delegates briefly describe their recent activities would speed things up and improve co-operation between delegates.

2.8.2 Discussion and Initial Findings

This case is about a large telecommunication vendor and very technical standardisation activities. CTM being a big company suggests a lack of a homogeneous approach to, and implementation of, standardisation-related activities. Moreover, the company's overall attitude towards standardisation may change over time, e.g. due to changing political, economical or strategic boundary conditions.

> *"For CTM the importance changes depending on the overall company strategy at the time … The importance changes because the surrounding political / technical environment changes"* <CTM>.

> *"Also given the financial crisis and financial situation in North America and Europe standards was seen as a non-essential area …"* <CTM>.

Nonetheless, in both study periods (2009 – 2012; 2013 – 2016) during which H.248.82 was developed CTM provided a Vice-Chairman of the ITU-T Study Group 16 (which had been in charge of the standard), the Rapporteur of the associated 'Question' (the corporate respondent) and the Editor of the standard[111]. A reason here may again be the desire to be perceived as 'positive'.

> *"It* [a formal leadership position] *may be more important if the company wants to be 'seen' as the leader."* <CTM>.

A company's chances to get its contributions accepted may be positively influenced by holding (one of) these leadership roles. On the other hand, chairpersons are normally required to be neutral[112].

> *"Assuming a leading role can be a positive or negative thing depending on the activity. It's hard to drive work being the leader as generally the leader has to be impartial. To drive the work you also need someone on the floor of a meeting"* <CTM>.

This is one reason why the importance of the role of the editor should not be under-estimated:

> *"My personal strategy for controlling a process has always been to seek the editorship"* <WG1[113]>.

One aspect that shines through at various points is that this is a Chinese company. This has had a number of ramifications that have led to several issues. For one, they are a latecomer in international standards setting:

> *"CTM are a reasonably new player ~7 years in standards"* <CTM>.

[111] See the Study Group's web site (http://www.itu.int/en/ITU-T/studygroups/2013-2016/16/Pages/default.aspx) for further deetails.

[112] For 3GPP, please see http://www.3gpp.org/ftp/Information/Working_Procedures/3GPP_WP.htm#Article_23.

[113] <WGx> identifies the respondent as WG member x.

While this is not an exclusively Chinese problem, the fact remains that overall participation by Chinese entities (firms, universities, etc.) in international standardisation is a relatively new phenomenon. This may have various negative implications. For instance, the company will most likely not be a member of the 'old boys network' and thus not be involved in the more informal activities and discussions where many important decisions are prepared or even made (see e.g. [Schoechle, 2009], [Dokko & Rosenkopf, 2010]). In the 3GPP group, the process is said to be steered by

> *"A group of interested companies* [who] *usually discuss the solutions in and outside the meeting" <WG2>.*

Moreover, being a newcomer from China apparently triggered the desire to demonstrate sophisticated technical skills and expertise.

> *"CTM has been eager to participant in standards and hire experts to show that they do have the expertise and experience and that they employ and can work in a multinational environment"* <CTM>.

Not least against the background of earlier struggles in standardisation between China and, particularly, the West (perhaps most notably the WAPI case[114]) the company perceives a strong need of being seen as 'positive' by others:

> *"Part of the perception problem is that Governments perceive CTM as a threat to work with. By working in open forums CTM is trying to be transparent with its processes"* <CTM>.

This is an issue particularly in ITU, where only government entities have a voting right. Another aspect that has to be linked to the national and cultural origin of the company (see e.g. [Zhang et al.; 2005]) is the frequently rather slow reaction by management:

> *"CTM due to culture and hierarchy can be slow in responding to work. The* [standardisation] *work can be quite mature before CTM has decided on a direction that it wants to take"* <CTM>.

These factors contribute to CTM's 'medium' success rate in influencing an emerging standard and in pushing their own standards. The 'adaptivity' of the company's stance towards the importance of standardisation (see above) may be another reason here.

Yet, being Chinese does not just have 'negative' connotations. For the country, the generation of IPR in general and patents in particular are of utmost importance (see e.g. [Hu & Jefferson, 2009], [Li, 2012]). The same holds for CTM

> *"In order to establish an IPR portfolio it is important for CTM to be part of new standards activities"* <CTM>.

The perceived importance of a strong link between R&D and standardisation is perhaps even more 'Chinese'. China's 12th Five-Year Special Plan on Technical Standards [China, 2012] strongly emphasises the close link between R&D, innovations and standards: "*to continuously improve the close integration between scientific and technological innovations and the research and development*

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[114] WAPI (WLAN Authentication and Privacy Infrastructure) was issued as Chinese national standard in 2003 and was also submitted for international standardisation in ISO. At the time it was perceived as an attempt to establish a barrier to trade and a security threat (only eleven Chinese companies – and thus the Chinese government – had access to the algorithms used). It was twice submitted to ISO and was both times rejected on technical grounds. It was also subject to an US-China trade dispute involving the then US Secretary of State Colin Powell and his Chinese peer. Eventually, the requirement to implement the standard in all WiFi equipment operating in China was postponed indefinitely (see e.g. [DeLacey et al.; 2006]).

of technical standards". CTM has also recognised the importance of that link, but seems to face some implementation problems.

> *"CTM has established the need to link the two but some areas are better at institutionalising it"* <CTM>.

Moreover, the typical direction of the link between R&D and standardisation would be from the former to the latter (see e.g. [Granelli at al.; 2010], [China, 2012]). Yet, in CTM the reverse direction – which is not unheard of either, see e.g. [Blind & Gauch, 2009], [Interest, 2007a]) – seems to be more important:

> *"As standards are typically ahead of the development sometimes it is the standards people identifying innovation for the R&D department rather than the other way around"* <CTM>.

The responses also reveal some oddities. For example, the very technical nature of the standards in the case at hand would suggest that perhaps inclusion of own IPR would have been a major goal of the activity. All the more so since

> *"This* [to exploit IPR] *has been a focus of CTM to ensure inclusion of IPR in standards. This has been a success for them"* <CTM>.

Yet, no patent claims have been filed by CTM for H.248.82[115] and TS 29.238[116].

The fact that the respondent aims to focus on technical aspects (as opposed to political ones) and the company's rather more quantitative measures of success (e.g. number of proposals submitted, number of leadership positions held) also suggest a rather more 'technical' evaluation of the activity. However, the identified success factors in this case (which is rated 8 out of 10 by the interviewee and therefore hardly related to the inclusion of any IPR) paint a different picture.

> *"This issue was discussed at quite a high level in CTM and at other companies. The co-ordination between the CTM delegates from the ITU and 3GPP was very good. There was good support from the customer management people who were dealing with customers to support us in the standards. […] We were also able to work with other vendors to gain support. With all these different people working on the issue we were able to ensure that 3GPP continue to refer H.248 related work to ITU-T SG16 where CTM has more influence. It was also good because CTM was seen as a positive player which generated good will. Some good relationships between CTM people and other delegates were also built"* <CTM>.

It would appear that 'success' here (maintained influence, good co-ordination between involved individuals and departments, good co-operation with other companies, improved relationships with other WG members) is rather more strategic in nature and decidedly non-technical. Specifically, the perceived need to keep H.248 in ITU-T rather than shift stewardship to 3GPP had a very strategic background:

> *"There were attempts via some companies in 3GPP to have 3GPP produce their own updates to H.248. Company xxx was very dominant at the time and were trying to change ways of working so it was an effort to make sure they didn't dominate"* <CTM>.

The perhaps most notable findings relate to CTM's Chinese origin, which has various ramifications. In a way, the internal structure of the company reflects the very hierarchical structure of CTM's home country. This has its benefits – after all, CTM has become a very major international telecommunication equipment manufacturer within around 20 years. Yet, it also slows things down

[115] See http://www.itu.int/ITU-T/recommendations/related_ps.aspx?id_prod=11863.

[116] Check through http://ipr.etsi.org/SearchIPRD.aspx.

which may well become a problem for a company that wants to be a leader in international standardisation. The fact that CTM apparently has a preference for working under the ITU umbrella may also be linked to this cultural and national background. ITU is a very formal organisation and this seems to appeal to the Chinese mentality (see e.g. [Kennedy et al, 2008] and [Jakobs, 2013b]).

In 2012/2013, China supplied ten ITU-T Study Groups / TSAG Vice Chairmen and one Chairman[117] as well as numerous Rapporteurs and Editors (many of whom come from CTM; see above). In contrast, Chinese companies were not represented at all at the equivalent levels in ISO. Similarly, China's representation in some of the major standards consortia was limited, with no representation at management level of the Open Mobile Alliance (OMA), the Object Management Group (OMA) and the IEEE-Standards Association. Three IETF WG Chairs (out of over 200) were from China, as were one OASIS director and one W3C Advisory Board member. It looks as if the ITU-T appealed to China.

Today, Chinese companies' representation by Chinese nationals at the top management level is one for the W3C Advisory Board and for the IEEE-SA's Board of Governors, still nil for the OMA, the OMG and also for OASIS as well as for the major governing boards of the Internet, the Internet Architecture Board (IAB) and the Internet Engineering Steering Group (IESG); six out of around 250 IETF WG chairs are Chinese working for Chinese organisations. The situation in ITU-T has not changed significantly.

The above suggests that cultural issues must not be under-estimated – the corporate culture and the culture of an SSO should match.

Another potential contributor for the comparably limited overall success of CTM in international standards setting may be the apparent discrepancy between what is seen as 'success' at the 'individual' level and at the 'corporate' level. The former is purely technical and numerical (e.g. number contribution submitted to standards bodies, success rate of those contributions). In contrast (at least in the ITU case), the latter relates to decidedly non-technical, strategic aspects (e.g. improved relations). A better alignment of these criteria might help improve the overall performance.

2.9 Cross-Case Analysis and Discussion

In this section the above findings will be combined and discussed in the context of the insights from the literature. This discussion will mostly focus on those aspects that may be argued to be relevant in other cases as well and thus suggest the need for further analysis.

Two important and related boundary conditions that are common to all standards featuring in the case studies should be pointed out up-front, as they will help explain some observations. For one, no patent statement and licensing declaration forms have been registered so far with ETSI, ISO or ITU for any of the standards. IPR is not normally an issue for the Bluetooth SIG, where every member agrees to license for free (RANDZ[118]) any patent rights they have that apply to an Adopted Bluetooth Specification to anyone who proves (via standard Qualification Tests) that they are interoperable. The situation with IEEE is again slightly different; the standard in question there (802.11) has lots of associated IP. However, as the activity under study focussed on maintenance work, IP issues have not occurred so far there either.

The second relevant point is that all standards operate in fairly mature areas. Accordingly, the specifications, modifications and additions that have been developed (almost) exclusively serve to

[117] By comparison, three Vice Chairmen came from Germany; the US supplied five Vice Chairmen and two Chairmen.

[118] Reasonable and non-discriminatory zero royalty.

adapt and (incrementally) extend the functionalities of the existing protocols to the ongoing changes in the environment within which they are supposed to function[119].

2.9.1 On the Importance of Invested Efforts and Enthusiasm

Two cases highlight the importance of both a company and its representative being prepared to invest into not just into a specific standardisation activity, but into standardisation in general. If taken serious, such company investments are substantial; salaries and travel funding may well be complemented by funding for dedicated research activities (e.g. simulations of a new standard for performance evaluation). In addition to the purely technical aspects (including the capitalisation of IP) such activities will primarily serve as a vehicle to convey a positive impression to (potential) customers and co-operation partners – the company will be perceived as technically savvy, truly interested in the technology they offer, and prepared to actively lead the development towards an improved technology or a succeeding one. This is all the more important as standards (may) exhibit considerable public good characteristics (see e.g. [Tassey, 2000]; i.e. the company may be seen as doing good deeds for the community). This is not unlike publicising the adoption of a standard for marketing purposes (e.g. management system standards like the ISO 9001 or ISO 14001 series; see e.g. [Ferguson, 1996]). Obviously, participation in, or leadership of, a standardisation activity will hardly be widely noted, but those active in the same sector may be expected to notice. This marketing aspect is of particular importance to Chinese companies (like CTM; see e.g. [Breznitz & Murphree, 2013]). Moreover, according to Cargill [1989] standards may well serve as keys to opening up new markets (GSM is a case in point; see e.g. [Gerpott et al.; 2001]).

To be successful in this respect, continuous participation, ideally by the same people, is essential [Grundström & Wilkinson, 2004]. Specifically, such networks are crucial when it comes to informal discussions, deal-striking and compromise-finding before a vote or a crucial meeting. Along very similar lines, [Doko & Rosenkopf, 2010] note that long-serving and well-connected individuals are much better positioned to successfully conduct political actions. As a consequence, any newcomer will only have very limited influence on the process without such a network.

Yet, there seems to be more to it than just accumulating social capital – all companies stress the need to ‘care’ about standardisation and the emerging standard in one way or other. That is, a certain level of enthusiasm is considered inevitable and indeed beneficial. However, if this is combined with a certain altruism (see below) and/or strong own (technical) views WG members[120] may ignore their respective employer’s direct commercial interests (if any, that is) and, ultimately, even work against them.

In fact, it is well known from the literature that in ICT standardisation individual WG members do not necessarily defend their respective employer’s position and do what would be best for it (see e.g. [Henrich-Franke, 2008], [Isaak, 2006], [Jakobs et al., 2010]). Instead, they may assume the role of, for example, a ‘user advocate’ (do what is in the best interest of the customers or the market), a ‘techie’ (promote the technically best solution) or even promote their own ideas; see also e.g. [Cargill, 2011]. Assuming either of these roles implies a certain level of altruism in the sense that these people do not act upon the dictum ‘he who pays the piper calls the tune’. This is all the more remarkable as employees may well suffer from such behaviour.

Accordingly, some effort should to into making sure that company interests (if any) are known to, and indeed represented by, their representatives in the WGs (see also e.g. [Jakobs et al., 2001]). To this end, some form of monitoring may be necessary. The case companies’ approaches to this issue differed. OSC and CDD do not monitor at all. In the former case, only one staff member (the

[119] The ITU-T H.248 Recommendation, for example, was first published in 2000; the first version of the ISO 9899 standard for the C programming language dates back to 1990.

[120] As mentioned in Chapter 1, this study focussed on the WG level, where the actual technical work is being done.

respondent) was active in and knowledgeable about standardisation, so monitoring would not have made much sense. CDD's attitude of trying to make the cake bigger (i.e. to increase the size of the market) rather than securing a bigger piece of the cake also makes monitoring less important. This 'corporate altruism' (which does not mean that the company does not keep a close eye on their business interests) is mirrored in that of their people in the WGs, at least one of whom sees himself as a 'techie', obviously without fear of any repercussions resulting from this view. Yet, such an attitude is likely to be found primarily in low-stake environments or if a company aims at capitalising on the provision of complementary products or associated services.

In contrast, CTM considers monitoring of delegates as very important (they also have a reward scheme).

2.9.2 On the Ambivalent Role of the Chairman

The literature frequently observes that those with a leading formal role in standardisation are highly important for the success of the process [Spring et al., 1995]. Holding such a role may also be of relevance for companies – chairing a Technical Committee, for example, may well help influence the process at the strategic level [Isaak, 2006].

Likewise, [Updegrove, 2007a] notes that the careful selection of the chairperson is crucial for the success rate of the technical process. Along similar lines, [Doko & Rosenkopf, 2010] observes that "*firms that hold official positions of leadership, such as chair or vice chair, might have more influence"*.

However, the insights from the case studies paint a slightly different picture. The chairperson is supposed to act in a neutral and impartial role. This implies that (s)he must not adopt or favour any national or company positions. Chairpersons need to be well-respected individuals with adequate capabilities and be supported by their respective employer [Updegrove, 2007b]. Accordingly, each delegate who assumes the role of a chairperson (or any other formal role in the process) will not be available to support his/her employer's interests[121] (at least not openly). Whether or not the opportunity to steer (or delay or speed-up) the process outweighs this loss will probably need to be considered on a case by case basis. For a large company, the 'loss' of one capable individual may be tolerable; they will still be able to have enough representatives in the WG. That said, even CTM – a very large company – considers the adoption of a leading role as a potentially mixed blessing and whether or not to do so depends on the respective activity. Nonetheless, they are very well represented in ITU-T SG 16 (the SG inter alia in charge of multimedia gateways). The same holds for CDD; they too let their representatives assume the roles of Chairperson in various groups. Likewise, the OSC representative chaired an ISO WG that has been of interest for his company for over 20 years. Still, a small company will almost always need to think twice whether or not to have a competent employee act as chairperson.

The need for such considerations is also reflected in the literature, albeit only in one citation and from a different perspective. Isaak [2006] reports that "*The POSIX committees shifted away from having star experts chair a group, for two reasons. If they expressed their opinions, it would create a possible conflict of interest and they deprived the group of their expertise if they remained quiet*".

That is, the problem of a potentially important voice not being heard is not just a potential problem for a company, but also for the WG and thus for the process itself. A neutral, external convenor, employed by the SSO, might be an alternative.

[121] Whether or not delegates are formally allowed to represent their respective employer depends on an SSOs guidelines and by-laws. In ISO, delegates are supposed to act as Subject Matter Experts, as opposed to company/national delegates. In contrast, acting on behalf on the employer (or client) is acceptable in IEEE.

2.9.3 On the Importance of the Editor

The above discussion highlights the importance of a good leader of a standards working group, and the potentially associated issues both group and employer may have. There are, however, other formal roles in most SSOs' WGs whose occupants may also have a considerable influence on the process. That of the editor is perhaps the most prominent one.

Unfortunately, in most cases in the literature leadership roles such as WG chair and editor are considered together (e.g. in [Jakobs, 2011a], [Jakobs, 2013a]). This is not incorrect in the sense that in many respects the role of the editor resembles that of the chairperson, e.g. in terms of the desirable capabilities of the role holder. They include, for example, being self-organised, efficient and knowledgeable, having working experience in the subject area of the project, being able to encourage all to work as a team to ensure that everyone in a meeting is given the opportunity to contribute [ISO, 2010a]. Based on a number of interviews with seasoned standards experts, Spring et al. [1995] state that a good editor greatly enhances the standardisation process.

But it's not just the process and the final standard that stand to benefit from a good editor. For companies as well an editorship may be a valuable asset. Looking at the two roles through the lens of social networks theory, Dokko et al. [2012] explain that both roles occupy central nodes in the interpersonal networks that exist between the members of any standards WG. In such networks, central nodes benefit from having greater prominence. This, in turn, improves their ability to advance their specific interests in interactions with other, less central nodes (i.e. other members of the group). In a WG, the Chair would hold such a central position. The editor would have more of a bridging function; this position requires more intense interaction with other WG members (primarily those who offer contributions to the emerging standards).

The responses from various WG members suggest that not just an editor's desirable capabilities resemble those of a chairperson. Rather, editors frequently seem to play a leading role in the group and drive the process, perhaps even more so than the Chair. Strangely, and despite the fact that at least ISO requires editors to be as neutral and impartial as chairpersons [ISO, 2014], this requirement for neutrality seems not to be taken that serious for editors.

2.9.4 Presentation and Language Skills

Lack of adequate language skills has frequently been reported to be a barrier to successful participation in standardisation (especially, but not only for Chinese companies; see e.g. [Kennedy & Suttmeier, 2008]). Likewise, presentation skills have been identified as being of importance as well; a standardiser lacking such skills will be considered as unprofessional [Brons, 2007], [Teichmann, 2010], [Teichmann, 2018].

Indeed, adequate language proficiency has been identified as a major issue for CTM. They also find that the level of support for non-native English speakers differs between SSOs, with the ITU at the high end of the spectrum and the IETF at the other. IEEE seems to be close to ITU in this respect; adequate written English language skills are said not to be an issue there. The same could then be said about ISO for which the OSC representative notes that the technical experts in the group are able to see the merit of the content even behind a poor presentation.

This focus on content rather than presentation may be rooted in the highly technical nature of the standards at hand and the associated very technical focus of the WG members. It may also be linked to the fact that – while seen as important to company interests – none of the standards considered has any associated patent claims.

2.9.5 On Altruism in Standards Setting

It is well known from the literature that in ICT standardisation individual WG members do not always assume the role of a company representative, i.e.; they do not necessarily defend their respective employers' position and do what would be best for them. Instead, they may assume the role of, for example, a 'user advocate' (do what is in the best interest of the customers or the market), a 'techie' (promote the technically best solution) or even follow their own agenda (promote their own ideas); see also e.g. [Cargill, 2011], [Jakobs, 2011a], [Jakobs et al.; 2001]. Assuming either of these roles implies a certain level of altruism in the sense that these people do not act upon the maxim 'he who pays the piper calls the tune'. This is all the more remarkable as employees may well suffer for such behaviour (see e.g. [Jakobs, 2011a]).

Apparently, CDD may even go beyond that level of individual altruism, to a corporate one. While – obviously – keeping a close eye on their own business interests, they generally do not seem to try and get a bigger piece of the cake, but to increase the size of the cake. And this attitude is mirrored in that of the people in the WGs, at least one of whom sees himself as a 'techie', obviously without fear or any repercussions resulting from this view. This approach may help explain the numerous Chair and Vice-Chair roles the respondents assume: With a certain level of such altruism the 'downside' of such roles – the requirement of neutrality and thus not being able to support company views – may become less relevant. Yet, such an attitude is likely to be found primarily in low-stake environments or perhaps in companies with a more long-term perspective.

2.9.6 Standardisation as a Marketing Tool

While not in the focus of the general public's attention, leadership in standardisation is well noticed by companies (customers, competitors, co-operators) active in the relevant sector. Thus, such leadership will be used by companies to send positive signals ('innovative', 'industry leader', 'technically advanced'). This effect may be more pronounced in private standards consortia, many of which actively market their specifications ([Cargill & Bolin, 2007], [Hawkins & Ballon, 2007]) but may also be observed in formal SDOs.

Specifically, Chinese companies consider active participation in standardisation as a tool for strategic positioning and marketing [Breznitz & Murphree, 2013]. This holds al the more as they were not necessarily welcomed with open arms by incumbent governments and companies who saw (companies from) developing countries like China much more in the role of 'standard takers' than that of 'standard makers' [Kennedy et al.; 2008]. Moreover, the rather intense struggle that surrounded the Chinese attempts to have their WAPI protocol standardised by ISO did not shed a very positive light on the country's attitude towards international standardisation (see e.g. [DeLacey et al.; 2006], [Kennedy, 2006]).

CTM are very well aware of this background and, accordingly, more than keen to improve Western companies' and governments' perceptions of their technical and diplomatic proficiency. This desire to appear 'positive' and to forge good relations with peers both at the individual and the corporate level also extends into the standardisation work where such new relations are viewed as a major success of the company's activities within the ITU.

Quite similarly, the desire to be seen as knowledgeable and influential in the standards world – specifically by their customers – is one of the main motivations behind OSC's active involvement in standards setting. For SMEs (like OSC) such active involvement is rather more the exception than the norm (see e.g. [Jakobs, 2004], [de Vries et al., 2009] or [EC, 2011]; even in the case of OSC their major standardisation activity covered in the case study dates back to 2004; not a sign of overly extensive major efforts in standards setting).

Despite all their major differences the two companies share one characteristic – they belong to the 'disadvantaged' stakeholders in ICT standardisation. As outlined above, CTM suffers from its Chinese origin and SMEs are a rare breed in the field typically due to a lack of awareness and insufficient resources in terms of both expertise, funding, time and strategic thinking [de Vries at al., 2009]. For such companies the importance of the marketing aspect of participation in standards setting may be assumed to be much higher than for well-established multi-nationals from e.g. Europe or the US.

2.9.7 On the Different Definitions of 'Success'

To the best of the author's knowledge hardly any scientific literature look sat how a company defines its 'success' (or lack thereof) in standards setting. Typically, success in standards setting is discussed in relation to e.g. standards wars (IEEE 802.11 vs. HIPERLAN in the 1990a [Jakobs et al., 20110a]; for more general discussions see, for instance, [Shapiro & Varian, 1999] or [Stango, 2004]), wide adoption of a new standardised technology (e.g. GSM, [Pelkmans, 2001]) or perhaps clever political manoeuvring (OOXML vs. ODF, [Blind, 2011]). But how does a company establish that whether or not a technical standards activity it was involved in should be considered a success or a failure for itself? De Vries & Veurink [2017] quite generically define 'success' as achieving a favourable outcome, where 'favourable' is measured in financial terms. But how can, for example, an improved relationship with a regulator be quantified in financial terms?

In fact, what a company considers as 'success' in standards setting is related to the 'marketing' aspect discussed above. In the study, views vary quite considerably between the individual companies. Both OSC and CDD consider 'customer satisfaction' as their main success criterion. For OSC, the fact that the final standard was reasonably well in line with their original proposal was also of importance (for economic reasons). Still, the purely 'technical' success in standards setting, i.e. having all contributions accepted and having a final standard that meets their needs, is not an end in itself but a means to the end of having satisfied customers. This implies, among other aspects, that the company needs to be able to quickly incorporate technology based on the new standard into its portfolio. In the field of 802.11, CDD was not able to do that, simply due to a lack of engineers; OSC was successful in this respect. Both companies are very clear about their respective definition of 'success'.

CTM, in contrast, seems to be somewhat unclear in this respect. On the one hand, they seem to apply purely quantitative criteria like the number of contributions submitted to SSOs and the success rate of those contributions, the number of approved work items and of leadership positions held. Moreover, inclusion of IPR in standards is also monitored. Apparently even some people have performance bonuses linked to that. On the other hand, one individual activity discussed in the case study was said to be successful based on highly strategic reasons (for instance, good support from other vendors and some regulators that enabled them to keep the activity within ITU-T, where the company is more influential). In any case, both measures leave out one crucial factor – the customer.

The success rate of contributions and the number of leadership positions may well be relevant criteria to evaluate the employees in charge. Likewise, the fact that an important activity will continue to be carried out in an SSO where CTM has a not inconsiderable influence may well be of relevance for the company per se. But none of these criteria is of immediate interest to their customers, or may be translated into either a better technology, a bigger market or a satisfied customer.

Having prevented or significantly delayed the emergence of a standard (either in general or of a standard with specific features considered undesirable) may also be seen as a success. OSC and CDD have done so, albeit following different approaches. OSC pre-empted the possible emergence of a standard with unwanted (from their point of view) features (and would, if need be, try to object at a higher, more strategic level), CDD tried to find technical problems in a problematic proposal. However, both agree that this can only be done so often.

2.9.8 On Success Factors

Quite a body of literature may be found on 'success factors'. However, while much has been said about e.g. success factors in product development (e.g. by [Ernst, 2002]), on business services (e.g. by [de Brenatni, 1991]) or on projects (e.g. by [Clarke, 1999]) the literature on success factors in the field of standardisation is rather more thin on the ground. V.d. Kaa et al. [2011] look at success factors relevant in standards wars, Riefler [2008] and Wurster [2012] focus on the success of a standardisation activity form an SSO's point of view and de Vries et al. [2006] look at best practice in company internal standardisation. Yet, these studies are of rather limited relevance if success factors of the technical work in SSOs' WGs are to be identified from a company perspective. Unfortunately, and not unlike the situation with respect to corporate success in external ICT standards setting, relevant literature is virtually non-existing (to the author's best knowledge; [De Vries & Veurink, 2017] may be considered a bit of an exception).

The success factors identified by the different case companies are as varied as are their definitions of 'success'. For OSC, technical competency was the core success factor. In their very technically oriented WG only technically superior proposals will prevail. For CDD, success is measured in terms of the degree to which they could offer their customers what they wanted, in a timely way. Accordingly, success factor number one would be to have the necessary manpower early enough to have a prototype ready completion of the standard. CTM's somewhat ambiguous measures of success are reflected in the identified success factors. Good technical arguments are certainly helpful for the more quantitatively oriented success factors (like having a proposal accepted). For the concrete case of the standardisation of the ITU-T H.248.82 protocol effective communication between the Huawei delegates well may have helped keep the activity inside the ITU (which was the main goal). And finally, a positive attitude is certainly useful for a company that wants to be seen as 'positive'. However, there does not seem to be a clear match between the these success factors and the criteria for success. This is in contrast to the other two vases, where the match is pretty good.

2.9.9 On Influential Factors

The findings from the case studies have confirmed some of the factors influencing standardisation that had previously been identified through the literature study, refined some others, and added a couple of new ones. Focussing on the latter two, the ambivalent role of a WG convenor (and of many leading roles in general) and the potential importance of the editor are worth mentioning. On a higher level, the need to clearly identify what exactly is to be achieved in standards setting – i.e. a definition of 'success' that goes beyond simple quantitative effects – has also been highlighted. Another interesting finding is the use of active participation in standards setting for purposes other than standardisation per se. Specifically, the potential use of such participation as a marketing tool is worth noting. It may serve to signal innovativeness, leadership capabilities and credibility to both peers and customers. Finally, the aspect of 'time' is interesting – to align standardisation with in-house development capacities (or vice versa).

2.10 Propositions

In the following, a number of propositions will be derived from the literature, the initial findings from the individual cases and from the discussion above. They relate to both the company level and the WG level. These propositions will require further studies and analyses to be confirmed (or falsified).

2.10.1 Company Level

- Companies need to take standardisation serious.
  The most general proposition – and perhaps the most important one. 'Taking serious' has several dimensions. It implies a high level of strategic thinking[122], a clear vision what to achieve (see below) and the provision of adequate funding[123] for a sufficient number of delegates for the necessary period of time[124] (which may well be a couple of years).

[122] The strategic importance of standards for firms is stressed in many papers, including e.g. [Breznitz & Murphree, 2013], [Kahin, 2011], [Kano, 2000] and [Grindley, 1995].

[123] [Spring et al, 1995] estimated the costs for the development of an average IT standard to amount to about $ 10,000,000. Even back in 1990, Swann [1990] reported that in the telecommunication sector firms' expenditures for standardisation

- It is important to have very clearly defined goals for company involvement in ICT standards setting.
  Questions like “What do I want to achieve through this activity?” “What would ‘success’ mean?” need to be answered up-front. Goals may differ widely (including e.g. to build a better image in the industry, the capitalisation of existing IPR or the enlargement of existing or the creation of new markets). Different goals will require different approaches. Ways how to best achieve the goals need to be identified[125] (e.g. to assume a leading role in the process; to push a standard with specific technical characteristics to support the speedy creation of a standard, regardless its features)[126].

- Standardisation is more than just setting a standard.
  This may look odd, but it is correct. Standardisation does not begin with the formation of a Working Group – requirements elicitation, research and perhaps some development work precede it, implementation, integration and perhaps marketing follow[127]. Thus, depending on what the standard is required for, the necessary resources (engineers, software developers, marketing people, etc.) will need to be made available in time and be aligned with the ongoing process (or vice versa which, in turn, requires a good idea of the nature of the process and potentially pro-active efforts to speed it up or slow it down).

2.10.2 WG Level

- Cultural aspects are an important element of any standards setting process.
  Here, ‘culture’ has three different dimensions. For one, SSOs differ in terms of culture[128]. The IETF is perhaps more straightforward, the ITU more formal and more forthcoming[129]. Similarly, corporate cultures differ[130], as do national cultures which, in turn, influence corporate ones[131]. Thirdly, individual delegates characters’ differ. It follows that, for example, a rather more introverted delegate accustomed to a strict hierarchy might feel more comfortable in the ITU[132]. In order to be successful it is important to match the cultures.

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amounted to roughly 1.0 – 2.5% of their turnover. Not least due to the proliferation of private standards consortia it may safely be assumed that this figure has risen in the meantime.

124 The importance of continuous participation, ideally by the same individuals is also highlighted in [Isaak, 2006] and [Simons & de Vries, 2006]. Jakobs, [2011] stresses the necessity to attend meetings personally; otherwise proposals will not be taken serious.

125 For example, Kearns & Sabherwal [2007] and Tallon [2007] (as well as may others) point out the need to align business strategy and ICT. The same holds for business strategy and standardisation management; the latter needs to support the former (see e.g. [Betancourt & Walsh, 1995] and [Forselius, 1998]. Bousquet [2003] observes that “*Standardization is one of the building blocks of your company’s strategy*”.

126 The goals to be reached in standards setting depend on the type of organisational strategy a firm adopts in a specific sector (see Miles and Snow [1978]). This strategy, in turn, determines the most appropriate approach to standardisation (see [Updegrove 2006a] and [Jakobs at al. 2010a]). These aspects are also discussed in sect. 2.3.2.

127 Söderström [2004] presents a full general standards life cycle that covers the fomer stages; Cargill & Bolin [2007] and Hawkins & Ballon [2007] show how standards are used as marketing tools.

128 See e.g. [de Vries et al, 2004] or [Jakobs, 2009b].

129 [Andersson & Bryant, 2008] highlight the need for co-operating SSOs not to cling to their own respective culture, using the case of co-operation between IETF and ITU-T.

130 See e.g. [Barkema at al., 1996] or [Maljers, 1990].

131 For instance, [Newburry & Yakova, 2006] and [Barkema at al., 1996] highlight difference between corporate cultures and how they are influenced by the respective national one.

132 E.g. [Kennedy et al., 2008] shows that at that time China wass most active in the ITU, which is a very formal and hierarchical organisation. This may be explained by the findings reported in [Hofstede, 1983]. He observes that in high-power distance countries (like China) “*centralization and autocratic leadership are rooted in the mental programming of the members of a society*”.

- The pros and cons of formal leadership positions need to be weighed carefully.
  A formal leadership role gives some leeway in shaping, accelerating or delaying a standard[133]. On the other hand, such roles commit to neutrality. Thus, a company 'loose' support on the floor if it nominates someone competent for this role, or it risks to screw the whole process if it is someone incompetent. Also, the different characteristics of and opportunities associated with the different leadership roles available (e.g. Chair, Vice-Chair, editor, secretary, etc.) need to considered, as does the appropriate level at which any activities should be located(e.g. WG Chair vs. TC Chair). One may suit a company's needs better than another[134].
- The role of the individual in ICT standards setter must not be under-estimated.
  Delegates' capabilities and characteristics differ. What is necessary and desirable for each task in a certain SSO needs to be established[135]. For example, in highly specialised technical fields relevant technical expertise may be more important than proficiency in English and presentation skills[136]. At a more strategic level the latter will become more important, along with 'diplomatic' skills (e.g. to form alliances). This holds particularly for cases where stakes are high (e.g. if intellectual property shall be incorporated into the standard)[137].
  Moreover, delegates need to know precisely which position to adopt. This includes, for instance, to know whether to support the best technical solution (wherever it comes from) for the greater good or to fight to include own technology and/or to align standardisation with the corporate internal development roadmap[138].
- It is not helpful to oppose too frequently in the process in order to push own ideas.
  Trying to prevent the emergence of an unwanted standard (i.e. assuming the 'opponent' role) may well be a goal in itself. However, this should not be done too often as it may well turn out to be counterproductive. Moreover, it is very difficult (if not impossible) for a single company to actually do so.

2.11 Brief Summary and Conclusions

In principle, the above holds for all types of companies, albeit to varying degrees. An SME, for example, may not have (or need) a dedicated standards department and will frequently act based upon tactical (as opposed to strategic) grounds, in a more ad-hoc fashion. Nevertheless, a number of conclusions may be drawn that hold for all types of organisations that wish to actively contribute to – and influence – the standards setting process.

Specifically, first and foremost it is essential that any standards setting activities support, and are aligned with, the overall business strategy for the sector in question. To be able to do so, the goals of a firm's involvement in a particular standardisation activity need to be very clear from the outset. That is, for each such activity a firm needs to know what it wants to achieve. After all, potential goals for such involvement are very diverse and may include, among others, the incorporation of IPR into an emerging standard, to establish a standard – any standard – to extend or create a market, to deploy a

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[133] See e.g. [Dokko & Rosenkopf, 2010] or Isaak [2006]. However, the latter also notes that in the case studied the 'stars' were not made chairpersons (see also sect. 1.2).

[134] For instance, holding the role of a WG editor may be helpful if close interaction with other WG members is deemed beneficial [Dokko et al., 2012].

[135] [Isaak, 2006], [Jakobs, 2011] and [Jakobs, 2014a], for example, discuss role and importance of individuals in ICT standards setting. Among others, Grundström & Wilkinson [2004] and Henrich-Franke [2008] stress the importance of interpersonal networks in the process.

[136] Spring et al. [1995] discuss the skills individuals participating in the standards setting process should possess; 'technical expertise' being the most important one for technical working groups.

[137] Jakobs [2011] reports that being present at meetings to discuss or defend a proposal to be crucial.

[138] Cargill [2011], [Jakobs et al., 2001] and [Jakobs, 2011] show that WG members do not necessarily represent their respective employer's views (sometimes unintentionally, and even though this may cost them their job)

working group as a platform for innovations, to align standardisation with internal R&D or to improve credibility and standing *vis-à-vis* customers and peers. The identification of the underlying goals also implies a clear idea of how 'success' in standard setting shall be measured. Here, as well, very different metrics may be applied like incoming royalties, increased sales in a new market segment, new products or services that can be offered, or improved relations with business partners. Conversely, simple numerical measures like counting accepted contributions or the number of leadership positions assumed is not very helpful; these are not ends in themselves.

It is also important to remember that standardisation is more than just setting a standard. That is, standardisation does not begin with the formation of a Working Group. Requirements elicitation, research and perhaps some development work precede it; implementation, integration and perhaps marketing follow. These elements of the overall process also need to be taken into account by standardisation management; they are, for instance, important for the timing of activities.

At a more 'tactical' level, leadership positions appear to be a double-edged sword. Whether or not it is in a firm's best interest to try and assume one will need to be considered on a case-by-case basis and will also depend on the underlying goals. Here, especially smaller companies will have to think very carefully if the benefits of being able to steer a process will outweigh the 'loss' of a qualified technical voice. Along similar lines, attempts to prevent the emergence of an unwanted standard should not be made too often; they may well backfire. That is, the options of opposition and trying to find a compromise everyone can live with need to be considered individually for each such case.

Moreover, some perhaps less tangible aspects should also not be under-estimated. For one, SSOs differ in terms of culture. The ITU meetings, for example, always meticulously follow well-defined and time-proven procedures; the IETF is much less formal. This may well make a difference particularly for non-native speakers for whom strict procedures that guide a discussion will be particularly helpful (e.g. to avoid being cut short by impatient peers). Likewise, corporate and national cultures differ. It is hardly just coincidence that Chinese firms are particularly active in the ITU, a very formal organisation. It would thus seem advisable to also take these aspects into account, e.g. when looking for the most suitable platform for a new standardisation activity (obviously, 'harder' criteria like e.g. SSOs' IPR regimes will typically play a more important role here).

Along similar lines, a representative's desirable experience and capabilities are important. Requirements here may well vary, depending on, for example, the type of technology to be standardised and the concrete environment within which standardisation will take place. In highly specialised technical WGs technical expertise will be more important than presentation skills, for example. At a more strategic level the latter will become more important, along with diplomatic and rhetoric skills. Moreover, and regardless the level of the standardisation process, representatives need to know which position to adopt. That is, provision of all relevant information and adequate training are essential.

Last but not least, thinking out of the box is highly recommended. There may well be 'non-standard' links between innovation and standardisation that do not necessarily meet the eye, but may still be important. They too should be identified and exploited.

3 The Role of The Individual in ICT Standardisation – A Literature Review and Some New Findings

3.1 Introduction and Motivation

E-business, mobile commerce, e-procurement, supply chain management – Information and Communication Technologies (ICT) have changed the way business is done, sometimes beyond recognition. One of their common characteristics is the electronic exchange of information between entities that may well be located anywhere on the globe. This, in turn, signifies the need for internationally accepted – and implemented – rules that govern this information exchange. Such rules are typically referred to as 'standards'.

Colloquially, the term 'standard' is used for specifications of very diverse origins. Windows is an industry/proprietary standard, http is a consortium standard and IEEE 802.11 (aka WiFi) is a formal standard. Yet, regardless of their respective origin, (successful) standards are crucial building blocks of virtually all ICT systems. Think of it – the success of the Internet, for instance, is to no small amount rooted in the simplicity and effectiveness of its core standards, TCP/IP[139].

In the 1980s standards and standardisation began to attract the attention of researchers on a broader scale. Initially, economists developed the greatest interest, although their focus was rather more on dominant designs that emerge through market forces than on consensus-based standards that emerge from standards bodies' committees or working groups. They used, for example, transaction cost theory to determine if and when a firm would switch from one standard to another or used the theory of network externalities to describe the uptake of a new product or service[140]. Subsequently, social scientists and some computer scientists joined the bandwagon. With the increasing importance of patents in ICT standardisation the importance of Intellectual Property Rights (IPR) increased as well and attracted researchers of the legal persuasion. These days, many other disciplines also contribute to standardisation research.

Nonetheless, one aspect of standardisation has received little attention so far – the role of the individual standards setter, i.e. those people who populate the working groups (WGs) and committees of the various Standards Setting Organisations (SSOs[141]). While many political decisions are made above WG level, these people are in charge of the actual standards development. Both technical and strategic decisions are made here, and the economic well-being of a firm that fails to have its Intellectual Property (IP) incorporated into an emerging standard may be severely damaged as a result.

In fact, and perhaps a bit surprisingly, I would consider these people to be one of the major influencing factors in standardisation. And since the development of an ICT standard may well take a couple of years, at least the core members of the individual WGs will over time form a tightly knit community. These communities have, for example, been described as "*dense trans-national personal networks*" [Henrich-Franke, 2008] or as a group for whom "*the value of the … community … exceeded corporate loyalty in many situations*" [Isaak, 2006]. Thus, we should look at the motivations, attitudes and views that influence these people's work if we want a better understanding of why a particular standard emerged the way it did. Once enough such knowledge has been accumulated it may help shape future standardisation activities in a way that maximises a new standard's value for society at large.

The remainder of this chapter is organised as follows. Section 3.2 discusses the importance of the individual in standards setting based on a literature review. To test and perhaps complement these

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[139] Transmission Control Protocol/Internet Protocol.

[140] For a good overview of this earlier work see [David & Greenstein, 1990].

[141] This term denotes both formal bodies like International Organization for Standardization (ISO) and the International Telecommunication Union (ITU) as well as private standards consortia, e.g. the World Wide Web Consortium (W3C).

theoretical findings section 3.3 outlines some relevant findings from a case study. Finally, some concluding remarks are made in section 3.4.

3.2 The Individual in ICT Standardisation

SST highlights the negotiability of technology and thus also of standards (see sect. 3.2 above). Therefore, this section will have a closer look at the role of the individual in ICT standards setting.

3.2.1 Overview

In almost all cases, a firm that actively participates in standards setting does so based on economic considerations. Whether these relate to the development of a new standard to open or extend a market, to have as much proprietary IP as possible incorporated into the standard or to prevent or delay the development of a new one does not really matter. In all these cases, a potentially significant amount of money may be at stake, perhaps even the survival of the firm. Accordingly, a firm should make sure that its interests are represented in the best possible way. This, in turn, implies that the capabilities and attitudes of its representatives need to be taken into account.

Kang et al. [2007] – rightly – observe that "*Performance in standardization is naturally affected by that of individual standardization experts*". That is, if a company (or a nation state) wants to participate effectively and efficiently in standards the education, training, and skills of its representatives in standards WGs play a role, but also their preferences, prejudices, and possibly hidden agendas. This becomes even more relevant if we assume that the Pareto Principle (the 80/20 law; see e.g. [Craft & Leake, 2002]) applies to the work done in standards WGs as well. In this case, the views of 20% of a WG's members may well influence the work of the whole group. The need for better education and training of those active in standards setting and generally of a more professional approach towards this process was already highlighted by Nielsen [1996] more than twenty years ago. She suggested e.g. compulsory leadership training could for committee chairpersons and work group leaders. To this end she called for the establishment of an 'institute for standards developers'.

Despite all this and despite the economic importance of standards, the 'human' side of standards setting has attracted rather little attention. Yet, after all, the committees and working groups (WGs) of all SSOs and their respective decision-making bodies are comprised of individuals. That is, ultimately ICT standards are made by people, not by companies, nation states or standards bodies. And each of the individuals that make up an SSOs' WG will have possibly very diverse backgrounds, views, capabilities, preferences and prejudices that will, one way or other, have an impact on the final outcome of the WG's work – the standard.

In the following I will try and summarise what little is known about the value, roles and behaviour of individuals in the standards setting arena.

3.2.2 A Literature Recap

Papers that look at aspects to be associated with the individual standards setter are comparably few and far between. Broadly speaking, these papers adopt two different perspectives. One is the 'corporate view'; i.e. how firms seek to increase their influence in standards setting through the choice of personnel. The other one could be referred to as the 'personal view' that provides a look into the standards bodies' working groups and analyses e.g. the motivations and characteristics of the people who do the actual technical standardisation work. It should, however, be noted that these perspectives are not necessarily clearly distinguishable and may well overlap; this will also show in the discussion below.

Most (of the rather few) papers adopting a corporate perspective are based on social capital theory. According to Bourdieu & Wacquant [1992], social capital is "*the sum of the resources, actual or virtual, that accrue to an individual or a group by virtue of possessing a durable network of more or less institutionalized relationships of mutual acquaintance and recognition*". Social capital is related to, but clearly distinct from, human capital. Burt [1997] defines the difference between the two thus: "*while human capital refers to individual ability, social capital refers to opportunity*". Still, social capital is inextricably associated with an individual. That is, from a corporate view the social capital of an employee in general and of a member of a standards working group (WG) in particular increases the value of this individual. On the other hand, social capital, once acquired, may well establish strong bonds between an individual and the 'source' of the social capital, in this case the standards WG. Isaak [2006] observes that standardisation of the Posix operating system benefitted from social capital accumulated by the WG members. He notes that social capital development was based on "*repeated collaborative problem solving over an extended period of time building respect, trust and reinforcing common values*". More specifically, he notes that in many cases loyalty to the WG was greater than loyalty to the employer – people changed the latter but were not prepared to give up their roles in the former, even if that implied self-funding of participation. Eventually, the importance of this phenomenon was also realised by organisations participating in the standardisation work; the US Department of Defense, for example, made sure that their representatives could work longer on the subject than the two year duty rotations would normally have allowed, in order be able to develop and deploy social capital [Isaak, 2006].

On a slightly different, more general note, Dokko & Rosenkopf [2010] argue that knowledge brought in by a new employee may help increase the employer's influence in standards setting. For one, this is due to an increased knowledge of another firms' positions, preferences and capabilities. On the other hand, the newly acquired social capital may come in handy in more political (as opposed to technical) activities, such as, for example, coalition forming. Typically, long-serving and well-connected individuals are much better positioned to conduct such political action [Dokko & Rosenkopf, 2010].

'Well-connected' is an important aspect here. Co-operation between individuals in WGs creates networks and a central position in such a network increases social capital and thus the 'usefulness' of an individual to his/her employer. Such a central position may, for example, be assumed by taking on a leading role in the standards setting process, e.g. that of a WG chairperson or of a document editor.

The importance of such networks in standards setting is also highlighted by Grundström & Wilkinson [2004]. Specifically, such networks are crucial when it comes to informal discussions, deal-striking and compromise-finding before a vote or a crucial meeting. Moreover, they note that any newcomer will only have very limited influence on the process without such a network.

In addition, trust is of particular importance here and this can only be acquired over time. In general, 'trust' is an important aspect in relation to both, social capital and standards setting. A functioning personal network can hardly be established without it. Trust is particularly important in the informal negotiations and deal-striking in standardisation [Dokko & Rosenkopf, 2010]. Zaheer et al. [1998] distinguish between interpersonal trust and inter-organisational trust and in standards setting the former is of particular importance. This is further corroborated by [Grundström & Wilkinson, 2004]. They quote several high-level standards setters[142] who in unison and emphatically stress the importance of trust.

Henrich-Franke observes that informal relations, also involving family members, have proved to be more important than the national needs and requirements of the WG members' respective home countries (this refers to a case in ITU where largely national positions are dealt with). Also, a common 'engineer habitus', rooted in a common background as radio amateurs, played a major role in the development of radio standards [Henrich-Franke, 2008].

Trust is also of importance in relation to boundary-spanners [Williams, 2002]. These are individuals who facilitate communication between different groups or entities [Tushman, 1977], for example

[142] Including Ericsson's then Director Product and Business Strategies and Director Access Standardisation, Corporate Technology.

between a firm's marketing and engineering departments, between different firms or between different cultures. Given the international, multi-firm environment that characterises standards setting, ideally each member of a standards WG were a boundary-spanner. At least, those who have assumed a leading role should be.

Spring et al. [1995] observe that the leadership (frequently, but not necessarily the chairperson) of a WG is crucially important. Along similar lines, Isaak [2006] notes that 'gurus' play an important leading role. According to Umapathy et al. [2007], hiring a guru as a representative in standards working groups may well be a way for an SME to punch above its weight in standardisation, thus potentially reversing the power distribution in the market.

The potentially strong impact one individual may have may also be exemplified through 'bulldogs'. According to Spring et al. [1995], a bulldog is "*A person who dominates and disrupts a meeting against the majority opinion of that group*". They estimate that 80% - 90% of all standards WGs have at least one such bulldog. Their influence is particularly prominent in standards bodies without clear decision-making procedures like voting. Most notably, this holds for the Internet Engineering Task Force (IETF), the Internet's standards setting body. Here, formal voting is replaced by 'rough consensus', a term very open for discussion. This is also reported in [Jakobs, 2003] – in the IETF process 'naysayers' and 'loudmouths' stand a good chance of delaying and possibly even obstructing the work; the process does not foresee any mechanisms to deal with such individuals.

In general, WG members can be classified based on their behaviour. Spring et al. [1995] distinguish between 'perfectionists' (attention to technical detail); 'doers' (ability to initiate proposals to get things moving); 'leaders' (ability to focus on objectives); 'diplomats' (ability to forge consensus); 'observers' (ability to listen attentively and monitor activities to ensure process is going in the right direction) and 'obstructionists' (ability to actively head-off bad ideas). Umapathy et al. [2007] have come up with a similar classification.

Apart from their actual behaviour in the standardisation process, individuals may also assume very different roles in this process. While 'company representative' was the single most frequently assumed role by a mile, Jakobs et al. [2001] found that a majority of WG members saw themselves as either 'national representative', 'user advocate' or 'techie' (promoter of technically clean and advanced solutions). Similarly, Cargill [2011] notes that "*a participant in a standardization effort wears many different hats simultaneously*". According to him, these hats cover, among others, 'professional pride' (doing what's right), 'corporate or organisational goals' (doing what's right for your company) and 'personal friendships' (doing what's right to make you feel good and for social and professional strokes). Along similar lines, Nielsen [1996] observes that these 'hats' may also cover different standards bodies and different associated corporate strategies. Accordingly, an individual's behaviour in standard setting may, and frequently will, also be context-dependent.

The above brief recap supports the 'prediction' of the SST approach that the individual standards setters are important elements in the process of ICT standardisation. From the 'corporate' perspective, they may become highly valuable assets through their accumulated social capital and/or their experience and capabilities. From the 'personal' perspective, links between members of a WG may become extremely strong; in some cases stronger than those to their employers (a fact that may be beneficially deployed by a wise employer).

However, this occasionally strong bond between WG members raises the issue of loyalty. More generally, it brings up the question 'Whom does the individual standards setter represent in his/her work in a WG?'. Strong bonds between members may suggest (part of) a WG setting its own agenda, independent of any employer's preferences. For example, a WG may decide to try and develop a standard that best addresses users' needs. Likewise, a personal agenda, driven by, for example, deep technical insights, personal preferences or simple prejudices may lead an individual or a small group to just represent themselves. In contrast, simple economics ('he who pays the piper calls the tune') may lead a standards setter to strictly represent his/her employer's position (perhaps even against own better judgement).

To know what drives WG members and what they stand for is clearly of considerable relevance for the outcome of a standardisation process. So, the next section will offer a look inside a particular standards working group.

3.3 The Case of IEEE 802.11

In almost all cases, a firm that actively participates in standards setting does so based on economic considerations. Whether these relate to the development of a new standard to open or extend a market, to have as much proprietary IP as possible incorporated into the standard or to prevent or delay the development of a new one does not really matter. In all these cases, a potentially significant amount of money may be at stake, perhaps even the survival of the firm. Accordingly, a firm should make sure that its interests are represented in the best possible way. This, in turn, implies that the capabilities and attitudes of its representatives need to be taken into account.

This 'human' side of standards setting has so far attracted comparably little attention[143]. Yet, after all, the committees and working groups (WGs) of all SSOs and their respective decision-making bodies are comprised of individuals. That is, ultimately ICT standards are made by people, not by companies, nation states or standards bodies. And each of the individuals that make up an SSOs' WG will have possibly very diverse backgrounds, views, capabilities, preferences and prejudices that will, one way or other, have an impact on the final outcome of the WG's work – the standard.

The brief recap of the literature on the role of the individual in standards setting supports the 'prediction' of the SST approach that the individual standards setters are important elements in the process of ICT standardisation. From the 'corporate' perspective, they may become highly valuable assets through their accumulated social capital and/or their experience and capabilities. From the 'personal' perspective, links between members of a WG may become extremely strong; in some cases stronger than those to their employers (a fact that may be beneficially deployed by a wise employer).

To know what drives WG members and what they stand for is clearly of considerable relevance for the outcome of a standardisation process. So, the next section will offer a look inside a particular standards working group.

3.3.1 Some Background

The IEEE WG 802.11[144] (Wireless LAN Working Group) is part of the IEEE 802 LAN/MAN Standards Committee. This WG has been in charge of the development of standards for wireless communication in unlicensed radio frequency bands. Today, these standards form the basis of the almost ubiquitous WiFi networks. In December 2013 the working group had around 500 members, ca. 320 of whom had voting rights. They met three times a year during the plenary sessions of the IEEE 802 group; 802.11 holds interim meetings an additional three times a year.

Like several other standards bodies (e.g. ISO WGs) IEEE 802.11 has 'individual' membership. That is, its members are supposed to act in an individual capacity, as opposed to acting e.g. as company or national representatives. In 802.11, the right to vote must be earned and subsequently maintained. Voting rights are conferred after attendance of three out of four consecutive plenary meetings and need to be maintained through continuing participation in both meetings and ballots[145]. Moreover,

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[143] See sect. 1.2 for an overview of what has been discussed so far.

[144] For more information see http://www.ieee802.org/11/.

[145] This has changed slightly. Today, to gain voting membership rights a members needs to participate in at least 2 plenary meetings out of 4 consecutive plenary meetings and then record attendance at a subsequent plenary (at which s/he may vote). See http://www.ieee802.org/11/abt80211.html.

members of all IEEE WGs are asked to disclose their affiliation in order to prevent the process from being dominated by any particular entity or interest category.

The individual voting right suggests that a direct association between employee's voting behaviour and employer's interest can not necessarily be taken for granted. Rather, other aspects like, for example, individual views, preferences, prejudices, and (hidden) agendas may influence voting behaviour. The goal of the study was to find out if and to what degree this is actually the case.

3.3.2 A Bit on Methodology

The 802.11 WG was selected for two reasons, in addition to its 'individual' membership. For one, it is the origin of one of the most influential standards recently developed in the ICT sector. Secondly, I could get access to a number of the most knowledgeable and experienced members of the group through Vic Hayes, the then immediate past 802.11 chairman[146] (see below for some more information).

Overall, the study used the same methodology as described in sect. 2.5. Despite the risk of potentially introducing some bias, this approach was chosen in order to ensure that the respondents really do know what they are talking about, based on a long track record of work in the 802.11 group. The option of addressing the whole group via its internal distribution list was ruled out; exploitation of such lists for other than technical purposes is considered highly inappropriate. The option of doing interviews suffered from a number of practical disadvantages: Performing face-to-face interviews was next to impossible as most 802.11 members were based in the North America. Also, experience indicates that most potential interviewees prefer to complete a questionnaire in their own time, rather then spend a considerable amount of time on the phone (or a face-to-face meeting).

The survey was based on a questionnaire with 16 open-ended questions, subdivided into three sections. Section one asked for the interviewee's background, section two for his/her motivation for the participation in and the role assumed during the process. Section three was the main part that asked for their observations regarding the activities and positions of fellow WG members in relation to the goals and views of their respective employers. All respondents had also been available for any subsequent clarifications (which were requested in some cases). Additional information from the group's archive were used as well[147].

An initial list with the names of thirty key persons was provided by Vic Hayes, who also distributed the invitation to participate in the survey. Thirteen questionnaires (out of thirty) were completed. One non-respondent quoted legal reasons, one considered it inappropriate to participate as current WG chair, three promised to respond but never did (despite several reminders) and the others didn't reply at all (also despite several reminders).

At the time of the study (second half of 2007), all respondents had over ten years of experience in the IEEE 802.11 WG. They had typically attended between 25 and 70 meetings, and the vast majority had voting rights. The respondents are thus highly unlikely to be representative for the whole 802.11 group. They are, however, much more likely to be representative for the much smaller sub-group of key persons. For most respondents the participation in the 802.11 WG had been their first exposure to standards setting. All have a strictly technical background.

The information presented in the next section was compiled from thirteen completed questionnaires. The questionnaire along with some information about the respondents may be found in Appendix B.

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[146] Vic (the 'father of WiFi') chaired the IEEE 802.11 WG from its inception in 1990 through 2000. He was instrumental for the success of the technology that eventually became known as WiFi. For a detailed account of the genesis of WiFi please see [Lemstra et al., 2010a].

[147] To be found at https://mentor.ieee.org/802.11/documents?is_dcn=DCN%2C%20Title%2C%20Author%20or%20Affiliation&is_group=0000.

3.3.3 Insights from the Survey

WGs are primarily populated by engineers. One would, therefore, assume the technical superiority of a proposal to be the decisive factor. However,

> *"I honestly do not believe in anyone claiming technical superiority as that can be a very short term truth or as has been proven many times over, an untruth". <6>*

Still, if not technical superiority than technical merits should be decisive. Yet, rather more non-technical aspects seem to be as important. Two typical responses:

> *"Most influence came from 1/3 powerful organizations (companies), 1/3 strong technical proposals, 1/3 active and respected company representatives". <7>*

> *"The influence came through a combination of strong technical proposals, active representatives and powerful organizations". <2>*

That at least some importance is assigned to strong technical proposals does not really come as a surprise. Neither does the fact that 'powerful organisations' play an important role. After all,

> *"There are active/respected representatives from most large organizations because it costs so much to commit people to creating the standard, and active/respected representatives gravitate to organizations that support the standards effort". <3>*

This suggests that at least in the ICT sector most large companies have a reasonably well developed idea of the importance of both standards and active participation in standardisation. Moreover, it is safe to say that 'powerful' and 'large' may be equated with 'deep pockets'. These companies can – and do – hire respected standards setters to competently present their proposals and to adequately defend and push them.

Continuity in participation – which is closely related to 'deep pockets' – is another important factor.

> *"Contributing something important to the process was only effective if you had the money to stick around and see it through to completion". <4>*

While this is bad news for Small and Medium-sized Enterprises (SMEs) they too stand a chance to have their proposal accepted. All it takes are knowledgeable, enthusiastic and strong enough representatives.

> *" ... But there are also examples of small companies with very smart/respected representatives who took and got a lot of bandwidth". <1>*

The responses so far suggest that the answer to the question "Which factors are important in ICT standardisation?" would be 'adequate funding', 'good proposal' and 'strong representative(s)'. The latter re-enforces the need to also answer the question "To what extent do WG members represent the interests of their respective employer?".

'Company representative' tops the list of the roles the respondents assumed[148]. However, there were other roles they assumed as well – some aimed at promoting a wireless standard (any standard, as opposed to a specific one e.g. supported by their respective employers), some wanted to support the user community. Also, these roles could change over time or several roles were assumed in parallel.

When asked if a company's representatives would typically act in unison, i.e. if they were they likely to represent their employer's interests, most responses were along the lines of

> *"On the whole members or voters from or representing the same company acted in unison". <6>*

[148] Apparently, the same may be said for their peers. While no quantitative figures are available here, the responses suggest as much.

Yet, deviating, more individualistic behaviour could occasionally be observed:

> *"There were some groups of individuals that acted in unison and other groups of individuals from a different affiliation worked independently". <5>*

However, it remains unclear whether this was due to strong individual positions, lack of relevant company directives, different departmental position with one large company or a simple misunderstanding

> *"But there are examples of individuals who did [follow a personal agenda] (for whatever reason, sometimes they even self did not notice that they pleaded against their own company)". <1>*

Alternatively, company politics might have played a role:

> *"Other times they would vote contrarily when it could be predicted, or sometimes just in case, the vote would confirm that alternate position anyway. That would ensure that the company had at least one vote on the prevailing side so that individual could later make a motion for reconsideration – again that's another political ploy". <4>*

Yet, some had chosen to not necessarily represent their respective employer but – mostly – to work for the greater good:

> *"Yes there were a number of individuals having their personal agendas, but this was not very frequent. They were usually very strong headed, but not very successful, but could consume a lot of meeting time". <2>*

One respondent identified seven such individuals (out of about 300 voters) by name – not a very high number. But

> *"These individuals I believe embody the essence of great standards creators for their efforts to create technical specifications which benefit everyone working in this technology space." <7>*

The same respondent continued

> *"Yes the ones who worked this way were generally very highly regarded and were generally successful (but not always)". <7>*

However, people had to be brave (or perhaps financially independent) to act this way. Several respondents mentioned loss of job as a consequence of deviating voting behaviour. One example

> *"In general, when a company's rep did not represent the affiliations point of view, they tended not to appear at the next meeting. There are exceptions to this rule, but in general, if you work for a company, you are voting for their proposal." <8>*

The idea of 'individual membership' implies that voting behaviour should not change with a WG member's new affiliation, or with a consultant's new client. No clear picture emerged here. Still, a concrete observation by one respondent:

> *"Yes. A change of affiliation either as an employee or consultant has caused changes in on formerly held positions. A recent case in the IEEE 802 where two companies had brought in opposing technologies resulted in a stalemate position. The larger corporation purchased the smaller opposing technology company. So there became a committee where all the members were the same as before but the purchased company voters now had a new affiliation and voted accordingly". <6>*

Even if only some respondents reported such occurrences it seems safe to assume that at least several WG members did change views depending on those of their current employer.

In cases where more than one person was needed to support a proposal or where interests of several people converged coalitions between individuals could occur independent of their respective employers' positions, albeit with an important qualification – no corporate interests are affected.

> *"Groups of members would often form, particularly when there are issues where only a small number of members are passionate on a topic. This was typical when the issue was not critical to an employer's interests". <10>*

And, at any rate, this seems to have been a rather infrequent occurrence as coalitions were mostly formed between companies, not between individuals.

> *"No, coalitions I saw are primarily company-based". <9>*

Moreover, clashes of egos could be observed. After all, 'being outspoken' and 'having a sense of purpose' are essential attributes for successful standards setters [Jakobs et al., 2001]. Accordingly, one responded noted that

> *"I have seen egos get in the way of many debates". <8>*

Yet, such personal clashes might well go hand in hand with clashes of corporate interests,

> *"... it was more of a combination of both ego and money. Many clashes were driven due to big investments in company technology directions where the direction of the standard was important to the financial health of the companies involved". <7>*

Eventually, the final votes will be cast. While coalitions are typically required at that point in time, this need seems to be even more pronounced in 802.11:

> *"In the end (the important decisions) are influenced most by the strength of companies (number of voters) and coalitions between companies. I have never seen that a decision is taken that is in the benefit of only one company (because it already has solutions/products)".* <1>

Accordingly, finding as many allies as possible, and forming strong alliances is an integral part of the game. This necessity is not least triggered by the IEEE balloting process, which requires a 75% level of support for a proposal to enter the next stage of the process.

> *"With respect to 802.11 DS PHY, main issues were agreed to by a coalition of companies out side of IEEE meetings and then were brought into IEEE 802.11 for debate. THis coordination between NCR/Aironet/Harris ensured sucess of 802.11b".* <11>

These observations suggest that once everything has been said and done the decision success and failure burns down to a simple head-count. A number of individual voters together will form the 'corporate vote' (there may be exceptions), and enough such 'corporate votes' (i.e., a strong coalition) will lead to the success of a proposal.

3.3.4 Discussion

At the end of the day, technical standards are developed by people, by those individuals who populate the WGs of the various standards bodies. While certainly not being an island, such a standards WG is a more or less closed community[149] whose members (most of them, anyway) work towards a common goal – a new standard. Views how exactly this standard should look like will differ in many cases, but the common goal remains.

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[149] This holds despite the fact that 802.11 meetings are open to everyone. Voting right, however, is conferred only to those who attend frequently. The core of these regulars represents a fairly closed and possibly tightly knit group (see also e.g. [Isaak, 2006] and [Henrich-Franke, 2008].

Overall, it seems that most WG members act with at least a view towards their respective employers' business interests. Yet, there are exceptions, which typically aim at technically superior solutions. Nevertheless, the reports about WG members adapting their point of view to the one held by their current employer do not hint at strong personal opinions (rather at pragmatism). This is corroborated by [van de Kaa & de Bruijn, 2015, p.583], who quote the IEEE 802.11 chairman "*so if a person gets a job with another company, he can suddenly have a different opinion, but that's how it goes.*"

No homogeneous picture emerges in this respect (of course, it is hard to vote against your employer's interests when you see people being fired for having done exactly that; another course of events not entirely unheard of, according to some respondents). Then again, the apparently fairly frequent clashes of egos suggest strong feelings about a proposal (there may be other reasons involved as well, though).

Nevertheless, high corporate stakes (like sunk R&D costs, IPRs or increased market shares) may occasionally culminate in overly heated debates between company representatives ("*The chaos this motion created was incredible, and the whole meeting went down in flames*"). The issue could be resolved at an informal meeting and some subsequently developed new and 'neutral' technology, i.e. one that implied neither an advantage nor a disadvantage to any stakeholder[150]. Such a technical solution to a mostly economic problem is probably only possible in an environment where (most) actors share said common goal and have a strictly technical background (as in the 802.11 case). The presence and relevance of such economic aspects, most notably those relating to IPR, is a characteristic of the ICT sector[151]. The need to 'follow the party line' in standards setting is most pronounced in cases where stakes are high (see also sect. 2.9).

In addition to the common goal, van de Kaa & de Bruijn [2015] identify a number of other incentives for consensus building that have got little to nothing to do with the individual standards setters, but again with corporate economic interests. One is the perspective of future gain, through e.g. licensing of patented technology incorporated into the standard, networking effects or shorter time to market. Competing external developments may also play a role in that they instil a sense of urgency and thus a greater willingness to compromise. In the 802.11 case, this competitor was the HomeRF initiative (see e.g. [van den Ende et al., 2012]).

The quotes in sect. 3.5.3 above show that coalitions between both companies and individuals may be observed, along with other individuals that follow their own agenda. This results in a mix of joint and individual contributions, the former being more prominent. This mix seems to be unique to 802.11. It may perhaps partly be explained by the a characteristic of the 802.11 process. A new feature or a new version of a standard my emerge in two ways. One option would be 'design by committee', where individual members present submissions. If a call for proposals is issued, a group of companies or individuals (possibly from outside) form proposal teams to develop a joint submission [Perahia, 2008]. Along similar lines, Ali-Vehmas [2016] finds a high number of 'stand-alone contributions', i.e. those with only one author. These contributors are, however, less active (and probably less influential) than with a joint authorship. He also finds evidence of a focused technology orientation of the contributors.

Another finding from this study also resonates nicely with the responses above. It finds that the co-operation pattern in 802.11 varies over time. That is, it oscillates between positive and negative assortativity. The former represents a more 'academic' form of co-operation (among peers), the latter a more 'industrial' form (e.g. between large and small companies). The latter dominates in the final stages of a standards development, when co-operation is needed to sort out the final technical details. In contrast, the earlier, conceptual work underlying different proposals is more research-oriented and

[150] According to Cees Links, as quoted in [Jakobs et al., 2010, pp.75/76].

[151] This is neither to say that all ICT standards have a strong economic dimension and/or associated Standard-Essential Patents, nor that IPR issues in standards setting are known only in the ICT sector.

thus shows an assortativity [Ali-Vehmas, 2016]. The final voting is just a head count (see above), so customers and suppliers need to be enlisted, along with other allies to have the largest possible coalition rally behind a proposal.

To summarise the main factors that had influenced the technical decisions taken in the IEEE 802.11 context, one respondents' view was particularly helpful and enlightening, thanks to the quantification provided.

> *"a) Supporters/opponents present during discussion 30%*
>
> *b) Reputation of supports/opponents 30%*
>
> *c) Purely the technical merits of a proposal 20%*
>
> *d) Solution already implemented somewhere 10%*
>
> *e) Company/national/group interests 3%*
>
> *f) Individual interests 3%*
>
> *g) Anything else (users/implementers) 4%"* <7>

Another response paints a similar picture (note the qualification at the end).

> *"The main factors influencing most technical decisions are:*
>
> *1. relative technical strength of the proposal, i.e., ability to satisfy the requirements*
>
> *2. relative cost of the solution (both manufacturability and impact on other parts of the system)*
>
> *3. encumbrance by intellectual property restrictions (this can be part of item 2, as well, considering licensing costs)*
>
> *4. reputation of individuals involved in the proposal*
>
> *5. reputation of the companies involved in the proposal*
>
> *By the time final technical decisions are made, all proposals are nearly equal with respect to items 1 and 2."* <10>

That is, when it comes to voting the reputation (and presence) of the supporters (and opponents) carries the greatest weight. This reinforces the assumption that companies should be very careful when selecting their representatives to standards bodies.

The importance of the qualifications and reputation of the individual representatives in ICT standards setting is out of the question. Yet, the comments suggest that in most cases these people tend to support their respective employer's interests (as opposed to their own agendas). There are exceptions to this rule, but they seem to be rather more infrequent. This holds all the more since apparently both individual ignorance and political considerations may also lead to a deviating voting behaviour. That is, the findings from this study (in line with those from an earlier one; see [Jakobs et al., 2001]) suggest that employers do not need to worry too much in this respect.

The study also suggests that other factors are more important than 'individual membership', including, for instance, corporate interests, (voting) procedures and (competing) external developments, In addition, 'cultural' elements may play a role. In this case, that would be the desire to not let one company (or a small group of companies) dominate the process and be the major beneficiaries of its outcome (see also [Jakobs et al., 2010]). This is, however, not to say that the importance of the individuals and their capabilities and expertise in standards setting must be underestimated. Rather, it seems that corporate interests dictate most WG members' behaviour.

The extent to which these findings may be generalised remains a bit of an open issue. On the one hand, existing corporate interests and potential competing external developments that contribute to triggering the process are not unique to 802.11. And despite some particularities the (voting) procedures of 802.11 are quite similar to those of other SSOs (as is the 'individual membership', come to that). The apparently rather strong technical orientation of the WG members may be explained by the technical nature of the technology to be standardised (WLANs); things may well look different for other technologies.

3.4 Some Concluding Remarks

Both the literature and the case study clearly demonstrate that standards setting is not just a technical activity. Rather, a fairly complex set of intertwined technical, legal, economic, social and psychological factors (and probably many others as well) together contribute to the shaping of a standard. These factors are either rather obvious (e.g. the legal boundary conditions), reasonably well understood (e.g. the technical specifics) or largely ignored and, accordingly, under-researched (e.g. the non-technical factors). Moreover, standards – through the technology they define – may have very considerable ramifications well beyond just the technical domain: The Internet as we know it, for example, would not exist without the underlying TCP/IP standards.

'Choice' is a central notion in the theory of the Social Shaping of Technology. Specifically, SST highlights the fact that choices are being made during the development of a standard and that these choices are the result of negotiations between members of an SSO's Working Group. Accordingly, these individuals' views, ideas, preferences etc. will exert a significant impact on the development of a standard. This is further corroborated by the literature and also by the case study presented above.

A person's values, beliefs, views and preferences are very much influenced by his or her respective environment. With respect to ICT standards, this holds particularly for the work environment. Studies into organisational culture also tell us as much: "*Organisational culture refers to deeply held beliefs and values ... the beliefs and values of culture ... exist as cognitive schema which govern behaviour and actions to given environmental stimuli*." [Ahmed, 1998, p.32]. That is, the organisational environment comprises not just technical artefacts and systems which WG members use to perform their work or any new technologies they may currently develop. It also includes corporate strategies as well as more intangible, but potentially deeply held corporate values or beliefs. The individual employees carry these characteristics, including any technical, strategic and economic goals or preferences, into a WG – they act as 'shape agents', typically on behalf of their employer, whether knowingly or unintentional.

This chapter is, in a way, a successor to [Nielsen, 1996]. Her paper "… *has been written to provide some initial thoughts on human factors in standards development and to stimulate thinking on human behavior as a dimension of standards committee work*". Her observation of context-specific actions of standards setters in different committees (their 'different hats') and her call for a better training of these representatives remain valid. They have been complemented by insights from social capital theory and from STS. In addition, a closer look inside a committee has shed some more light on the mechanisms at work there. It has also shown that individual views and preferences may well be overridden by corporate interests. Despite this, the chapter has also shown that at least from a company's perspective a continuous participation of adequately knowledgeable and competent representatives with a high social capital remains of crucial importance for the success of a standards setting activity.

4 Why Then Did the X.400 E-mail Standard Fail? Reasons and Lessons to be Learned

4.1 Introduction and Motivation

"Whoever wishes to foresee the future must consult the past; for human events ever resemble those of preceding times." N. Machiavelli.

"The disadvantage of men not knowing the past is that they do not know the present." G. K. Chesterton.

The mere fact that five centuries lie between the above quotes hints at the wisdom they convey. Nonetheless, most historians are reluctant to try and directly transpose insights from the past to the present or the future. And for a reason – in all likelihood, the two environments are very diverse, and actions or events at one particular point in time may lead to outcomes very different from those they might have yielded in a different age.

Still, I would argue that looking back in history to try and learn for the future should be possible if we do not look back over too long a period of time. In this paper I will have a closer look at developments that took place around thirty years ago. While times clearly have changed since then, and despite the fact that the 1980s are almost pre-historic for the Internet, I feel that valuable insights can be gained by looking back. This holds particularly since the times back then and today share some similarities when it comes to networking. In the 1980s, the Open Systems Interconnection (OSI) initiative, launched by the International Organization for Standardization (ISO), set out to create a whole new communication environment from scratch. These days, the same may be said for the activities towards the Future Internet. This holds specifically for the widely popular 'clean slate' approach. I can only hope that its proponents at least attempted to learn something from the past in general, and from the case of OSI and X.400 in particular. Otherwise, we are bound to see the same (or similar) mistakes being made all over again.

There are almost as many definitions of a standard as there are standards. In this paper, I will use the definition provided by ISO, according to which a standard is a document that has been "*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*" [ISO, 2011].

In the ICT sector compatibility standards are a sine qua non. They enable interoperability between heterogeneous systems that use, for example, different programming languages, communication protocols, and representations of information. All ICT artefacts and systems embody a considerable number of standards. For example, a recent study found that a 'standard' laptop incorporates over 250 of them [Biddle et al.; 2010]. Standards shape the ICT landscape to a considerable degree.

The Commission of the European Union rightly observes that "*Standards are not only technical questions. They determine the technology that will implement the Information Society, and consequently the way in which industry, users, consumers and administrations will benefit from it.*" [CEU, 1996]. Accordingly, standardisation may be seen as an interface between technical and non-technical (e.g. economic, organisational, or social) considerations. Standards – the outcome of the standardisation process – result from a process of social interactions between stakeholders. That is, stakeholders cannot just focus on the technical merits of a particular solution; they also have to think about the economic and perhaps societal consequences of a future standard. For a manufacturer, for instance, pros and cons of joining the standardisation bandwagon vs. trying to push a proprietary solution need to be considered. Standards-based products or services may imply price wars and lower revenues, but may also open new markets and widen the customer base. Offering a proprietary solution may yield (or keep, rather) a loyal customer base, but may also result in a technological lock-in and, eventually, marginalisation. It should also be noted that not always do all stakeholders benefit from a standard. Selfishness in the form of pushing an inferior standard that will only benefit one company may also be observed, as may be the desire to prevent a competitor's (beneficial) technology from being standardised.

The social shaping of technology (SST) approach towards studying the relation between technology and society "*explores a range of factors – organisational, political, economic and cultural – which pattern the design and implementation of technology*" [Williams & Edge, 1996]. SST observes that "*The shaping process begins with the earliest stages of research and development*" [Williams, 1992]. In the ICT sector standards frequently represent a very early stage of development. The notion that choices can be made during the development of a technology – or a standard – is a cornerstone of the SST approach. These choices have a significant impact on the design of ICT standards. They may be based on a multitude of aspects that may be purely technical, but may also be of a societal or economic nature. Accordingly, there is a multitude of factors that potentially influence the outcome of a standardisation process, ranging from technological advances to changes in societal norms, corporate business interests and market needs to the views and attitudes of the individuals that actually design the standard.

If we accept that we can indeed learn from history and that standards are an important shaper of ICT, then knowledge about how earlier standards emerged, why they emerged the way they did, and which factors influenced their development would allow us to predict – to a certain extent – how future technologies will look. If we also accept that standards have not just technical ramifications but also strong economic and societal implications then the knowledge of what shapes a standard may offer the chance to steer technological development in a way that the outcome will be beneficial to all.

This chapter adopts a historiographical approach[152] to the analysis of a consensus-based standards setting process. This approach leads to certain insights and conclusions, but can only tell part of the whole story. To get a fuller picture, the problem would also need to be analysed from other angles, using other approaches. Specifically, a social sciences approach could lead to complementary insights. Likewise, marketing theories might help shed more light on the analysis of the related problem of a battle for dominant design in the market place.

The remainder of this paper is organised as follows: after a very brief review of the literature about standards wars and related phenomena in ICT (in section 4.2) some popular beliefs relating to the failure of the OSI initiative in general and X.400 in particular will be discussed in section 4.3. Subsequently, section 4.4 will offer some socio-technical arguments why X.400 was bound to fail. Finally, section 4.5 will identify some lessons that can be drawn for the future.

4.2 Battles and Wars Over ICT Standards – A Literature Recap

Standards wars have long been a popular subject in the literature, from very different perspectives. While the topic has primarily been discussed by economists, (see e.g. [Shapiro & Varian, 1999], [Stango, 2004], [Augereau et al., 2006]), historians, social scientists, and others have also contributed.

[152] According to Goodman and Kruger, historiography "… *is a way of addressing data and sources, asking questions and building theories based on evidence*" [1988, p. 316]. Vann [2023] defines historiography as "… *the writing of history based on the critical examination of sources, the selection of particular details from the authentic materials in those sources, and the synthesis of those details into a narrative that stands the test of critical examination*". That is, I do not (only) look at the events of the past directly, but also at the interpretations of those events in the works of others [Furay & Salevouris, 1988]. Of course, this inevitably also leads to an interpretation of the past. Schmidt [1985, p. 358] observes that "*Every history is an interpretation of the past and none of them is final*". Along similar lines, McDonald [2016, p. 67] notes that "… *history is an interpretation of the past that is bound and shaped by the present*".

'Internet vs. OSI' has frequently been considered an example of a standards war (e.g. in [Russel, 2006]). It would thus seem to be obvious to consider X.400 vs. the Internet's Simple Mail Transfer Protocol (SMTP) as one battle that was fought in this war. Accordingly, a brief look at the analyses of some of the better known such battles should yield some helpful lessons for the case at hand.

BetaMax vs. VHS video cassette formats, Ethernet vs. Token Ring protocols for Local Area Networks (LANs), and WiFi vs. various competitors in the field of Wireless LANs (WLANs) are among the best-known examples of battles between competing ICT standards. Other well-studied examples here include those between two different 56k modems in the late 1990s [Augereau et al., 2006] and between browsers in the early/mid 2000s [Oshri et al., 2008]. A little more recent are the cases of Blu-ray vs. HD-DVD in the field of optical disks, and of the standards for document formats, OOXML and ODF (see [Egyedi & Koppenhol, 2010] or [Blind, 2011]).

The following brief case outlines and the subsequent discussion shall highlight some factors that have been associated with a victory in a standards war.

- BetaMax vs. VHS
  Despite the 'maturity' of the case scholars are still not in full agreement as to what caused the victory of the VHS format (invented and marketed by JVC) nor are they with respect to other, related issues. For instance, the widely held claim (e.g. by [Cusumano, et al., 1992]) that BetaMax (produced by Sony) offered superior image quality has more recently been challenged by Liebowitz & Margolis [1995]. Analysing the importance of network effects Ohashi [2003] found "*that it would have been possible for Beta to capture the market if it had used its first-mover advantage to build an installed base through low pricing*".
  Yet, many authors (e.g. Grindley [1990] and Cusumano, et al. [1992]) agree that the fact that JVC's strategy was much more open than Sony's eventually led to the VHS victory. Sony was reluctant to be an OEM supplier. In contrast, JVC joined forces with partners that offered manufacturing capacity, provided access to the North American and European markets and, most importantly, offered content.

- Blu-ray vs. HD-DVD
  This case bears some resemblance to the Beta-VHS case. For one, the technologies are descendants of the VHS cassette. Sony was a main actor in both cases, and both eventual losers initially seemed to have a competitive edge – higher image resolution and built-in backward compatibility, respectively. The latter was at least an early perception. In 2007 (when players first hit the market in noticeable numbers) Brookey [2007] reported that Blu-ray was not backward compatible with DVDs. Indeed, according to the Blu-ray Disc Association backward compatibility is not a requirement of the Blu-ray Disc format. Today's Blu-ray players, however, are capable of also playing DVDs. Yet, other factors proved to be decisive. According to Gallagher [2012], this holds particularly for Sony's superior corporate strategy, which included the provision of complementary products and, particularly, the utilisation of its technology in another Sony product, the PlayStation 3. In contrast, Spark [2009] highlights the dynamic developments in the membership of the supporting consortia, where some large studios changed the level of support over time or switched sides entirely. He argues that the final blow for HD-DVD came "*when Warner Brothers announced that it would cease its support for HD-DVD and would instead exclusively support Blu-ray*. Plus, he notes that *"... those close to the deal stated that Warner Brothers received marketing support from Sony as part of the agreement*." Along similar lines, Compaine & Cunningham [2010] cite lack of exclusive support by large studios as the major reason for the outcome of the battle. Moreover, in the wake of Warner Brother's announcement WalMart delivered another blow to HD-DVD when it announced that it would phase out HD-DVD [Cozzarin et al, 2011].

- Ethernet vs. Token Ring
  Strangely, this case is hardly covered at all in the literature. This is all the more surprising since it represents one of the exceptionally few cases where one standards body, the Institute of Electrical and Electronics Engineers (IEEE), put efforts into the development of three competing standards (the third one being Token Bus, supposed to work in production environments; it never really got off the ground).
  Explaining the victory of Ethernet (developed and supported by DEC, Intel, and Xerox (DIX)) over its IBM-sponsored rival von Burg [2001] highlights the "*importance of communities and sponsor strategies for successfully establishing and improving a standard*". This community, in turn, was able to innovate, produce, and extend the market at a rapid pace. On the other hand, while IBM did support the development of a standard through IEEE, its desire for market dominance frustrated potential partners. This lack of a Token Ring community meant that Ethernet's pace of innovation could not be met, leading to an increasing price gap.
  Moreover, DEC, one of the Ethernet sponsors, provided a ready market for LAN products and Intel, another sponsor, provided the chip designing and manufacturing capacity. Together with the fact that Ethernet also became an IEEE standard (802.3) made it a 'safe' technology for investors and suppliers [von Burg, 2001].

- WiFi vs. HomeRF and HiperLAN
  It would seem that the success factors in this case were more related to technological aspects than in the previous ones. The main reason underlying the development of the HomeRF standard (by the HomeRF Working Group) was the allegedly inadequate support for isochronous services – i.e. for telephony – by the IEEE 802.11b specification. According to Lemstra & Hayes [2009] the reason for its eventual failure was the fact that systems implementing the standard would have had to be based on a proprietary technology, since only one consortium member was developing the HomeRF physical layer in silicon. This notion is seconded by Dovev et al. [2012], who also note that many consortium members felt the dependence on this one vendor would have made the standard a proprietary system; this they considered undesirable. In contrast, several silicon vendors supported the 802.11b standard, thus quickly bringing down the prices for the chipset. Moreover, it turned out that *"voice services was not a market need"* [Jakobs et al., 2010], rendering the main reason for the HomeRF development obsolete. The different bandwidths offered by the two systems was another decisive factor. Here, the rules of the Federal Communications Committee (FCC) played a crucial role. Exploiting a – still debated – FCC ruling 802.11b-based products could offer 10Mbps bandwidth in 1999. Following another FCC ruling – which was delayed by lobbying and protests by those who had a vested interest in 802.11b – this could eventually be matched by HomeRF 2.0, but only by mid-2001. By then, however, 802.11b already dominated the market.
  HiperLAN was a European development, led by the European Telecommunications Standards Institute (ETSI). There were two different developments, HiperLAN/1 and /2. The former was different from the 802 specification in most respects; in fact, "*There was a fair bit of competitiveness w.r.t. the IEEE 802.11 work – also technology-wise*" [Kruys, 2007]. In contrast, the specifications of the HiperLAN/2 and IEEE 802.11a modulation schemes were almost identical. Still, HiperLAN/2 was a centralised system with a focus on support of isochronous traffic (not unlike HomeRF) and Quality of Service (QoS). It was based on the Asynchronous Transfer Mode (ATM) technology that was very high on the agenda around the millennium change.
  "*HiperLAN/2 was never implemented because of the huge success of the IEEE b/g products after Apple announced their first sub 100$ product in 1999. …… The fact that there was no demand for QoS from the market at the time made the demise of HiperLAN/ 2 inevitable*" [Kruys, 2007].

There is a noticeable difference between the cases of (W)LANs (and document formats) on the one hand and those of the recording media (and browsers and modems) on the other. The latter were actually battles for dominant design between technologies based on proprietary standards; they were fought in the market (for more details see e.g. [v.d.Kaaa et al., 2011], [Suarez, 2004]). The former were fought between standards proper that were developed by working groups of different standards setting bodies (of course, the market and the different standards-based products played an important role in these cases as well).

Despite their general difference the cases above also share one striking characteristic (albeit in different expressions) – the importance of having adequate alliances in place when it comes to pushing a technology or a standard in the market. In the cases of the video recording technologies this refers primarily to the need of supporting content providers. For the local area networks, the ability to enlist – by means of openly available standards – companies with complementary capabilities and expertise proved decisive. This is indeed a lesson to be learned from history, and it seems like Sony (Blu-ray) and Intel (WiFi) have understood that.

Sadly, this lesson does not apply to the case at hand – the struggle between the different e-mail system. After all, being associated with the OSI protocol suite X.400 enjoyed the support of pretty much all Western governments (including that of the US) and of most large suppliers, so the formation of an alliance was not really an issue. On the other hand, the Internet and its protocols – including its main messaging programme, the Simple Mail Transfer Protocol (SMTP) – on the other hand, was initially a small US-based research network, initiated by the US Department of Defense (DoD) and developed by a smallish number of universities, research institutions and motivated individuals (think of David vs. Goliath).

Another aspect worth considering relates to the market relevance of a standard. A focus on services for which the market had no demand (voice, QoS) at least contributed to both HomeRF's and HiperLAN's demise. Along similar lines, the WLAN case demonstrates that it is may be extremely difficult for a latecomer to fight an incumbent with a large installed base, all the more so if the new technology doesn't offer any significant benefits (as happened to HiperLAN). Yet again, these insights do not really help explain the e-mail case. Back in 1984, SMTP did not have an installed base worth mentioning, definitely not in Europe. Neither had X.400, but at least on paper it did offer significantly more sophisticated services than SMTP, and it did meet actual market needs (interconnection of incompatible proprietary systems). One should have thought that the outcome of this 'battle' was very clear up-front. So, what went 'wrong'?

In contrast to many others (e.g. [Maathuis & Smit, 2003], [Russel, 2006]) I would argue that the e-mail case was not at all an example of a standards battle, at least not initially. This is simply due to the fact that in the early stages of development X.400 was the only combatant to be taken serious. In fact, as we will see (in section 4.4; with the benefit of hindsight), X.400 managed to shoot itself in the foot quite effectively, thus avoiding the necessity of any 'battle'.

So, while the brief descriptions above illuminate that the outcome of standards battles frequently depend on the same, reoccurring elements, (initially) these elements did not play a major role in the case of e-mail. That is, accepted wisdom from earlier standards battles cannot readily be applied to the X.400 case. In the following, I will, therefore, first discuss some popular beliefs regarding the reasons behind the 'victory' of the Internet over OSI (of which X.400 was an integral part). Subsequently, I will focus on X.400 and will offer some explanations why X.400 never became as popular as could have been expected.

4.3 Why Did OSI Fail – Two Popular Beliefs

Common wisdom has it that the increasing popularity of the Internet was the one reason why OSI (and thus, X.400) never made it (see e.g. [Maathuis & Smit, 2003]). Another popular explanation is OSI's alleged 'installed base hostility' (made by e.g. [Hanseth, 2002]).

In the following these propositions will be discussed for the OSI suite of services and protocols in general.

4.3.1 The Standardisation Process – the IETF's Alleged Superiority

"The Internet killed OSI" is a popular point of view (see e.g. [Malamud, 1992], [Lehr, 1995]). And there is a certain level of truth to this claim; eventually, the Internet actually did deliver the final blow to OSI.

Many factors contributed to the Internet's success. The communication software was part of the then increasingly popular unix operating system, it was simple and easy to install and to maintain, and it was free. Yet, it would be too simplistic to assume that these were the only reasons. In fact, the Internet's standards setting process has frequently been identified as a (the?) main reason behind its success (see e.g. [Lehr, 1995]). This process's most important characteristics include an evolutionary design approach, the importance assigned to backward compatibility, interoperable implementations, and a considerable degree of pragmatism.

The step-by-step approach is indeed a cornerstone of the process of the Internet Engineering Task Force (IETF), the body in charge of developing the Internet standards. It aims at standardising comparably small but interoperable components, which can be combined to provide the desired functionality. Most importantly, though, a certain level of pragmatism is essential. This includes the tendency to prefer a quick solution over lengthy discussions on merits and disadvantages of different proposals and the rather relaxed attitude towards the use of external specifications. Both characteristics distinguish the IETF process from those of the 'official' standards bodies (e.g. ISO and ITU-T). Certainly in the ICT sector these bodies exhibit a certain tendency towards 'all-embracing' solutions that solve all problems at once. This leads to sometimes extremely complex specifications that even large companies are hesitant to implement (because of their complexity and because they tend to solve problems which nobody ever encountered). In contrast, IETF specifications tended to be simple, and different implementations have to be been tested for interoperability prior to the final release of a standard.

Yet, all that glitters is not gold. Over time, a few more critical accounts of the process have been published, including two documents commissioned by the IETF itself. One of them [Davies, 2004] reveals a considerable number of problems as perceived by individual Working Group (WG) members. The author acknowledges that many of the IETF's problems are rooted in the unexpected and unforeseeable growth of the Internet in terms of both size and importance. The IETF has largely failed to adapt its processes to this changed environment "*Many of the problems and symptoms appear to be fundamentally caused by the organization failing to adapt its management and processes to its new larger size, and failing to clearly define its future mission once the initial mission had been completed or outgrown*." [Davies, 2004]. More specifically, he observes that the IETF process is largely built on "*one-to-one personal trust relationship*", a very powerful model that does, however, not scale well. Also beyond personal relations it is safe to say that the IETF's process as such does not scale well either [Jakobs, 2003]. On a related note, Davies observes that "*The IETF has Difficulty Handling Large and/or Complex Problems*".

Moreover, several characteristics considered by many as being unique to the IETF may also be found in other standards bodies. These include, for example, the claim that "everyone can speak" that can safely also be made by e.g. ISO. Plus, being allowed to speak does not necessarily imply that everyone actually does speak or, perhaps more importantly, is actually listened to. A closely related problem is discussed in [Spring et al., 1995] – those who want to delay and possibly even obstruct the work stand a good chance of being successful; the process does not foresee any mechanisms for how to deal with such individuals: "*The IETF does not have a strategy for dealing effectively with an individual who is inhibiting progress, …*" [Davies, 2004]. With roughly 10% such individuals on a typical committee (according to [Spring et al., 1995]) this is a potentially disastrous situation.

The popular claim that IETF's 'individual participation' makes a difference is not valid either. For one, it also holds for ISO [ISO, 2012]. Moreover, research from the mid-1990s shows that even back then a sizable minority of IETF WG 'members' considered themselves as national/company representatives [Jakobs et al., 2001].

Despite the fact that the IETF's step-by-step approach does indeed have its advantages the discussion above suggests that the alleged superiority of the IETF's standardisation process over those of other standards bodies is at least questionable. Accordingly, it may be dismissed as a valid reason for the claim that the Internet was the reason for OSI's failure appears to be questionable.

'Time' is another and probably more important aspect to be considered here. It may seem hard to believe today, but back in 1986 (when the first version of X.400 had already been two years old) the 'ARPA Internet' only comprised around 2,000 hosts (just about twice the number of the UK's academic network JANET), most of them located in the US [Quarterman & Hoskins, 1986]. Originally, the Internet was the successor to the ARPANet that had been developed under the auspices of the Advanced Research Projects Agency, a DoD agency. The ARPANet was designed for flexibility and robustness and was only used to interconnect DoD's research contractors. Also, the IETF was founded only in 1986.

OSI, on the other hand, was very much rooted in Europe, enjoyed the support of the European Commission, the US administration, and of almost all major manufacturers. The OSI Reference Model was adopted in 1984, and by the mid-1980s first implementations of the OSI protocol stack were available; most OSI standards had either already been adopted or were at least in a very stable state. It seems very unlikely that this comparably small research network in the US and its standards should have posed any threat at that time.

4.3.2 Installed Base Hostility

Another issue which has been raised in the literature refers to the fact that OSI failed to provide for a smooth transition from previously used networks; it had been designed without taking into account the characteristics of older networks. Any such transition requires some form of 'jumping'. In particular, X.400 was allegedly 'installed-base hostile' (see e.g. [Hanseth, 2002]). This claim is justified to a certain extent: X.400 was indeed 'installed-base hostile' in a way due to the fact that it was an integral part of the OSI initiative, and accordingly initially required the use of underlying OSI protocols. This requirement was eventually circumvented to enable X.400 to run over TCP (Transmission Control Protocol; the Internet's most popular transport protocol) as well. Prior to this, however, this strict requirement regarding the underlying communication protocols implied that a prospective user company had to install a complete OSI-based infrastructure if it wanted to employ X.400. This would have been a very costly exercise in terms of both time and money, not to mention training and related issues.

On the other hand, the originally envisioned X.400 system, as an enabler of interoperability between heterogeneous, proprietary e-mail systems, was anything but 'installed-base hostile'. Quite the contrary, it was supposed to enable the individual proprietary elements of said installed base to communicate. One of the individuals behind the early X.400 development, Ian Cunningham [1983] notes that "*Standard protocols are the glue that will connect all the individual systems into a worldwide network*". Moreover, X.400 was designed to take advantage of the widely installed base of X.25 networks, which at that time represented the most widespread packet-switched network in Europe.

In summary, X.400 being part of the OSI stack implied a certain degree of installed-base hostility. This may indeed have contributed to its non-uptake. X.400 per se, however, was an enabler of interoperability between e-mail systems. Thus, installed-base hostility cannot be considered a major reason for its failure.

4.4 Standardising X.400

Before actually attempting to answer the question why X.400 never really made it, let me first provide a bit of background on the early stages of its development.

4.4.1 The Initial Development of X.400

In 1978, the International Federation or Information Processing (IFIP) established a Working Group on 'International computer-based messaging'. IFIP is a non-governmental, non-profit umbrella organisation for national societies working in the field of information processing. It was established in 1960 under the auspices of the UNESCO. The task of IFIP's then newly founded Working Group 6.5 was "*to concentrate on standards for data structures, addressing, and higher level protocols to effect international computer mediated message services*" [Stefferud, 1979]. The basic idea was to develop a system that could serve as a backbone to interconnect the increasing number of incompatible and proprietary electronic messaging services without the need for individual system-to-system gateways. IFIP's work formed the basis for the subsequent formal standardisation work carried out within the International Telegraph and Telephone Consultative Committee (CCITT), the predecessor to the standardisation sector of today's International Telecommunication Union (ITU-T). Later on, work on electronic messaging also commenced within ISO. Schmidt & Werle [1998] give a highly interesting account of the developments within both standards bodies towards the first X.400 series of recommendations, with some focus on what went on inside CCITT. However, the publication date of their book implies that later events, especially the non-uptake of X.400, could not be covered.

CCITT published the first X.400 series of recommendations in 1984; a much more elaborate version was published in 1988. Most of these recommendations are still in force today; the current versions date from 1999. SITA, (Société Internationale de Télécommunications Aéronautiques), the air transport industry's IT and communications arm, still uses X.400 for all operational messaging in the industry.

Pretty much in parallel with these developments work on electronic messaging was also ongoing in the realm of the Internet. A specification of network text messages was published in 1977, the initial specification for the associated transfer protocol followed in 1982. Both specifications saw various updates and extensions throughout the years, the latest versions dating from 2008.

4.4.2 Early Days

As stated above, IFIP's early work on what was to become X.400 was triggered by the very real need to interconnect an array of incompatible proprietary e-mail systems. Coopersmith [2010] notes that "*many firms and organizations invested considerable resources developing email systems since the late 1970s, but encountered major user resistance because of the many incompatible systems*". To extend the user base and thus make e-mail service commercially viable the individual systems had to be interconnected; this held for both corporate and public systems. Initially, dedicated gateways were used to interconnect systems. For example, in 1992 British Petroleum (BP) had eleven different systems in use throughout the Group, with some 33,000 users. All systems were interconnected via gateways, primarily on a peer-to-peer basis [Jakobs & Lenssen, 1994]. Yet, such gateway-based interconnection proved to be a costly and functionally complex exercise. Accordingly, a (standards-based) backbone network was urgently needed to provide for smooth interconnectivity between the different e-mail systems. Ultimately, this need was behind the development of X.400.

It appears safe to say that X.400 was born into a very favourable environment – it could be assumed to very much simplify the interconnection of different e-mail systems, thus reducing complexity and costs while at the same time increasing functionality (gateways cannot always map the full functionality between two systems). There were also other aspects very much in favour of a successful adoption and diffusion of X.400. For one, almost all governments and most major vendors supported OSI and thus X.400 (see e.g. [Aschenbrenner, 1986]). This held despite the fact that by 1983 the

ARPANET had been fully converted to the TCP/IP protocols. Moreover, and again despite the ARPANet, OSI – and thus X.400 – initially did not face any real competition from other networks. More specific to X.400, the fact that the CCITT was responsible for the standardisation activities implied that the (then) monopoly PTTs were in charge; certainly another very favourable aspect.

4.4.3 Why Then Did It Fail?

Still, there were also a number of less favourable factors. In fact, several reasons may be identified that 'collaborated' in a disastrous way and – taken together – led to X.400's failure.

First and foremost the close integration into the OSI protocol stack was a double-edged sword. While it created wide support, it also meant that X.400 was dependent on an extremely complex set of underlying protocols, some of which had not been fully specified at the time of the publication of its 1984 version. The same holds for the Directory Service (the ITU-T's X.500 series of recommendations). As the name suggests the DS was supposed to be the data networking world's equivalent to White Pages, Yellow Pages, and directory enquiries. The DS's availability would have contributed considerably to X.400's user-friendliness.

More generally, the OSI set of protocols were very function-rich, designed to solve all potential communication problems from the outset (see e.g. [Egyedi, 1999], [Jakobs, 2002]). Such complex standards may easily lead to ambiguities, through inadequate wording and/or through the introduction of optional functionalities. The latter was used extensively in the whole OSI suite. Almost inevitably, this led to implementations that fully complied with the standard, yet were not interoperable (this is a fairly common phenomenon; see e.g. [Egyedi, 2007]). To at least reduce this problem, so-called profiles had to be developed. A profile specifies which options should be implemented, thus reducing the functionality of an application for the sake of interoperable implementations [Manros, 1989].

X.400's own complexity was another, related issue. The initial version from 1984 comprised seven parts requiring a total of 327 pages of description, its successor from 1988 had 580 pages in 8 parts. This increase was due to the limited functionality of the 1984 version and to improved explanations and documentations in the 1988 version.

In addition to these more general – albeit important – aspects a number of other, more specific reasons may be found to explain the failure of X.400. These will be discussed below.

4.4.4 Unfortunate Timing

Timing was one of X.400's major problems – in two respects. First, in the early eighties, CCITT's work was organised in four-year intervals, called 'study periods'. Accordingly, their 'Recommendations' (read 'standards') were published only every four years, at the end of each study period; this practice was abandoned only when the ITU was restructured in 1993.

Thus, if another four year delay was to be avoided, something had to be published by the end of the 1980-84 study period – regardless of its (technical) maturity. In the case of X.400, this led to the publication of rather premature specifications in 1984. Crucial parts of the specifications were extremely sketchy (e.g. the security features), or missing altogether (e.g. the message store).

Another similar, time-related problem was outside the control of CCITT. The first version of X.400 was supposed to be fully integrated into the 7-layer OSI protocol stack, as part of its top-most 'Application Layer'. This, in turn, implied that initially the proper functioning of X.400 required a full-blown underlying OSI stack. As X.400 was the first standardised element of the OSI Application Layer, potential early adopters would have had to implement the full OSI stack for just this one, overly function-rich application [Schmidt & Werle, 1998].

To make things worse, not all necessary underlying standards had been adopted in 1984. In particular, the OSI presentation layer standard was not even fully specified by then and therefore the 1984 version of X.400 was written to sit directly on top of the session layer (this was changed in the subsequent 1988 version, but not without considerable difficulties). This caused a further reduction of functionality in the 1984 version.

Moreover, the standards for the Directory Service (DS) were not available in 1984 (its first version was published in 1988). It is easily conceivable that the unavailability of this service further contributed to a reduced usefulness, and user-friendliness, of X.400.

4.4.5 Inadequate First Implementations

Not least due to the complexity of even the incomplete initial X.400 version early implementations were frequently incompatible. That is, it was next to impossible to exchange messages between systems from different vendors. Such inadequate first expressions of a technology are extremely dangerous.

In cases when decisions to adopt are based only on initial expressions of a technology poor first implementations may easily deter potential early adopters, prevent any subsequent bandwagon-effect, and thus easily reduce to zero this technology's chances of being adopted. Cowan [1992] notes that observable early benefits of a technology will outweigh all other aspects; in particular, higher benefits to be gained from a different technology at some later stage will be ignored. These benefits, in turn, cannot be identified at all due to the lack of opportunities for experimentation. It follows that the market can – and frequently will – adopt the 'wrong' technology (i.e. ignore the 'right' one) when left on its own. That is, possibly superficial, implementation-specific shortcomings which hide the system's inherent advantages may have a devastating effect.

Also, it may frequently be observed that in the absence of a sound basis for judgement and decisions the adoption of a particular technology by just one firm may encourage others to follow. If this happens, chances again are that an inferior technology will be adopted, which may be highly useful for the initial adopter (who will have evaluated the alternatives and selected the technology to best suit his needs), but does not necessarily meet other entities' demands. They, in turn, will then make their choices solely based on the initial adopter's policy decision. In this case as well little, if any, experimentation with alternative technologies or systems will occur; they will rapidly be discarded.

4.4.6 Non-Adaptivity

The X.400 specifications also suffered from a side-effect of the enormous speed of technical development in the ICT domain, and from the fact that these technical developments – which occurred in parallel with the X.400 standardisation process – were ignored.

Technical work on the specifications started in the mid-seventies. At that time, 'dumb' terminals, typically connected to a mini computer or a mainframe, were the prevailing end-user systems. Consequently, during standardisation work an environment was assumed that was built around this type of technology. A technical detail may serve to highlight the associated problems: the initial X.400 specifications did not include a 'Message Store' (MS). An MS would have allowed to store messages permanently on a local machine (and to retrieve them). Mini or mainframe computers used to run continuously (they were hardly, if ever, switched off under normal circumstances) and thus did not need a dedicated MS. Yet, the diffusion of PCs meant that more 'intelligent' end-user systems became available that were typically switched off at the of a working day and would have required an MS. Thanks to its design, adopting X.400 to this new environment was less than trivial and was not really attempted at all for quite a while.

4.4.7 An Ill-advised Paradigm Shift

Maybe even worse, X.400 suffered from a paradigm shift during its design. Initially, the work done within IFIP had aimed at interconnecting different proprietary e-mail systems through a standards-based 'backbone' network. This approach had been in line with the very real need of most corporate e-mail users who had to interconnect different e-mail systems deployed at various sites or departments.

However, during the course of the standardisation work this changed. According to James White, then a CCITT Special Rapporteur on X.400, CCITT considered the backbone functionality only as a tactical goal, whereas the development of an over-arching architecture for message handling systems was seen as the strategic goal [Manros, 1989]. This strategic goal implied that X.400 was to become the ubiquitous e-mail system, providing functionality to the end-user's desktop.

In fact, in all likelihood this shift was a crucially important contributor to X.400's problems in the market. Here again technical progress overtook standards development. By the mid-eighties, LAN-based e-mail systems had become the systems of choice for internal communication in virtually all organisations. Not unlike PCs, such LAN-based systems did not really fit into the assumed X.400 environment.

Taken together, these two developments – the diffusion of PCs and LANs in the mid to late eighties – rendered the strategic idea of 'X.400 to the desktop' virtually obsolete. In more general terms, the time span between the start of the standards setting activity and the completion of the final documents led to a missed window of opportunity. Other systems (i.e. PCs and LANs, with their own proprietary e-mail systems) had occupied the major market segment of corporate internal communication systems. Somewhat ironically, this left X.400 with the backbone market for which it had been intended in the first place, but for which it was now less suited.

4.4.8 National Monopolies and the Standardisation Process

Finally, a very different, non-technical aspect also needs to be mentioned. Although the initial specifications failed to provide for several important features X.400 systems have always been extremely complex and hard to manage. Indeed, X.400 aimed at providing the one solution to all e-mail related problems (and then some). All voting members on CCITT committees came from Post, Telegraph and Telephone administrations (PTTs) that were the (then) monopoly organisations in charge of the respective national (telephone) networks, or from equivalent organisations. It thus does not come as a big surprise that they did not adopt a user-friendly, gradual design, with a first specification evolving along with upcoming new requirements. Rather, they were in a position to follow a 'take it or leave it' approach, and design a system that clearly reflected PTTs' ways of thought and that met their specific needs, as opposed to those of their users. The distinction between 'Administrative' and 'Private' Management Domains' (ADMDs and PrMDs, respectively), as foreseen in the X.400 recommendation, is a case in point. Basically, this distinction's major purpose was to make sure that any international traffic would be routed through – and thus charged for – ADMDs, run by the PTTs [Schmidt & Werle, 1998]. As [Schmidt & Werle,1998, 229-30] put it: "*The standardization of X.400 is an impressive example of an attempt at early, comprehensive standardization ... X.400 demonstrates the pitfalls of ex ante standardization: if the work of the standardization committee is protected from the influence of the markets, and if the marketing of products is years away, a comprehensive system of standardization may remain largely theoretical*".

4.4.9 Specific Problems and General Issues

A closer look at X.400's standardisation and subsequent adoption reveals that most problems encountered were specific to this particular case. The exceptions include the 'complexity of the standard' and its 'inadequate first implementations'; these are general issues that could hamper the uptake of any ICT standard. The need for an 'integration into the OSI stack' is a bit of a hybrid – many ICT standards need to be integrated into an ecosystem of existing standards. However, OSI was a special case in that it formed the environment into which X.400 had to fit, but was not fully available when X.400 was. Indeed, the latter contributed considerably to X.400's problems.

'Unfortunate Timing' was a CCITT-specific problem; their four-year cycle pretty much enforced the publication of a premature standard. The same holds for 'Non-Adaptivity'. The rather lengthy standardisation process of at least four years should have strongly suggested the need to watch relevant technological developments and to adapt accordingly if need be. Yet, this did not happen. The 'Ill-advised Paradigm Shift' was another X.400-specific problem and was in fact closely related to the problem of the 'National Monopolies'. In the absence of any competition the PTTs were in a position to adopt the stance that X.400 was to be the ubiquitous e-mail system.

4.4.10 And the Winner Was …………..?

Despite the undeniable general need for open, vendor and platform independent communication the developers of X.400 apparently failed to realise that a system as complex as this, operating on top of an equally complex protocol stack would be useful only for a handful of large, technically sophisticated organisations. Moreover, they apparently under-estimated the growth rate of the Internet. Accordingly, X.400 became a failure in the market place even though it correctly anticipated general initial requirements.

Today, the vast majority of users deploy e-mail systems which interconnect their clients with a central server via a local area network. Most of these systems operate on top of Internet protocols. These include SMTP for message transfer, the Internet Message Access Protocol (IMAP) and the Post Office Protocol (POP) to enable the clients to access the mailboxes stored on the server, and Secure/Multipurpose Internet Mail Extensions (S/MIME) to encode and encrypt messages that comprise multiple parts (e.g. text, graphics, and a video). In addition, numerous complementary standards exist. Yet, some of the functionalities provided by X.400 (which is now almost 40 years old) are still not available with SMTP. These include, among many others, notifications whether or not a message has reached its destination, or has been read by the recipient. An associated specification exists, had been on the IETF's 'draft standard' level from 2004 until early 2012, and was then updated by another RFC that is now at the 'proposed standard' level (RFCs are a series of documents published by the IETF that contain technical and administrative documents about the Internet). To the best of my knowledge neither has ever been commercially implemented and deployed.

In short – SMTP et al. 'won', but the users didn't.

As an aside – a number of stakeholders did not win either. Standardisation is a costly business. Weiss and Toyofuku [1996] estimate the development cost of the Ethernet 10BaseT standard at around $10,000,000. The US Office of Technology Assessment (OTA) reports that "*… it has been estimated, for example, that the development of a major international telecommunications standard may require in the range of 1,000 person-years of experience, 20 person-years of actual effort, and $3 million*" [OTA, 1992]. Oksala et al. [1996] report that "*Some have suggested that the OSI effort ... may have cost the governments and corporations that contributed to its development more than half a billion dollars*". None of these figures directly relates to X.400 standardisation, but they give a good idea about the costs to be associated with the development of ICT standards. While such costs are shared by the participating organisations it is safe to assume that the investments sunk in the standardisation and the subsequent attempts at commercialisation and/or implementation of X.400 were quite massive.

4.5 Summary and Some Lessons to be Learned

There was a clear need for a standards-based electronic mail system in the late seventies / mid-eighties (and beyond). X.400 was an attempt – initiated by the CCITT – to standardise such a system, with backing from virtually all Western governments. Still, it never really got off the ground.

It has turned out that at least initially the major reason for this failure had not been the success of the Internet (which was little more than a US research network by that time). Rather, the standards committee's negligence with respect to technical developments which took place in parallel with the X.400 specification work has to be blamed. As a result, only with considerable difficulties could X.400 be integrated into the technical environment that was state-of-the-art in 1984, when its first specifications were published. To make things worse, the original idea underlying X.400, i.e. to create a backbone e-mail system to interconnect the numerous proprietary systems that had hit the market, had to take a back seat to the idea of a ubiquitous e-mail system to the desktop. This further complicated integration of X.400 into existing (corporate) IT environments. In contrast, integration of the originally planned backbone would have caused comparably little problems (and might have led to a successful system).

As a consequence, we may note that – lesson one – standards setting in the ICT arena, where technical developments continue to happen at a very high speed, needs an adequate level of flexibility to be able to react to outside developments that are likely to affect the system to be standardised. A second lesson – old news for some – would have to be that all-embracing, over-arching, and therefore very complex standards carry a much greater likelihood of failure than modular, extendable, and thus more flexible ones.

However, there's a caveat. Apparently, the success of a simple but working system, like Internet mail, carries the risk of the system remaining more or less at this simple level. Comparing the functionalities of X.400 and the various standards that together describe the functionality of Internet e-mail you will still find a significant gap. Some functionality, e.g. delivery notifications or gateways to other communication services are available over the Internet, but only as non-standard, proprietary products or services (Deutsche Telekom's 'eBrief' (e-letter) would be a case in point). Thus, lesson number three (which is related to number one) would be that also those standards that form the basis of successfully working systems need to be continuously monitored, updated if necessary, and actually be implemented. The latter should go without saying, but experience indicates that this is not necessarily the case.

Related to the above, lesson number four would be to make sure that at least for communication systems standards all necessary underlying and complementary standards are available upon publication. While speed may sometimes be a virtue in standardisation, this is by no means always the case. In fact, this may be considered as lesson number five.

On a final note – the case of OSI and the Internet has frequently been portrayed as a 'US versus Europe' affair; "*American research and university communities pushed IP, while both European researchers within the computer communications field and telecom operators pushed OSI*" [Hanseth, 2001]. More to the point, it has been said to be an example of "[North-American] *technical prowess and business acumen versus the* [European] *authoritarianism of a sclerotic bureaucrac*y" [Rogers & Kingsley, 2004]. This may have been the case for OSI and the TCP/IP protocol suite in general. Yet, it certainly does not hold for X.400, where North-American researchers were instrumental in IFIP's early activities, as well as for the work within CCITT [Schmidt & Werle, 1998]. On the other hand, the one individual who tried to bridge the gap between SMTP and X.400 was a European (Steve Kille, then with University College London). He took the problem to the IETF and wrote the specifications necessary to interconnect the two systems. It would seem that interested individuals from the US were heavily involved in the bureaucratic CCITT activities and Europeans in the market-driven work in the US.

5 Standardisation of Smart Systems – Learning From the Past?!

5.1 Introduction

In the past couple of years standardisation has seen a development that may eventually change the whole standardisation landscape – the mergers of formerly separate sectors. The – almost finalised – integration of (tele)communication and information technology led to ICT. A next step – currently being taken – is the integration of ICT and broadcasting. IPTV[153] and Internet Radio are well-known cases in point.

Such mergers of technologies will continue, and they are likely to do so on a broad scale. These emerging new technological fields will also be based on technical standards. Examples here would include, among others, Intelligent Transport Systems (i. a. ICT, transport telematics, traffic engineering, Power Engineering, Automotive) and Smart Manufacturing (aka 'Industry 4.0'; i. a. ICT, Production Engineering, Robotics, Control Engineering).

One common characteristic of these fields is the prominent role of ICT. In fact, the integration of ICT into 'traditional' technologies (transportation, manufacturing, etc.) is decisive; it represents the 'smart' bit. And while compatibility and interoperability are important aspects in many technologies, they are the 'sine-qua-non' for smart systems. This, in turn, implies that (compatibility/interoperability) standards play a pivotal role. Without them, smart technologies simply will not materialise. Another characteristic is the reliance on an underlying smart communication infrastructure, comprising mainly the Internet of Things (IoT) and Cyber-Physical Systems (CPSs).

These (e)merging technologies represent a considerable problem for standards setting. On the more technical side, this holds specifically for the smart infrastructure. By definition, the IoT is based on standard communication protocols to interconnect uniquely addressable objects. Yet, 'object' is a very broad term; it may be a sensor or a mainframe computer. The most prominent common characteristic of the majority of IoT nodes will be 'power-constrained'. The communication infrastructure needs to take this restriction into account, e.g. through appropriate modifications of existing protocols and/or through dedicated new ones. In their current form, most standards are too complex for the constrained devices of the IoT. To make things worse, many of these devices run proprietary protocols, thus creating isolated data silos. This increased variety also implies that interoperability will be even harder to achieve than in other areas of the ICT sector.

Moreover, both the infrastructure and – even more so – the applications will require co-operation between standardisation entities with very different cultures, backgrounds and different technology life cycles. On top of that, most smart applications need to address issues of information security and safety and of trust (think of e.g. e-health). These aspects as well will need to be considered in the standardisation process, adding yet another dimension of complexity.

This chapter looks at the development over the past twenty years of the standardisation entities for a smart communication infrastructure, for some popular smart applications and at the links between them. In doing so, it aims at taking a glimpse into the future of standardisation in these sectors, informed by developments of the past. This represents a first step towards an answer to the question how the standardisation environment for smart systems may look like in the future. This, in turn, should help industry to optimally position themselves when dedicated standardisation activities for smart systems will eventually truly get off the ground.

This chapter first provides a (brief) section (5.2) about the methodology applied. This is followed by an in-depth literature review. Here, sections 5.3 and 5.4 offer a brief introduction to the elements of a smart communication infrastructure, the characteristics of the smart applications deploying it and about the environment within which both are standardised, respectively. Subsequently, some

[153] Internet-based television.

important aspects of the standardisation processes of four smart sample applications (Intelligent Transport Systems, Smart Manufacturing, the Smart Grid and Smart Cities) are discussed in sect. 5.5. This discussion covers the respective major players, the links between them and the chronologies of the processes. Sect. 5.6 provides the analogous information for the smart infrastructure, comprising wireless communication as well as the Internet of Things and CPSs. Findings from a survey among three different groups of stakeholders are presented and discussed in sect. 5.7. Finally, sect. 5.8 discusses some resulting managerial issues and makes some recommendations; sect. 5.9 provides a very brief conclusion.

5.2 Methodology[154]

Ultimately, the present study aims to sketch the future standardisation environment for a smart ICT infrastructure and the (e)merging technologies that deploy it. The focus is on this environment's ability to actually deliver the standards that are necessary to build technically sound, applicable and beneficial smart applications and an adequate underlying communication infrastructure.

To this end, the empirical part of the study targets, on the one hand, those who are involved in the actual development of smart systems and in the associated standardisation processes and, on the other hand, those who do the underlying research[155].

The resulting need to look inside working groups suggests the use of case studies or a qualitative survey. ICT standardisation is a very heterogeneous environment. Its diversity extends to the stakeholders, the characteristics of the individual SSOs that together establish a major part of this environment and the individuals that populate the SSOs' working groups (WGs). To try and cover at least part of this heterogeneity and in order to avoid the 'generalisability problem' typically associated with a case study approach, the study is based on a qualitative survey. Fink [2003, p.61] state that a qualitative survey is used to "… *collect information on the meanings that people attach to their experiences* …". For further information about the survey methodology see sect. 5.7.

The survey is complemented by an archival analysis, as some relevant information could be extracted from 'historic' information (e.g. certain common development patterns may be identified and potentially extrapolated). The idea is to learn from the past and to avoid the repetition of mistakes.

As suggested above, the study deployed two sources of information.

5.2.1 Archival Information

A review of the relevant scientific literature provided valuable information for the background and the state-of-the-art of smart infrastructures and applications and about the standardisation landscape for smart systems.

Information provided on individual SSOs' and Working Group's (WG's) web sites was highly valuable for the drawing of the various timelines and SSO maps depicted in sects. 5.5 and 5.6. In addition, they were invaluable as sources of contact information.

5.2.2 Questionnaires

Other relevant information was compiled through questionnaires. Different questionnaires were used for different types of interviewees. All questionnaires were semi-structured and comprised open ended questions.

The questionnaires were deliberately kept as short as possible; they should not be off-putting due to sheer length. For more details see sect. 5.7.

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[154] Additional information will be provided in sect. 5.7.

[155] Obviously, this focus excludes those who work for SSOs.

5.3 Smart Infrastructures/Applications and Standardisation

Figure 5.1 below visualises the development from simple (networked) embedded systems, which have been around for quite some time now via CPSs to an overarching field of application of these technologies, in this case Smart Cities. Caragliu et al. [2011] *"... believe a city to be smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance*". While numerous comparably simple predecessors of smart cities exist today[156], a long way remains to be gone to achieve this status.

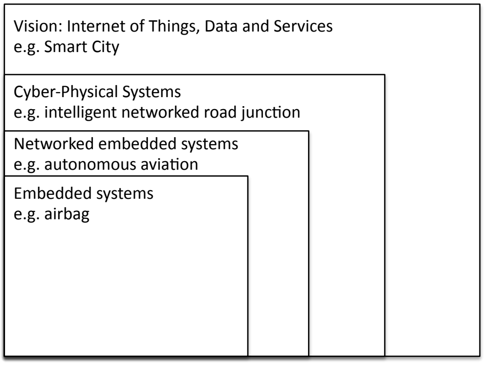

Figure 5.1: From airbags to smart cities (adapted from [acatech, 2011])

This report focuses on the upper two layers of this model.

5.3.1 Definitions

The British Royal Academy of Engineering defines that "[A] *'Smart infrastructure' responds intelligently to changes in its environment, including user demands and other infrastructure, to achieve an improved performance*" [RAEng, 2012]. This infrastructure may deploy different technologies and systems, including, for instance, Cyber-Physical Systems (CPSs), the Internet of Things (IoT), Wireless Sensor Networks (WSNs) and Machine-to-Machine Communication (M2M).

For the European Commission, CPSs are "*integrated systems of computation, networking, and physical processes. Embedded computers and networks in these systems monitor, control and manage the physical processes, with feedback loops where physical processes affect computations and vice versa. Further they can exchange information between them and with human users*"[157]. The defining characteristics of a CPS include the integration of both 'physical' and 'virtual' artefacts and the ability to communicate with the outside world, including humans. CPSs are assumed to be part of people's daily lives by 2050 [EP, 2016].

The European Research Cluster on the Internet of Things (IERC) defines the IoT as "*A dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual 'things' have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network*"[158]. That is, a CPS may be a node of the IoT and may, accordingly, communicate via the IoT.

[156] See also e.g. http://www.smart-cities.eu/.

[157] According to a presentation on ICT 30 2015: "Internet of Things and Platforms for Connected Smart Objects", https://www.ncpwallonie.be/assets/4b1f0aa4-4455-437f-a7ab-cdfcdbe1ebb8/pieter-friess-h2020-ict30.pdf (accessed 12 December 2022).

[158] http://www.internet-of-things-research.eu/about_iot.htm.

In contrast, not every IoT node is a CPS, as the defining characteristic for an IoT node is ability to uniquely identify each node; it does not need to have a 'physical' component. They also note that the IoT adds the 'anything' dimension to 'anyplace' and 'anytime' (see Figure 5.2).

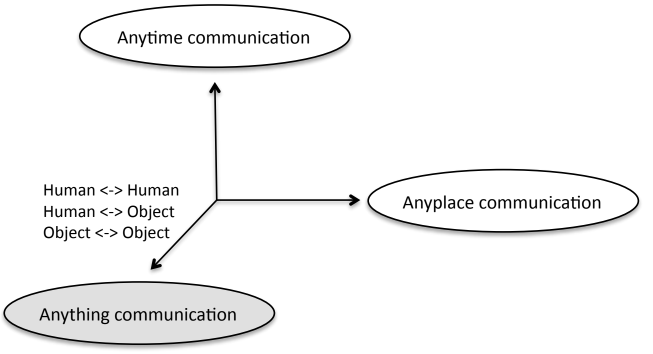

Figure 5.2: The three dimensions of IoT communication (adapted from [ITU, 2012a])

A WSN is a "*network of nodes that cooperatively sense and may control the environment, enabling interaction between persons or computers and the surrounding environment*" [IEC, 2014]. Finally, M2M describes communication between two or more entities that do not necessarily need any direct human intervention.

To integrate these various technologies, an 'all-IP' approach has long been proposed (see e.g. [Vasseur & Thubert, 2006]). To accommodate the typically resource-constrained IoT nodes (e.g. sensors, actuators) or CPSs, the Internet Engineering Task Force (IETF) developed a dedicated standard, 6LoWPAN (IPv6 over Low-power Wireless (Personal) Area Network) [IETF, 2007]. It is designed as an adaptation layer located between the data link and the network layer of a traditional communication stack [Rüth et al., 2017]. CPSs and the IoT link to, and may deploy, WSNs and M2M communication (see Figure 5.3).

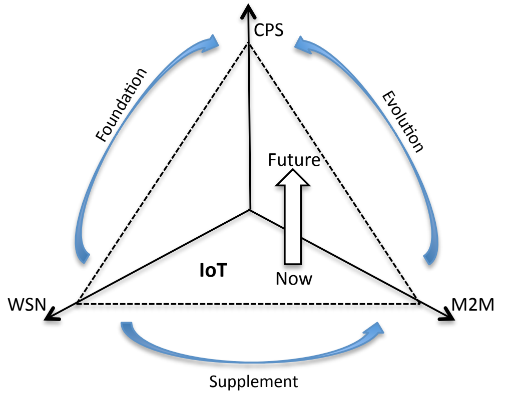

Figure 5.3: Constituents of a smart infrastructure (adapted from [Chen et al., 2012])

Frequently, applications will have hard requirements on the underlying communication system (think of e.g. autonomous driving). Notably, guaranteed levels of latency, resilience, reliability and predictability of the system will become more important than the 'traditional' metrics for (wireless) communication systems like bandwidth and throughput. According to Fettweis et al. [2014], end-to-end latencies of less than 1 ms will be required out of which only 200 μs will be available for the wireless link. This is about one order of magnitude faster than today's LTE[159] networks. Moreover, latency and resilience are diametrically coupled.

As a consequence, application design, communication technology, operating systems and control loops will need to be extremely closely coupled – loosely coupled systems will hardly, if ever be able to meet these requirements. To achieve this, close multi-disciplinary co-operation will be necessary from the outset. This co-operation will cover various sub-fields of Computer Science, Mechanical/Electrical/Telecommunications Engineering, possibly also Biology and other Natural Sciences plus the respective application area(s).

5.3.2 Application Areas

A number of application areas may be identified that are likely to stand to benefit from, or indeed require, the deployment of a smart communication infrastructure, comprising CPSs and/or the IoT. Table 5.1 summarised application areas identified in the literature for both the IoT and CPSs.

Table 5.1: Application areas of a smart communication infrastructure

[Gunes et al., 2014]	[NIST, 2015]	[NIST, 2016]	[AIOTI, 2015a]	[IoT-A, 2013]
Smart Manufacturing	Smart Manufacturing and Production	Manufacturing	Manufacturing/ Industry Automation	Productive Business Environment
Health Care and Medicine	Healthcare	Healthcare	Healthcare	Healthcare
Intelligent Transport Systems	Transportation and Mobility	Transportation	Vehicular/ Transportation	Smart Transport Logistics
Critical Infrastructure	Civil Infrastructure & Energy	Infrastructure (communications, power, water)	Energy	Smart Energy
Smart City		Cities	Cities	Smart Cities
	Buildings and Structures	Buildings	Home/Building	Smart Houses
Emergency Response	Emergency response	Emergency response		
			Living Environment	Ambient Assisted Living
		Environmental monitoring	Environment	
		Agriculture	Farming/ Agrifood	
		Supply chain/retail		Retail
	Defence	Defence		
			Wearables	

[159] Long Term Evolution.

Each of these application areas is inherently multi-disciplinary, as is research into them. Table 5.2 below shows some of the major disciplines involved in the five most frequently named areas.

Table 5.2: Disciplines involved in different application areas (no claim for completeness)

Healthcare	Smart Buildings	Smart Manufacturing and Production	Intelligent Transport Systems	Smart Grid	Smart Cities
Medicine Tele-communication Computer Science Mechanical Engineering …..	Architecture Civil Engineering Computer Science Tele-communication …..	Production Engineering Tele-communication Computer Science Robotics Control Engineering ….	Transport Telematics Traffic Engineering Power Engineering Automotive Computer Science, Tele-communication …..	Power Engineering Computer Science Tele-communication …..	The grand total of the others plus Urban planning Economics Environmental studies …..

5.4 The General Standardisation Environment

Both smart infrastructure and smart applications are wide fields for standards setting activities. The former almost exclusively falls into the ICT realm, whereas the latter represents a mixture of ICT and non-ICT efforts. The distinction between ICT and non-ICT is of a certain relevance since the ICT sector stands out with respect to the complexity of its standardisation environment.

Most industry sectors have a rather simple standardisation environment. A number of National Standards Organisations (NSOs) contribute to the work of ISO and IEC at the international level. An additional regional level in between has been established in Europe through the European Standards Organisations (ESOs). In the US, numerous national sector-specific SSOs exist. If accredited, they may contribute to the international standardisation work through the American National Standards Institute (ANSI), the US national representative to ISO and IEC. Similarly, the new Standardization Law of the People's Republic of China foresees sectoral standards. However, here as well international activities are channelled through the national institutions in charge (see [SESEC, 2017]).

The situation is different for ICT (specifically in telecommunications). This sector is characterised by a number of national/regional bodies and, particularly, by a huge number (more than 200) of private standards setting consortia[160]. The proliferation of these consortia began in the late 1980s and was primarily triggered by the fast-paced development of ICT technologies and a widely perceived slowness [Lehr, 1992] and non-responsiveness to users' needs on the side of the 'formal' Standards Development Organisations[161] (SDOs) [Cargill, 1995]. The number of consortia and the complex links that exist between them and the SDOs yield an almost impenetrable web of SSOs (see Figure 2.2). The links between them represent some level of formal of co-operation. Such co-operation may take the form of exchanging information about planned new work items, the joint development of common standards or anything in between. In the absence of a central co-ordinating entity, these links currently represent the most important (distributed) co-ordination mechanism in standards setting.

[160] Private SSOs such as the World Wide Web Consortium (W3C).

[161] E.g. ISO and ITU at the global level and e.g. the ESOs at the regional European level.

The links between private standards consortia are not normally particularly well developed, but some do exist. There are more links between consortia and formal SDOs; for instance, consortia may submit their specifications for an SDO for (international) standardisation ('responsive standardisation'; see below). The number of SSOs active in telecommunication standardisation is comparably limited, with relatively strong links between them. For instance, 3GPP[162] and oneM2M are joint initiatives by several regional SSOs. Specifically, oneM2M develops standards for Machine-to-Machine (M2M) communication and for the IoT. The Global Standards Collaboration (GSC) is a less formal form of co-operation between regional SSOs and the ITU. The IT standardisation landscape is the most densely populated and most complex part of the ICT standardisation environment. Here as well comparably strong links exist between individual players.

Co-ordination of the different standardisation activities remains an important issue. A lack of co-ordination, eventually resulting in the development of functionally equivalent (and thus competing) standards, will reduce market transparency, decrease interoperability and ease of use, fragment the market and increase transaction costs [Egyedi 2014]. Indeed, various co-ordination mechanisms have been developed over time, ranging from highly formalised high-level regulatory documents to very informal co-ordination through individuals who contribute to the work of multiple SSOs.

In the context of smart applications SSOs mostly develop what not just Sherif [2001] calls 'anticipatory standards'; they are typically specified at the introduction of a technology and are crucial for interoperable communication systems. Anticipatory standards are in contrast to 'participatory' and 'responsive' standards. The former proceed in parallel with implementations, thus enabling testing of the specifications prior to their adoption. In most cases, the latter rubberstamp existing successful specifications.

5.5 Standardisation of Selected Application Areas[163]

This section will look at the standardisation of a smart infrastructure and four sample application areas. They include Intelligent Transport Systems (ITS), Smart Manufacturing, the Smart Grid and Smart Cities. This selection was made for three reasons. For one, it would not realistically be feasible to cover all (potential) application areas. Secondly, these sectors are among those that attract the greatest attention in the research community. And finally, the selected areas represent one comparably mature field (ITS), two more recent developments including a trend in the private sector (smart manufacturing) and a typically private utility that is nonetheless a crucial part of the (regulated) public infrastructure (smart grid) as well as a rather more futuristic area (Smart Cities).

Smart applications receive information from and send instructions to the underlying infrastructure, the individual elements of which need to communicate with each other in order to meet the applications' requirements. Figure 5.4 shows the resulting framework that underlies this report.

[162] 3rd Generation Partnership Project.

[163] As of early 2017, when the report upon which this chapter is based was submitted.

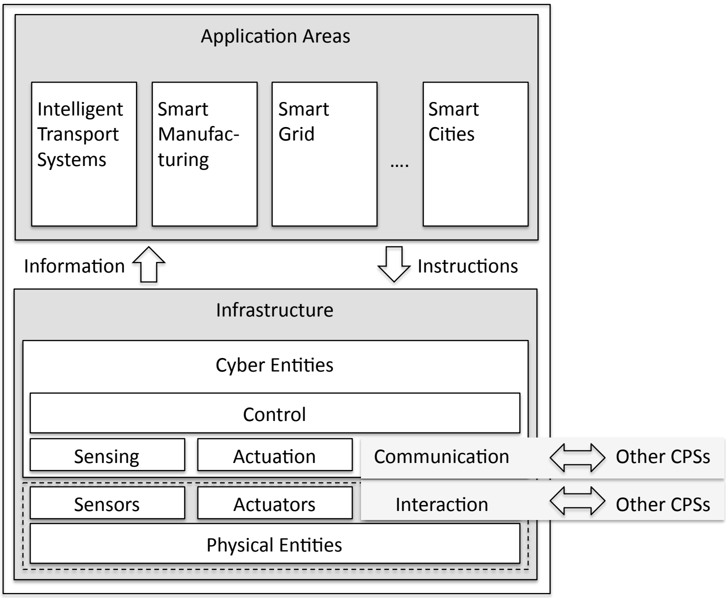

Figure 5.4: The study's framework (adapted from [NIST, 2016])

Each application area will pose problems that can only be solved through close co-operation of different disciplines. Future Intelligent Transport Systems, for example, will require specialists from ICT, transport telematics, traffic engineering, the automotive sector and power supply (plus possibly a few others) to co-operate. The design of smart buildings will bring together expertise from e.g. architects, electrical/control/telecommunication engineers and computer scientists.

5.5.1 Intelligent Transport Systems (Automotive)

According to the European Commission, Intelligent Transport Systems (ITS) result from "*the integration of information and communication technologies (ICT) with vehicles and transport infrastructure to improve economic performance, safety, mobility and environmental sustainability*"[164].

In ITS, inter-vehicle communication and road-to-vehicle communication play important roles in assisting safe (or even autonomous) driving. The quality of such may, therefore, be a matter of life or death. Accordingly, real-time and robust communication must be secured for ITS.

The ITS standardisation landscape is populated by three rather different types of entities. For one, there are those from the 'traditional' automotive sector. Their major common characteristic is their comparably old age (certainly by ICT standards). They may be further subdivided into specialised entities that deal exclusively with automotive/transport issues (like CLEPA and SAE; see Table 5.3) and into more general SSOs that have covered transport-related aspects for quite some time. Typically, they have added ITS related topics to their portfolio only more recently, either through dedicated groups or by expanding the coverage of existing groups (e.g. IEC and CENELEC). Private consortia that focus exclusively on ITS topics form the third group. Most members of this group were founded only in this millennium (e.g. CCC and OAA).

Another distinction refers to their actual standardisation activities. Some SSOs provide platforms for actual standards development (Type 1 in Table 5.4; e.g. AUTOSAR and CEN). Others develop

[164] http://ec.europa.eu/research/transport/multimodal/intelligent_transport_systems/index_en.htm.

technologies and contribute associated specifications to the standardisation process (Type 2; e.g. CAR2CAR). Members of the third category do not actually develop specifications or technology, but act at a rather more strategic level (e.g. ACEA). Still, they may well also co-operate with SSOs.

Relevant standardisation activities in Europe were triggered by the European Commission's Mandate M/453 [EC, 2009]. This requests the ESOs to "*Carry out an analysis of the required European standardisation activity based on the existing roadmaps of the standardisation process for Co-operative ITS services within the European Standardisation organisations*". This analysis should, inter alia, initially identify and develop "*the minimum set of European standards required in the field of Cooperative systems to ensure interoperability for vehicle to vehicle communications, for vehicle to infrastructure communications and for communications between infrastructure operators*". This Mandate relates only to road transport.

Table 5.3: Most relevant SSOs in the ITS (automotive) sector
1 = develops standards.; 2 = actively contributes to standards development; 3 = other

SSO Name	Brief Description	Type
ACEA (European Automobile Manufacturing Association)	Manufacturers consortium, no standards activities except recommendations. Founded 1991.	3
AUTOSAR	A worldwide development partnership comprising largely OEM manufacturers and Tier 1 automotive suppliers. It pursues the objective of creating and establishing an open and standardized software architecture for automotive electronic control units. Founded 2002.	1
AVNU Alliance	Standardisation and certification body in the field of low-latency communications. Founded 2009.	3
CAR2CAR	CAR 2 CAR focuses on wireless V2V communication applications and creates standards ensuring the interoperability of cooperative systems spanning all vehicles classes, across borders and brands. Founded in 2002.	2
CCC (CARCONNECTIVITY Consortium)	The CCC is a global collaboration to develop smartphone-based connected-car solutions. Founded 2011.	3
CEN (European Committee for Standardization)	CEN provides a platform for the development of European standards for all sectors excluding electro-technology and telecommunications. *TC 278 – Intelligent Transport Systems; est. 1992* *CEN/CENELEC Focus Group on European Electro-Mobility; est. 2010* *CEN/CENELEC eMobility Coordination Group (eM-CG); est. 2012*	1
CENELEC (European Committee for Electrotechnical Standardization)	In charge of standardisation in the electrotechnical engineering field in Europe. *TC 69X – Electrical systems for electric road vehicles, est. 1969, reactivated 2010* *BTTF 69-3 – Road traffic signal systems*	1
CIA (CAN in Automation)	Non-profit international users' and manufacturers' group. The aim is to provide an unbiased platform for future developments of the CAN protocol and to promote the image of CAN. Founded 1992.	1
CLEPA (Europ. Assoc. of Automotive Suppliers)	Represents suppliers for car parts, systems and modules. Promote standards, don't develop them. Founded 1952.	3

SSO Name	Brief Description	Type
EasyWay	Investment programme bringing together road operators and authorities from 23 European Member States. Established 2000.	3
ERTICO	A partnership of around 100 companies and institutions involved in the production of Intelligent Transport Systems (ITS). Founded 1991.	2
ETSI (European Telecommunications Standards Institute)	Produces globally-applicable standards for communication systems, including fixed, mobile, radio, converged, broadcast and Internet technologies. *Intelligent Transport Systems (ITS) (est. 2007)*	1
IEC (International Electrotechnical Commission)	Develops International Standards for electric and electronic products, systems and services. *TC 69 – Electric road vehicles and electric industrial trucks, est. 1969* *JWG 1 – Vehicle to Grid Communication Interface; Est. 2010* *SC 23H – Plugs, Socket-outlets and Couplers for industrial and similar applications, and for Electric Vehicles*	1
IEEE (Institute of Electrical and Electronics Engineers)	A professional association in the fields of electrical engineering and telecommunications. They also develop standards in these fields through their Standards Association, an ANSI-accredited SDO. *WG 1609 – Dedicated Short Range Communication Working Group (est. 2003)* *WG 1512 – Incident Management Working Group, established 1999.* *WG IEEE 802.11p (inactive)*	1
IIC (Industrial Internet Consortium)	An open membership, international not-for-profit consortium that is setting the architectural framework and direction for the Industrial Internet. Founded 2014.	2
ISO (International Organization for Standardization)	Independent, non-governmental organization, the world's largest developer of voluntary international standards. *TC 204 Intelligent transport systems (est. 1992)* *TC 22/ SC 31 – Road vehicles – Data communication (est. 2014)*	1
ITU (International Telecommunication Union)	The United Nations' specialised agency for information and communication technologies *ITU-T SG12 – Performance, QoS and QoE; Q4/12 – Hands-free communication and user interfaces in vehicles, (est. 2005).* *ITU-T SG16 – Multimedia; Q27/16 – Vehicle gateway platform for telecommunication/ITS services/applications (est. 2009).* *ITU-R SG5 – Terrestrial Services – Systems and networks for fixed, mobile, radiodetermination, amateur and amateur-satellite services.*	1
OAA (Open Automotive Alliance)	The OAA is a global alliance of technology and auto industry leaders committed to bringing the Android platform to cars. Founded 2014.	3
SAE (Society of Automotive	A non-profit organization dedicated to advancing mobility.	1

SSO Name	Brief Description	Type
Engineers International)	SAE members develop technical information on all forms of self-propelled vehicles. Founded 1905. *ANSI-accredited SDO.*	
United Nations Economic Commission for Europe (UNECE) Inland Transport Committee (ITC)	A United Nations regional commission. It promotes the harmonization and improvement of technical and operational regulations, standards and recommendations. Established 1947.	1, 2, 3

Figure 5.5 shows the very thinly populated standardisation environment in 1996, with hardly any links between the individual entities (links between WSC members and ESOs are depicted in Figure 2.3 and are not shown in the subsequent figures). This is not too surprising since the term ITS became popular only in the late 1980s – early 1990 (see also below).

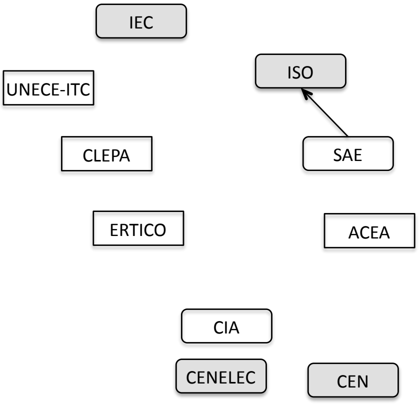

Figure 5.5: Entities and links between them in ITS (automotive) standardisation 20 years ago
(No links between SSOs could be identified for that time, except for the depicted one)
(Links between the ESOs and the WSC and between their individual members (in grey) are depicted in Figure 2.3)

In 2017, the environment had become much more complex, with a number of additional players forming a much more elaborate web with different types of links between them (see Figure 5.6). On the one hand, this is in line with the general trend in standards setting towards closer co-operation. On the other hand, the Figure also shows that links between private consortia are still very limited; for quite a few no links to other SSOs active in the same sector could be identified.

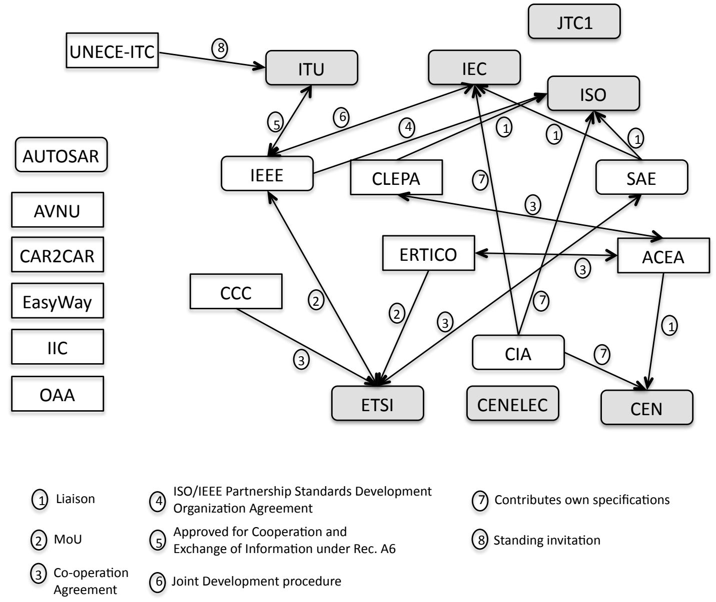

Figure 5.6: Entities and links between them in ITS (automotive) standardisation today
(Links between the ESOs and the WSC and between their individual members (in grey) are depicted in Figure 2.3)

The Figure also shows that only two entities from the Automotive sector (Ertico and CCC) have direct links to SSOs in the telecommunication sector.

In addition to the links depicted in Figure 5.6 above ITU-T runs the 'Collaboration on ITS Communication Standards'. This group comprises mostly SSOs from the telecommunication sector. It aims to identify communication requirements of ITS applications, harmonise and incorporate suitable ITS communication standards into ITU Recommendations, create a coherent package of security frameworks and standards for use within ITS communication and to investigate regulatory and legislative issues. Yet, this initiative focuses exclusively on the telecommunication part within ITS.

The timeline depicted in Figure 5.7 also offers some interesting insights. As noted above, the idea of ITS emerged in the late eighties. In the early nineties, the first standardisation-related entities that were founded (in 1991) were not SSOs, but lobbying[165] and rather more policy-related entities. The associated Technical Committees (TCs) of the major international and European SDOs were established one year later[166].

A second 'wave' of standardisation-related bodies started almost ten years later, again led by a non-SSO (EasyWay, a programme run by European road operators and authorities and the European Commission). Between 2002 and 2010 both major specialised consortia (Car2Car, Autosar) emerged, as well as Working Groups in the telecommunication sector focussing on communication support for ITS services and applications. This development was not least triggered by the diffusion and increasingly advanced functionalities offered by mobile communication systems.

[165] Using the term somewhat loosely in the case of ERTICO, whose mission is to "*Develop, promote and deploy intelligent transport systems and services which needs multi-stakeholder engagement*".

[166] CiA develops, standardises and markets 'Controller Area Networks', which may be deployed in a multitude of sectors, including ITS.

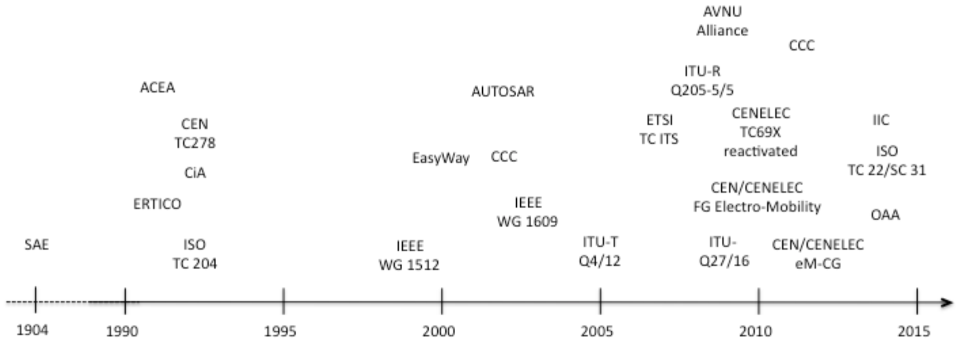

Figure 5.7: Timeline of the establishment of important standardisation entities in the ITS (automotive) sector

All in all, it seems safe to say that the ITS sector today is reasonably stable (in terms of organisations involved). While the co-ordination between SSOs could certainly be improved, reasonably well-established links and co-ordination mechanisms are in place. Nevertheless, ITS standardisation is still largely limited to comparably simple technologies and applications. Moreover, applications like electric vehicles and autonomous driving may change the current situation, e.g. through proprietary standards. Similarly, Chinese standardisation efforts in the filed of, for instance, electric vehicles may also eventually contribute to a once again more dynamic situation (see e.g. [SESEC, 2015]).

5.5.2 Smart Manufacturing

The idea of 'smart manufacturing' emerged in the late 1980, became more popular as a research topic in the late 1990s and got off the ground with the advent of the German 'Industrie 4.0' initiative in 2013.

Smart Manufacturing has been defined as "*the dramatically intensified application of 'manufacturing intelligence' throughout the manufacturing and supply chain enterprise*". It "*comprises the real-time understanding, reasoning, planning and management of all aspects of the enterprise manufacturing process and is facilitated by the pervasive use of advanced sensor-based data analytics, modelling, and simulation*" [Davis et al., 2012]. From a more practical perspective, Lu et al. [2015] state that smart manufacturing uses "*information and communication technologies … to 1) Optimize the use of labor, material, and energy to produce customized, high quality products for on-time delivery. 2) Quickly respond to changes in market demands and supply chains*". The European Commission views smart manufacturing as "*a novel architectures for factory automation based on CPS and IoT*"[167].

Figure 5.8 shows the four levels of the classical manufacturing pyramid, according to IEC 62264, with the associated levels and tasks.

[167] https://ec.europa.eu/digital-single-market/news/h2020-info-day-smart-cyber-physical-systems-digital-automation-smart-anything-everywhere-and.

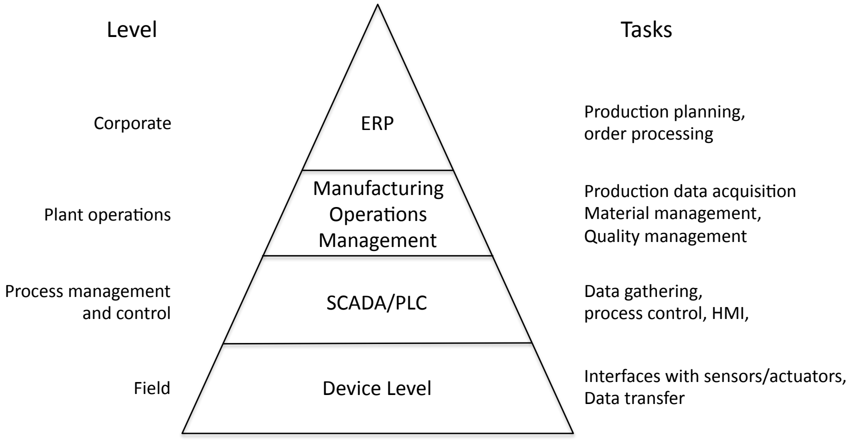

Figure 5.8: The manufacturing automation pyramid (based on IEC 62264)
SCADA = Supervisory Control And Data Acquisition, PLC = Product Life Cycle, HMI = Human-Machine Interface

[AIOTI, 2015c] argues that "*The intrinsic existence of smart interconnected devices defies the concept of rigid hierarchical levels*". They call for an updated version of this representation, which maintains the pyramid structure but takes into account that the smart objects at the bottom layer may be in contact with all upper layers. They call the resulting model the "*Industrial IoT automation pyramid that will be the basis for future Cyber-physical production systems (CPPS)*" (Figure 5.9).

The nature of the standards for each layer is independent of the underlying model. Moving top-down, standards become increasingly technical, from rather more high-level descriptions of processes, models, architectures and languages down to actual communication protocols [Lu et al., 2015]. This dichotomy 'process' – 'protocol' is also reflected in the nature of the SSOs that address them. Whereas 'formal' SDOs tend to be more active in the former field, private consortia and associations tend to focus on the more technical side, e.g. on communication systems (see also Table 5.4).

Table 5.4: Most relevant SSOs in the smart manufacturing sector
1 = develops standards.; 2 = actively contributes to standards development; 3 = other

SSO Name	Brief Description	Type
ASTM International	ASTM International develops technical standards for a wide range of materials, products, systems, and services. *Committee F42 on Additive Manufacturing Technologies (est. 2009).*	1
AVNU Alliance	Standardisation and certification body in the field of low-latency communications. Founded 2009.	3
CENELEC (European Committee for Electrotechnical Standardization)	Responsible for standardization in the electrotechnical engineering field. *TC 65X – Industrial-process measurement, control and automation (est. 1968).*	1
CIA (CAN in Automation)	Non-profit international users' and manufacturers' group. The aim was to provide an unbiased platform for future developments of the CAN protocol and to promote the image of CAN. Founded 1992.	1
CLPA	CLPA is the organisation of manufacturers of CC-Link compatible products and users of CC-Link technology. Founded 2000.	2

SSO Name	Brief Description	Type
eClass e.V.	eCl@ss e.V. is a registered society that specifies, maintains and diffuses the classification standard of the same name. Founded 2000.	2
ETSI (European Telecommunications Standards Institute)	Produces globally-applicable standards for communication systems, including fixed, mobile, radio, converged, broadcast and Internet technologies. *TC M2M (est. 2009); TC SmartM2M (est. 2012).*	1
IEC (International Electrotechnical Commission)	Develops International Standards for electric and electronic products, systems and services. *TC 65 – Industrial-process measurement, control and automation (est. 1968)* *WG 10 – Security for industrial process measurement and control – Network and system security* *WG 16 – Digital Factory* *SMB SG 8 – Industry 4.0 Smart Manufacturing (est. 2014)*	1
IIC (Industrial Internet Consortium)	An open membership, international not-for-profit consortium that is setting the architectural framework and direction for the Industrial Internet. Founded 2014.	2
IO-Link	The IO-Link community develops and markets IO-Link as a technology. The IO-Link Community works as a Committee C IO-Link (C) organized within the Profibus Nutzerorganisation e.V. (PNO). Founded 2006.	2
ISA (International Society of Automation)	A global, non-profit organisation with more than 40,000 members world wide developing standards in the field of industrial automation and related sectors. Founded 1945. *ISA-95 – Enterprise-Control System Integration (est. 1996).*	1
ISO (International Organization for Standardization)	The independent, non-governmental organisation is the world's largest developer of voluntary international standards. *TC 261 Additive manufacturing (est. 2011)* *TC 184 – Automation systems and integration (est. 1983)* *SC4/AG1 – Industrial data/Digital Manufacturing (est. 2015; since 2016 WG15))* *SC5 – Interoperability, integration, and architectures for enterprise systems and automation applications (est. 1970).* *TMBG/SAG/SMCC – ISO Smart Manufacturing Coordinating Committee (est. 2016)*	1
ODVA (Open DeviceNet Vendor Association)	ODVA is a trade and standards development organisation advancing open, interoperable information and communication technologies in industrial automation. It develops and maintains the Common Industrial Protocol (CIP) and the network adaptations of CIP. Founded 1995.	2
oneM2M	The goal of oneM2M is to develop technical specifications which address the need for a common M2M Service Layer that can be readily embedded within various hardware and software. Founded 2012.	1
OPC Foundation (Open Platform Communications)	OPC is an interoperability standard for the secure and reliable exchange of data in the industrial automation space and in other industries. The OPC Foundation is responsible for the development and maintenance of this	2

SSO Name	Brief Description	Type
	standard. Founded 1996.	
PI (Profibus and Profinet International)	PI is the largest automation community in the world and responsible for Profibus and Profinet, two important enabling technologies in automation today. Founded 1995.	2

The standards setting environment for smart manufacturing is not too dissimilar from the one in the ITS sector – a comparably small number of entities with very limited links between them (see Figure 5.9).

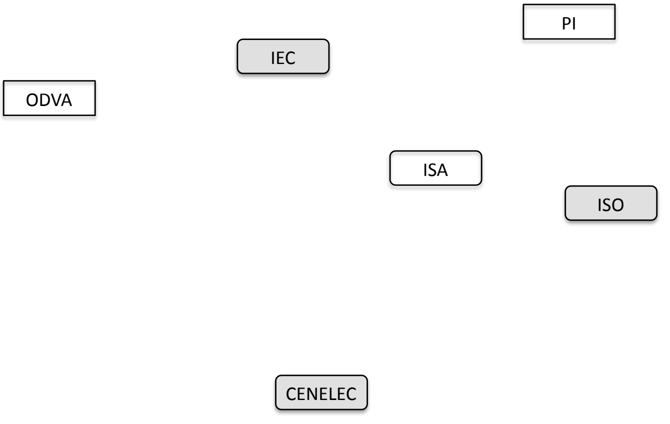

Figure 5.9: Links between SSOs in the Smart Manufacturing sector 20 years ago
(No links between SSOs could be identified for that time)
(Links between the ESOs and the WSC and between their individual members (in grey) are depicted in Figure 2.3)

Again similar to the development in the ITS sector, the situation today is very different from the one in 1996. The number of important players has almost tripled and a number of different types of links have been established (see Figure 5.10).

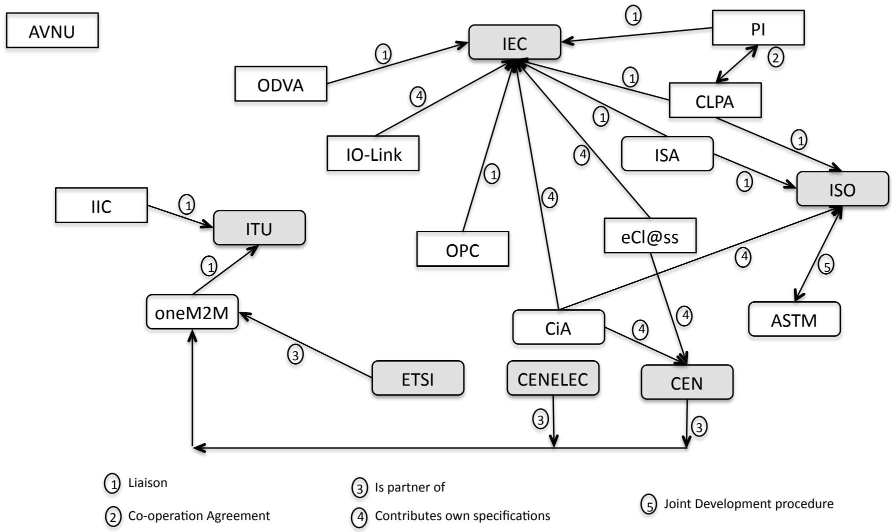

Figure 5.10: Links between SSOs in the Smart Manufacturing sector today
(Links between the ESOs and the WSC and between their individual members (in grey) are depicted in Figure 2.3)

Figure 5.10 allows two observations. For one, almost all private consortia and alliances (eCl@ass being the exception) focus on communication aspects and stay clear of the upper layers of the automation pyramid. The explanation might be that "*The role of ICT will be instrumental addressing the increased complexity that manufacturing industries will have to face at many levels; e.g. increased product customization, largely dynamic delivery requirements, agile and rich collaboration patterns and networks of different technical disciplines and organizations. These requirements coupled with the advent of innovative manufacturing technologies such as additive manufacturing or high precision zero-defect manufacturing call for robust interoperability solutions that integrate the factory with the environment*, …" [AIOTI 2015c].

The other observation is that the SSOs from the telecommunication sector appear to be isolated from the other entities, with ITU not even being active yet in this sector. This is a bit of a surprise since already today supply chains are becoming global and the same may be expected for future manufacturing [IEC, 2015]. Against this background the need for global communication services appears obvious. Likewise, frequency bands for wireless in-house communication under production conditions may also need to be discussed (within ITU-R).

The timeline (Figure 5.11) is also similar to the one of the ITS sector. Some older entities (ISO/TC 184 as well as IEC TC 65 and its European mirror entity, IEC TC65X) working on process automation pre-date all others by quite a while. In the mid-1990s a number of entities emerged most of which had specified and developed products for plant-floor communication. Many of their specifications found their way into the IEC process and were eventually standardised. In the nearer past, a number of SDOs established TCs or other groups that specifically focus on smart manufacturing. The agglomeration of newly founded entities in 2014/15 is quite remarkable and suggests an increasing importance recently assigned to smart manufacturing.

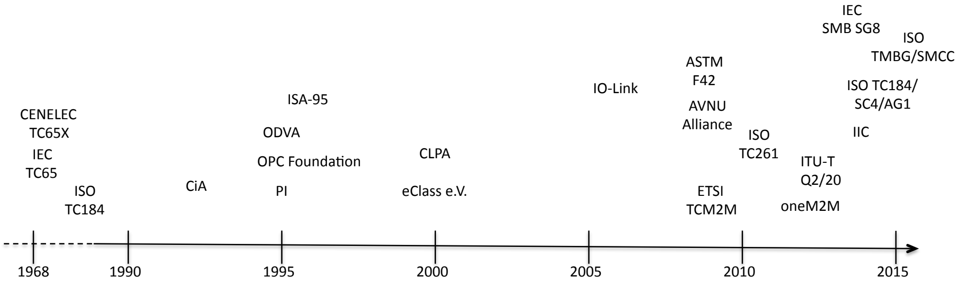

Figure 5.11: Timeline of the establishment of important standardisation entities in the Smart Manufacturing sector

5.5.3 Smart Grid

According to [Gungor et al., 2010], "*The smart grid is a modern electric power-grid infrastructure for improved efficiency, reliability, and safety, with smooth integration of renewable and alternative energy sources, through automated control and modern communication technologies*".

More specifically, Farhangi [2010] observed "*The existing electricity grid is unidirectional in nature. It converts only one-third of fuel energy into electricity, without recovering the waste heat. Almost 8% of its output is lost along its transmission lines, while 20% of its generation capacity exists to meet peak demand only (i.e., it is in use only 5% of the time). In addition to that, due to the hierarchical topology of its assets, the existing electricity grid suffers from domino-effect failures*". The 'smart grid' is supposed to address these shortcomings. "*In essence, the smart grid needs to provide the utility companies with full visibility and pervasive control over their assets and services. The smart grid is required to be self-healing and resilient to system anomalies. And last but not least, the smart grid needs to empower its stakeholders to define and realize new ways of engaging with each other and performing energy transactions across the system*" [Farhangi, 2010]. Notably, the latter refers to the fact that the distinction between energy producer and energy consumer will become blurred. In this context, the EC [2006a] envisions that "… *local generation enables each user node in the future network to behave as both sink and source*".

First initiatives towards a more intelligent power supply system started in the late 1980s (see e.g. [Werbos, 2011]). In 2005, the European Technology Platform 'SmartGrids' was established. It represents a first step towards the implementation of the vision of 'A European Strategy for Sustainable, Competitive and Secure Energy' [EC, 2006b], published by the European Commission as a Green Paper. Table 5.5 shows the most important SSOS that are active in the field.

Table 5.5: Most relevant SSOs in the smart grid sector[168]
1 = develops standards.; 2 = actively contributes to standards development; 3 = other

SSO Name	Brief Description	Type
CENELEC (European Committee for Electrotechnical Standardization)	In charge of standardisation in the electrotechnical engineering field. *CEN-CENELEC-ETSI Smart Grid Coordination Group (SG-CG) (est. 2011).* *TC 8X – System aspects of electrical energy supply (est. 2003).*	1

[168] Smart Metering has been excluded as it is considered a different, albeit closely related area. This view is apparently shared by the EC who issued different mandates on Smart Meters (M/441) and Smart Grid (M/490) to the ESOs. In response, the ESOs set up two distinct Coordination Groups: on Smart Meters (SM-CG) and on the Smart Group (SG-CG).

SSO Name	Brief Description	Type
	TC 205 – Home and Building Electronic Systems (HBES; est. 1996)	
ETSI (European Telecommunications Standards Institute)	Produces globally-applicable standards for communication systems, including fixed, mobile, radio, converged, broadcast and Internet technologies. *TC M2M (est. 2009); TC SmartM2M (est. 2012).* *CEN-CENELEC-ETSI Smart Grid Coordination Group (SG-CG) (est. 2011).*	1
IEC (International Electrotechnical Commission)	Develops International Standards for electric and electronic products, systems and services. *TC 8 – Systems aspects for electrical energy supply (est. 2003).* *SC 8A – Grid Integration of Renewable Energy Generation (est. 2013).* *TC 23 – Electrical accessories (est. 1933).* *WG 12 – Electrical accessories / Home and Building Electronic Systems (HBES; est. 2015).* *TC 57 – Power systems management and associated information exchange (est. 1964).* *PC 118 – Smart grid user interface (est. 2011)* *Systems Committee (SyC) Smart Energy (est. 2014).* *SG 3 – Strategic Group on Smart Grid (est. 2008);* *=> since 2013: SEG 2 – Systems Evaluation Group – Smart Grid*	1
IEEE (Institute of Electrical and Electronics Engineers)	A professional association in the fields of electrical engineering and telecommunications. They also develop standards in these fields through their Standards Association, an ANSI-accredited SDO. *802 LAN/MAN Standards Committee (est. 1980)* *Transmission and Distribution Committee (est. 1997).* *Power System Relaying Committee (est. 1947).* *IEEE SCC21 Standards Coordinating Committee on Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage – P2030 Smart Grid Interoperability (est. 2009).*	1
IIC (Industrial Internet Consortium)	An open membership, international not-for-profit consortium that is setting the architectural framework and direction for the Industrial Internet. Founded 2014.	2
ISO (International Organization for Standardization)	The independent, non-governmental organization is the world's largest developer of voluntary international standards. *TC 242 Energy Management (est. 2008; became ISO/TC 301 Energy management and energy savings in 2016).*	1
ITU (International Telecommunication Union)	The United Nations' specialised agency for information and communication technologies *SG13 – Future networks (& cloud); Q.11/13 Evolution of user-centric networking, services, and interworking with networks of the future including Software-Defined Networking (est. 2013).* *Liaison OASIS* *SG15 – Transport, Access and Home; Q.15/15 Communications for Smart Grid (est. 2013).* *Liaison IEEE 802, SGIP*	1

SSO Name	Brief Description	Type
JTC1 (ISO/IEC Joint Technical Committee 1)	JTC1 is the joint ISO/IEC entity for the development of global ICT standards for business and consumer applications. *SC 25 Interconnection of information technology equipment (est. 1990).*	1
OASIS (Organization for the Advancement of Structured Information Standards)	OASIS is a non-profit consortium that drives the development, convergence and adoption of open standards for the global information society. *Energy Interoperation TC (est. 2009). Formal liaison IEC.* *Energy Market Information Exchange (eMIX; est. 2010).*	1
oneM2M	oneM2M develops technical specifications for a common M2M Service Layer to connect devices in the field of M2M applications. Founded 2012.	1
SGIP (Smart Grid Interoperability Panel)	SGIP is a consortium that securely accelerates and advances Grid modernisation through interoperability. Founded 2009.	2
ZigBee Alliance	The ZigBee Alliance is an open, non-profit association driving the development of global wireless ZigBee standards to enable smart objects to work together. Established 2002.	1

At least in Europe, power supply is subject to (national) regulation. In addition, the European Commission's 2030 policy framework [EC, 2014] aims to "… *drive progress towards a low-carbon economy which ensures competitive and affordable energy for all consumers, creates new opportunities for growth and jobs and provides greater security of energy supplies and reduced import dependence for the Union as a whole*". As a result, the electricity system will become more complex to plan, control and balance. More flexibility will be needed to ensure that the system will be able to cope with the new challenges. National regulations will need to be adapted accordingly (see also e.g. [ESGTF, 2015]).

In 1996, the standardisation arena relating to the Smart Grid was even thinner populated than in the two cases above (see Figure 5.12). It is little wonder that mostly those SSOs active in the field of electrical engineering were around back then, working primarily in the field of power distribution. JTC1/SC25, the one exception, is active in the rather generic field of the interconnection of IT equipment. Links between these SSOs were non-existing (except for those between IEC – JTC1 and IEC – CENELEC).

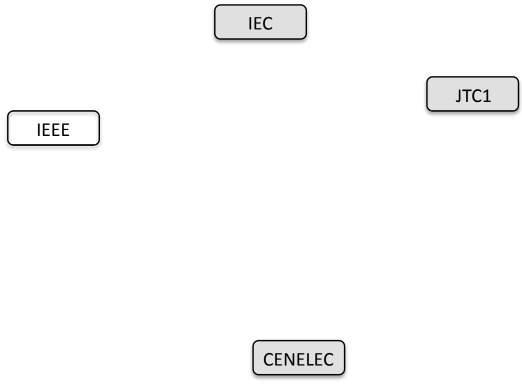

Figure 5.12: Links between SSOs in the Smart Grid sector 1996
(No links between SSOs could be identified for that time)
(Links between the ESOs and the WSC and between their individual members (in grey) are depicted in Figure 2.3)

Again similar to the development in the other two sectors discussed above, the web of SSOs working on Smart Grids has become much more complex today, involving many more players with a much more elaborate network of co-operations between them (see Figure 5.13). Today, the global co-ordination on Smart Grid is done by IEC's Strategic Group 3 (SG3) [ITU, 2015].

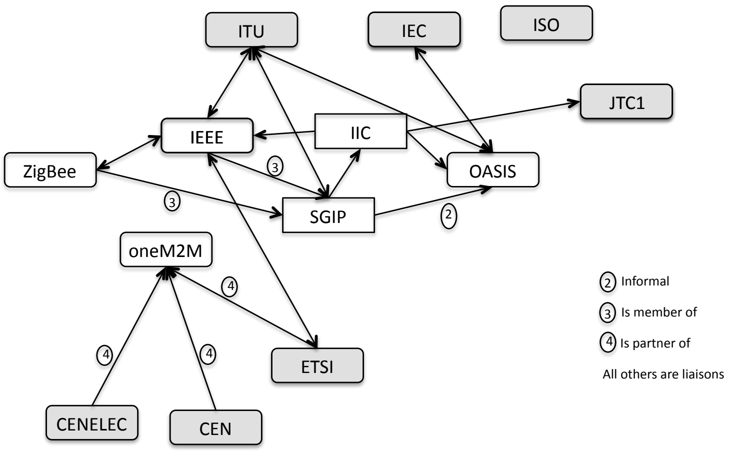

Figure 5.13: Links between SSOs in the Smart Grid sector today
(Links between the ESOs and the WSC and between their individual members (in grey) are depicted in Figure 2.3)

Compared to the other two sectors the number of private consortia contributing to Smart Grid standardisation is rather limited (to four), three of which also work on grid-specific aspects, not just on communication problems (as in smart manufacturing). Smart Grid standards setting is mostly done by the SDOs (led by IEC), which have been active in the 'traditional' fields of e.g. energy supply, electrical accessories, power systems management or communication systems for decades (see also Figure 5.14 below).

The lack of private standardisation entities may be explained by the fact that typically the energy sector is highly regulated. In Europe, consortium standards have not normally been recognised by the regulators. A similar situation may be observed, for example, in the medical sector. (see e.g. [Denjoy, 2013]). In such sectors, consortia's influence may only occur through SDOs with which they co-operate. This holds despite the fact that recent European regulation stipulates greater openness towards private ICT standards consortia [EU, 2012].

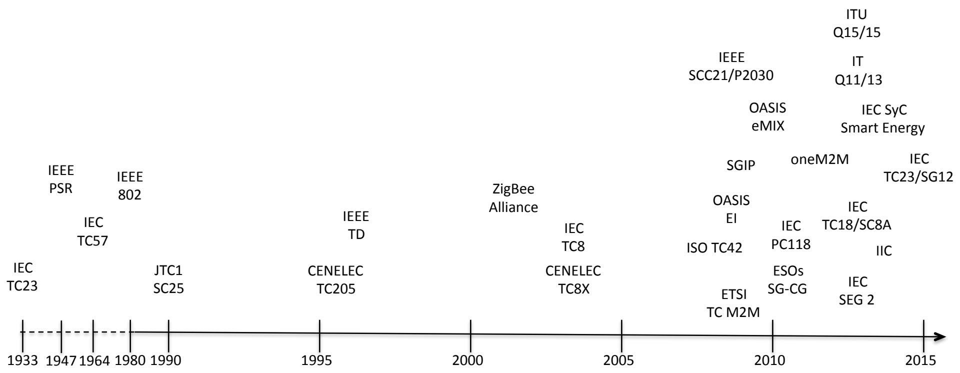

Figure 5.14: Timeline of the establishment of important standardisation entities for the Smart Grid

The timeline of the creation of entities working on standards for the Smart Grid further resembles the development that could be observed for smart manufacturing (Figure 5.11), where a certain mushrooming of entities may be observed for the past seven or so years. For the Smart Grid, this effect is much more pronounced. Here, we see the formation of numerous ‘specialised’ entities starting in 2008. Prior to that point, only more ‘generic’ aspects were covered (power supply, communication). In contrast to ITS and smart manufacturing, which have been around in more primitive forms for decades, the Smart Grid may be considered as a truly novel application area, certainly in terms of associated standardisation.

5.5.4 Smart Cities

‘Smart Cities’ is arguably the broadest application area. A smart city will, among others, comprise smart buildings, utilize the smart grid, provide smart transport facilities and e-health services and also incorporate smart production sites. It will, therefore, be a particularly complex construct. Nevertheless, a survey by TU Vienna identifies 90 smart cities with 300,000 – 1,000,000 inhabitants and 77 with 100,000 – 300,000 inhabitants[169]. According to Navigant [2011], however, there are many pilot projects and small-scale developments but no examples yet of a smart city on a large scale that implement the model depicted in Figure 5.15 (which is quite similar to the model used by TU Vienna). Truly smart cities are still closer to Science Fiction than to real life.

[169] http://www.smart-cities.eu/.

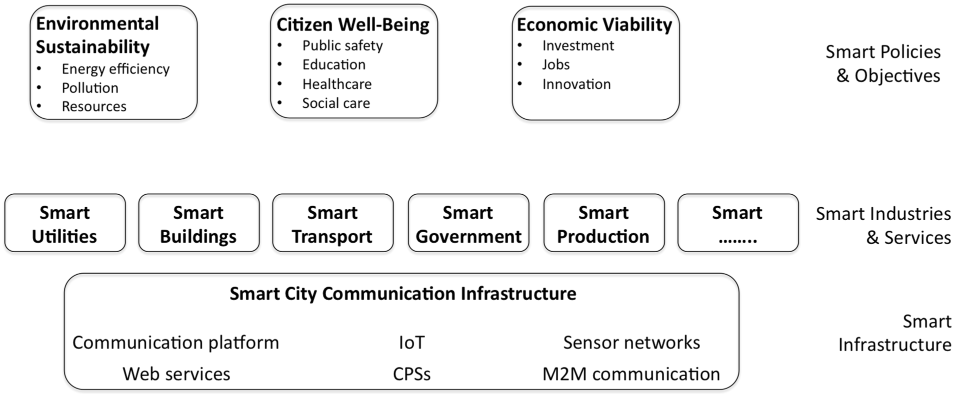

Figure 5.15: Smart City model (according to and adapted from [Navigant, 2011])

As can be seen, (virtually) all other applications contribute to the objectives of Smart Cities. In a way, a Smart City represents a superset of smart applications. In addition, standards for 'smart policies and objectives' provide guidance to city leadership for the development of an overall smart city strategy, the identification of priorities, the development of a practical implementation roadmap and for an effective approach to monitoring and evaluating progress [BSI, 2015].

Table 5.6: Most relevant SSOs for Smart Cities
1 = develops standards.; 2 = actively contributes to standards development; 3 = other

SSO Name	Brief Description	Type
CEN (European Committee for Standardization)	CEN provides a platform for the development of European Standards for all sectors excluding electro-technology and telecommunications. *CEN-CENELEC-ETSI Coordination Group on Smart and Sustainable cities and communities (est. 2012).*	1
CENELEC (European Committee for Electrotechnical Standardization)	Responsible for standardization in the electrotechnical engineering field. *CEN-CENELEC-ETSI Coordination Group on Smart and Sustainable cities and communities (est. 2012).*	1
ETSI (European Telecommunications Standards Institute)	Produces globally-applicable standards for communication systems, including fixed, mobile, radio, converged, broadcast and Internet technologies. *TC M2M (est. 2009); TC SmartM2M (est. 2012).* *CEN-CENELEC-ETSI Coordination Group on Smart and Sustainable cities and communities (est. 2012).*	1
IEC (International Electrotechnical Commission)	Develops International Standards for electric and electronic products, systems and services. *SEG 1 – Systems Evaluation Group – Smart Cities (est. 2013).* *SyC Smart Cities – Electrotechnical aspects of Smart Cities (est. 2016).*	1
IEEE (Institute of Electrical and Electronics Engineers)	A professional association in the fields of electrical engineering and telecommunications. They also develop standards in these fields through their Standards Association, an ANSI-accredited SDO. *Smart Cities Initiative (est. 2014).*	1

SSO Name	Brief Description	Type
ISO (International Organization for Standardization)	The independent, non-governmental organization is the world's largest developer of voluntary international standards. *ISO/TC 268 'Sustainable cities and communities' (est. 2012).* *ISO/TMB/SAG (Strategic Advisory Group) Smart Cities (2014 – 2016).*	1
ITU (International Telecommunication Union)	The United Nations' specialised agency for information and communication technologies. *Joint Coordination Activity on Internet of Things and Smart Cities and Communities (JCA-IoT and SC&C) (2011 – 2015).* *Focus Group on Smart Sustainable Cities (FG SSC) (2013 – 2015)* *SG 20 – Internet of Things (IoT) and its applications including smart cities and communities (SC&C) (est. 2015)*	1
JTC1 (ISO/IEC Joint Technical Committee 1 on Information technology)	The joint 'IT arm' of ISO and IEC. *WG 11 'Smart cities' (est. 2016)* *SC 41 Internet of Things and related technologies (to be established 2017)*	1
World Smart City Forum	Community of professionals exploring the most important factors that hinder the broad roll out of Smart Cities today. Led by IEC in partnership with ISO and ITU. Founded 2016.	3

Figure 5.16 shows the late 2016 status of SSO entities whose activities specifically focus at Smart Cities (again, those which develop more generic technologies or services that may also be deployed in a smart city context are not included) and the links that exist between them.

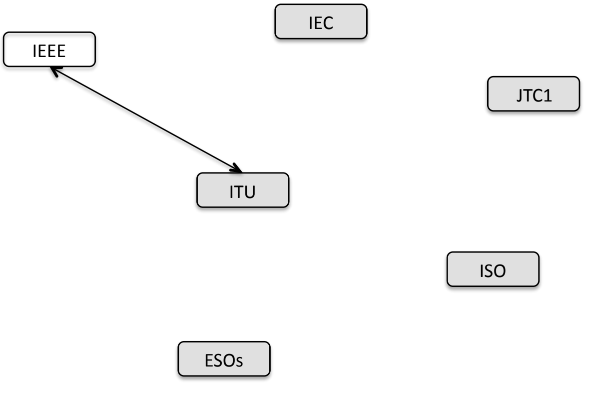

Figure 5.16: Entities and links between them in 'Smart City' standardisation today
(Links between the ESOs and the WSC and between their individual members (in grey) are depicted in Figure 2.3)

So far, the ITU has assumed a leading role in Smart City standardisation (not unlike IEC has done for the Smart Grid). Figure 5.16 also suggests that 'Smart Cities' is a fairly new topic for standardisation (it resembles the situation in the other fields twenty years ago). Only a very limited number of players are active in this field and the links between them are neither particularly close nor numerous. Moreover, only a minority of entities within the individual SSOs focus on actual technical standardisation work. Most are charged with high-level tasks like requirements identification as well as survey, road mapping and/or co-ordination activities (which only refer to internal co-ordination within one SSO). In conjunction with the fairly young age of the activities, this explains the limited links between the entities.

Figure 5.16 also shows the complete absence of private standards consortia. This may be explained by the fact that smart city standardisation focuses rather more on the strategic level (i.e. the top level in Figure 5.15), as opposed to the technical one. It seems fair to assume that little money is to be made form such activities, so consortia would stay clear off them.

As can be seen from the timeline depicted in Figure 5.17 below, 'Smart Cities' is indeed a very new field[170]. The first entity, ITU-T's Joint Coordination Activity on Internet of Things and Smart Cities and Communities (JCA-IoT and SC&C; now disbanded), was established only 2011.

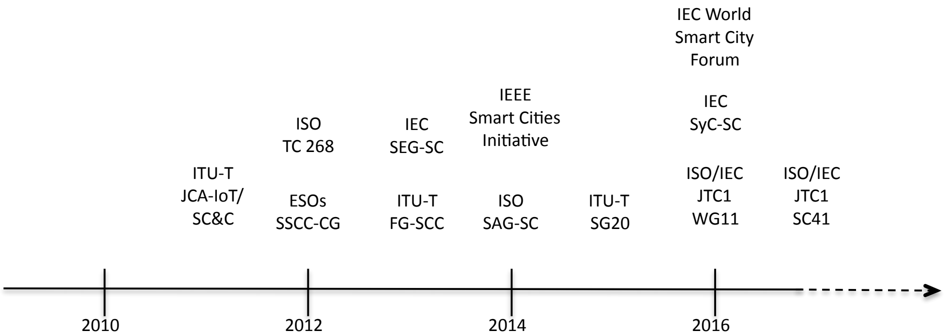

Figure 5.17: Timeline of the establishment of important standardisation entities for Smart Cities

The situation is similar to the one observed for smart manufacturing and the smart grid in that here as well we see a wave of newly founded standardisation entities over the past five years (note the different scale of the x-axis). Yet, a major difference to the other sectors is that smart cities do not have any immediate predecessor technologies – all related standardisation activities started from scratch in the 2010s[171].

5.6 Infrastructure Standardisation

This section compares the above developments with those in the underlying communication infrastructure. The focus will be on mobile/wireless communication and the IoT.

5.6.1 Mobile/Wireless Communication

Wireless communication is not exactly a new invention – the first wireless telephone conversation took place in 1880 [Hecht, 1985]. The world's first commercial mobile telephone service was launched in St. Louis in 1946 and the first cellular system, the Nordic Mobile Telephone 450, was introduced in 1981 [King & West, 2002]. Yet, mobile communication really got off the ground only after the release of the first GSM specification (1990); with the first commercial GSM system being launched in 1991. The first specification of a wireless LAN (WLAN), IEEE 802.11, was published in 1997.

[170] Please note the scale of the x-axis, which is much larger than in the previous timelines.

[171] Except for those that relate to the underlying communication infrastructure, which are not specific to smart cities.

Table 5.7: Major SSOs developing standards for wireless/mobile communication
1 = develops standards.; 2 = actively contributes to standards development; 3 = other

SSO Name	Brief Description	Type
3GPP	The project develops complete system specifications cellular telecommunications network technologies. Established 1998.	1
3GPP2	The project covers high speed, broadband and Internet Protocol (IP)-based mobile systems. Established 1998.	1
Bluetooth SIG	A large global community of companies that aims to harmonise, through technical standards, the communication between connected devices. Founded 1998	1
CCIR (Comité Consultatif International pour la Radio)	The predecessor of ITU-R. Like ITU-R, they dealt with technical and operating questions related to radio communications and issued associated recommendations. Established 1927.	1
CEPT (European Conference of Postal and Telecommunications Administrations)	A coordinating body for European state telecommunications and postal organisations, inter alia harmonising telecommunication and radio spectrum regulation. Established 1959.	1/3
EIA (Electronic Industries Alliance)	A standards and trade organisation that developed standards interoperability standards. Founded in 1924, they ceased operations in 2011. TIA is a successor.	1
ETSI (European Telecommunications Standards Institute)	Produces globally-applicable standards for communication systems, including fixed, mobile, radio, converged, broadcast and Internet technologies. *TC BRAN (est. 1997).* *TC M2M (est. 2009); TC SmartM2M (est. 2012).*	1
GSM (Global System for Mobile Communications (originally: Groupe Spécial Mobile)	A committee with CEPT, charged with the development of a European standard for digital cellular voice telecommunications. Transferred to ETSI in 1989. Established 1982.	1
IEEE (Institute of Electrical and Electronics Engineers)	A professional association in the fields of electrical engineering and telecommunications. They also develop standards in these fields through their Standards Association, an ANSI-accredited SDO. *802 LAN/MAN Standards Committee (est. 1980)* *IEEE 802.11 – Wireless Local Area Networks (est. 1990)* *IEEE 802.16 – Broadband Wireless Access (est. 1999)* *IEEE 802.22 – Wireless Regional Area Networks (est. 2004)*	1
IrDA ()	An industry-driven interest group that develops specifications for wireless infrared communications over the 'last one meter', mainly for portable devices. Established 1993.	1
ITU (International Telecommunication Union)	The United Nations' specialised agency for information and communication technologies	1
NFC Forum (Near Field Communication)	The NFC Forum develops standards that aim to ensure interoperability for safe contactless transactions, access of digital content and between connect electronic devices	1

SSO Name	Brief Description	Type
	(founded 2004).	
NGMN Alliance (Next Generation Mobile Networks)	A mobile telecommunications association that aims to develop a common view of future wireless networks. They support SDOs by providing a coherent view of what mobile operators require (founded 2006).	2
oneM2M	oneM2M develops technical specifications for a common M2M Service Layer to connect devices in the field of M2M applications. Founded 2012.	1
TIA (Telecommunications Industry Association)	An ANSI-accredited trade association for the global ICT industry. Founded 1988.	1
WiFi Alliance	A non-profit international association that certifies interoperability of WLAN products based on the IEEE 802.11 standards. Founded 1999.	3
ZigBee Alliance	The ZigBee Alliance is an open, non-profit association driving the development of global wireless ZigBee standards to enable smart objects to work together. Established 2002.	1

As could also be observed for the Smart Grid and Smart Manufacturing, the establishment of the first telecommunication SDOs dates back decades (even centuries). Yet, the timeline that may be observed for the establishment of relevant standardisation entities in the field of mobile/wireless communication over the past 30+ years resembles the ITS case. That is, we see a more evenly distributed development over time, with slightly less pronounced peaks than in the cases of the smart grid and smart manufacturing (Figure 5.18).

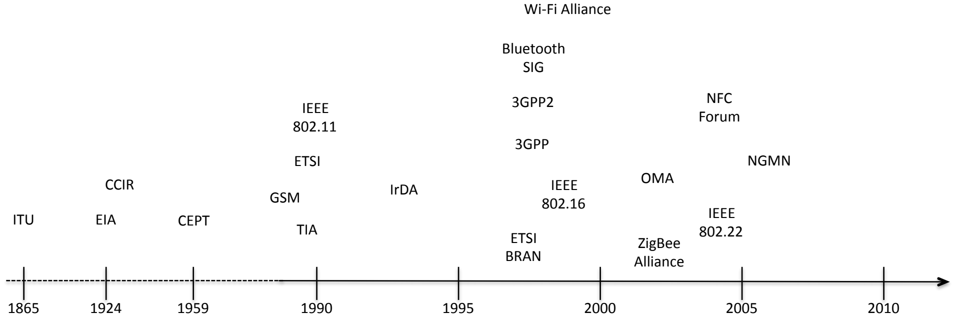

Figure 5.18: Timeline of the establishment of important standardisation entities for mobile/wireless communication

The largest wave of SSO foundations occurred in the mid/late-nineties, when several major entities were formed. It pre-dates predated those in SM and SG by more than ten years. This is not such a big surprise since smart applications depend on an established ICT infrastructure. Today, all three application areas discussed require a wireless communication infrastructure as it offers much greater flexibility than a wired one [De Pellegrini et al., 2006], [AIOTI, 2015b]; of course, the Internet still represents the communication backbone. Nevertheless, at least initially standardisation in at least one smart application area, ITS, could apparently proceed without underlying standard-based wireless communication protocols and services. The begin of standardisation activities for wireless communication preceded that for ITS by only a few years.

5.6.2 The IoT and CPSs

Smart infrastructure standardisation almost exclusively focuses on the IoT. In late 2016 only a small subgroup of ISO/IEC JTC1/WG10 'Internet of Things' actually targeted CPS standardisation[172]. The most prolific standards-related work on CPS has been done by the US National Institute of Standards and Technology (NIST; [NIST, 2016]).

Most standardisation activities in relation to the IoT link to wireless communication systems and resource-constrained devices. Relevant activities in this field are ongoing in e.g. oneM2M, where standards for a common M2M Service Layer are being developed. Within ETSI, the 'Smart M2M Communications' committee works on the interface between the service layer and the application layer. Other ETSI TCs as well as IEEE, ITU and numerous other SSOs work on wireless medical devices and wireless industrial applications. Within the IETF, several WGs focus on constrained devices. Cyber-security and privacy are other important fields of standards setting in which a vast array of SSOs are active (including e.g. ITU-T, ISO, IEC, CEN, ETSI, W3C, OASIS and the IETF).

Several SSOs have become active in IoT standardisation and have already developed a considerable number of standards. According to ISO, there are currently (late 2016) over 900 IoT-related standards. Of those, around 140 come from the Institute of Electrical and Electronics Engineers (IEEE), 200 from the International Telecommunication Union (ITU) and 300 from the joint committee for ICT standardisation of the ISO and the International Electrotechnical Committee (IEC; ISO/IEC JTC1) [ISO, 2016b].

The ITU has identified a 'List of Internet of things (IoT) relevant organizations and forums'[173]. Updating and adapting this list to include only organisations and entities that develop native IoT standards (as opposed to those that develop more generic standards that may also be deployed by the IoT) yields the list of SSOs shown in Table 5.8; without any claim for completeness.

Table 5.8: Major SSOs developing dedicated IoT-specific standards
1 = develops standards.; 2 = actively contributes to standards development; 3 = other

SSO Name	Brief Description	Type
CEN (European Committee for Standardization)	CEN provides a platform for the development of European Standards for all sectors excluding electro-technology and telecommunications. *TC 225/WG 6 – Internet of Things Identification, Data Capture and Edge Technologies (est. 2016).*	1
ETSI (European Telecommunications Standards Institute)	Produces globally-applicable standards for communication systems, including fixed, mobile, radio, converged, broadcast and Internet technologies. *TC M2M (est. 2009); TC SmartM2M (est. 2012).*	1
IEEE (Institute of Electrical and Electronics Engineers)	A professional association in the fields of electrical engineering and telecommunications. They also develop standards in these fields through their Standards Association, an ANSI-accredited SDO. *P2413 – Standard for an Architectural Framework for the Internet of Things (est. 2014).* *P1451 – Smart Transducer Interface Standards (est. 1994).*	1
IETF (Internet Engineering	The IETF is the Internet's standardisation body. It	1

[172] The Convenor is Chinese; out of the eight experts that attended the two meetings so far seven were from Asia and one from Germany.

[173] http://www.itu.int/en/ITU-T/jca/iot/Pages/sdo.aspx.

SSO Name	Brief Description	Type
Task Force)	comprises a number of Working Groups (WGs). A WG covers a comparably narrow aspect and is dissolved once it has achieved its goal. *6LoWPAN – IPv6 over Low power WPAN (2005 – 2014)* *6Lo – IPv6 over Networks of Resource-constrained Nodes (est. 2013)* *CoRE – Constrained RESTful Environments (est. 2010).* *ACE – Authentication and Authorization for Constrained Environments (est. 2014).* *DICE – DTLS In Constrained Environments (2013 – 2016).*	
IIC (Industrial Internet Consortium)	An open membership, international not-for-profit consortium that is setting the architectural framework and direction for the Industrial Internet. Founded 2014. *'Architecture' Task Group (est. 2014).*	2
ISO/IEC JTC1 (Joint Technical Committee 1)	JTC1 is the joint ISO/IEC entity for the development of global ICT standards for business and consumer applications. *WG 7 – Sensor Networks (est. 2009).* *WG 10 – Internet of Things (est. 2015).* *SC 41 – Internet of Things and related technologies (to be established).*	1
ITU (International Telecommunication Union)	The United Nations' specialised agency for information and communication technologies *SG 11 – Protocols and test specifications* *Question 12/11 – Internet of things test specifications (est. 2013).* *Question 7/11 – Signalling and control requirements and protocols for network attachment supporting multi-screen service, future networks, and M2M (est. 2013).* *Question 3/11 – Signalling requirements and protocol for emergency telecommunications (est. 2013).* *SG 13 – Future networks (& cloud) (est. 2013).* *SG 16 – Multimedia* *Question 27/16 – Vehicle gateway platform for telecommunication/ITS services/applications (est. 2009).* *SG 20 – IoT and its applications including smart cities and communities (est. 2015).* *Internet of Things Global Standards Initiative (IoT-GSI; est. 2011; completed).* *Joint Coordination Activity on Internet of Things and Smart Cities & Communities (JJCA-IoT and SC&C; est. 2011).*	1
OGC (Open Geospatial Consortium)	Through its Domain Working Groups, the OGC develops interfaces that enable real time integration of heterogeneous sensors into the IoT information infrastructure. *Sensor Web Enablement DWG (est. 2002).*	1
OIC/OCF (Open Connectivity	The OCF creates specifications and sponsors an open source project to enable the IoT's billions of connected	2

SSO Name	Brief Description	Type
Foundation)	devices to seamlessly communicate with one another (est. 2014).	
oneM2M[174]	oneM2M develops technical specifications for a common M2M Service Layer to connect devices in the field of M2M applications. Founded 2012.	1
W3C (The World Wide Web Consortium)	W3C develops most of the standards related to the WWW. Its WoT interest group is a fairly new player. Ultimately, it aims to bridge incompatible IoT platforms through the Web. *Web of Things Interest Group (est. 2015).*	1

CPSs and the IoT are still fairly new subjects for standardisation. The first entity to work in a closely related field (WSNs) only emerged in the mid-1990s, to be followed by a second SSO a couple of years later (thus no Figure depicting the web of IoT-related SSOs in 1996). Against this background, the level of interconnectivity between the individual SSOs is remarkably high.

'True' IoT standardisation really got off the ground only after 2010, when especially (though not exclusively) the ITU became active in the field through a number of WGs. This is also reflected in Figure 5.19; where the ITU may be found pretty much in the centre of the web of SSOs.

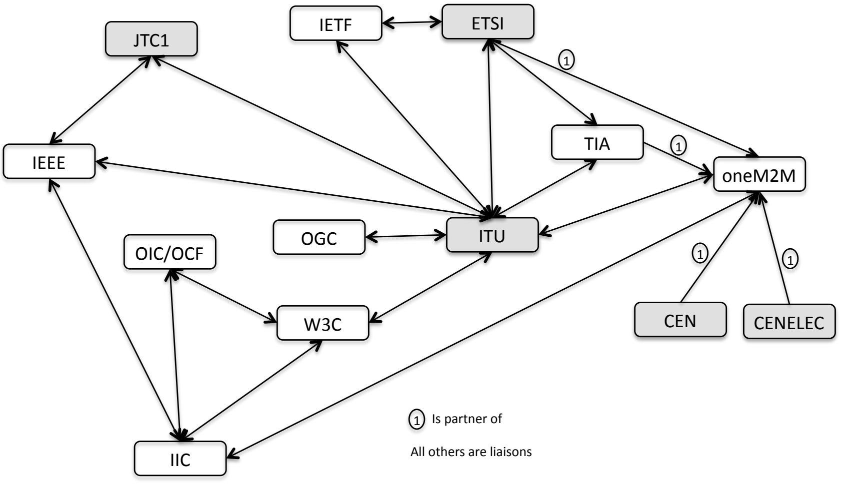

Figure 5.19: Links between SSOs working on IoT-related topics today
(Links between the ESOs and the WSC and between their individual members (in grey) are depicted in Figure 2.3)

Hardly any standards consortia are around also for the IoT (the OGC being the one – minor – exception; the IIC and the OCF are not really SSOs). This is all the more astonishing as the IoT is a much-hyped technology with bright prospects for the future in terms of potential revenues to be earned. The timeline resembles that the SG and SCs, where a massive wave of newly found entities may also be observed since around 2010 (see Figure 5.2).

[174] Some of its member ('Partner') organisations have also become active in IoT-related standardisation, including TSDSI (Telecommunications Standards Development Society) and TTA (Telecommunications Technology Association).

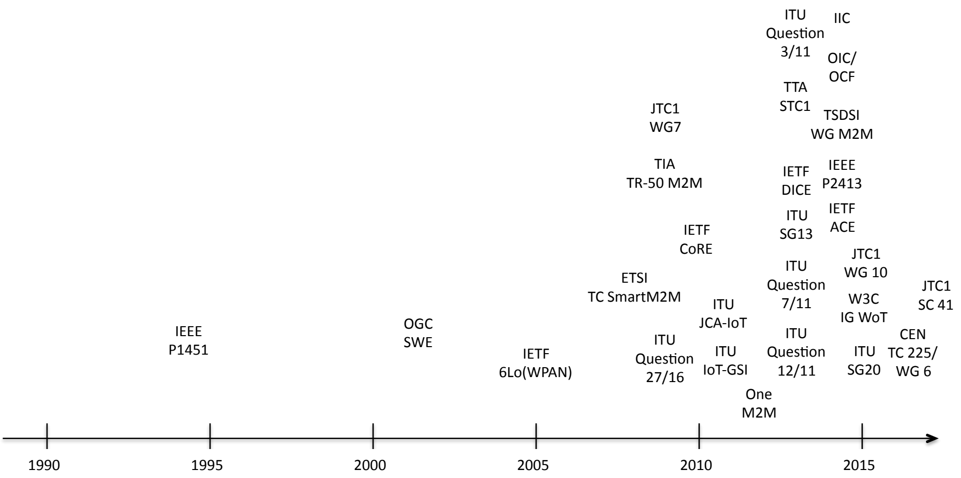

Figure 5.20: Timeline of the establishment of important IoT-related standardisation entities

The establishment of the vast majority of dedicated IoT standards setting entities (new SSOs or specialised sub-units of existing ones) occurred between 2008 and 2016. It got off the ground in 2009, with a peak in the period from 2013 – 2014. In 2015, JTC1 established its WG 10 'Internet of Things'. This WG, together with WG 7 'Sensor Networks' is now part of the recently (in 2016) established JTC1/SC 41 'Internet of Things and related technologies'. This consolidation and, more so, the 'elevation' of the topic to Sub-Committee status further highlights the importance JTC1 assigns to this field of work.

That is, standardisation activities for a dedicated IoT infrastructure started at around the same time as Smart City standardisation and the second 'wave' of standardisation of the Smart Grid and Smart Manufacturing. So, here again application-specific standardisation started without a dedicated infrastructure. Such a largely mutually independent standardization of the IoT and its applications is a somewhat dangerous development. For one, a dialogue between the ICT world (developing the IoT-based infrastructure) and the world of applications (which will utilise this infrastructure) is crucial. After all, the latter needs to provide requirements for the former, and experts from the infrastructure side need to make clear any (technical) restrictions that may apply and potentially impact the applications. Moreover, and also due to an inadequate level of co-ordination between individual standardisation activities there is a real risk of creating new silos. Co-ordination largely occurs *within* individual SSOs, which may lead to the emergence of SSO-specific silos in which only standards from this SSO can seamlessly interoperate. This would then come in addition to proprietary silos. Furthermore, and considering the sheer number of standards setting entities that are active in the IoT domain and in the different application areas, respectively, one could be tempted to wonder if global interoperability can be achieved at all [Meddeb, 2016]. The creation of a cross-SSOs co-ordination entity would be a valuable next step. In addition, entities that actually try to address concrete application-related problems from a multi-disciplinary perspective will eventually be required. It remains to be seen if improved co-ordination helped get the mushrooming of standards and specifications under control.

5.6.3 Security and Privacy

Security encompasses a set of services, including authentication, authorisation, integrity and confidentiality. In addition, privacy needs to be guaranteed and, ideally, mechanisms to support the development of a certain level of trust between parties should be provided.

In fact, a widely perceived lack of security and privacy may well be a potential show-stopper for the IoT and its applications. It is very likely that people will resist them if there is no confidence that they will not cause serious threats to privacy [Atzori et al., 2010]. Likewise, virtually all application areas have strong security requirements; accordingly, industry concerns also very much focus on this aspect [Li et al., 2015]. These concerns as well need to be addressed by standardisation.

Since such concerns are not unique to the IoT, a large number of protocols to ensure security and privacy already exist. Accordingly, one might be tempted to think there is no real need to design new, dedicated security protocols for the IoT [Keoh et al., 2014]. Yet, the major issue that stands in the way of a one-to-one adoption of existing protocols is – again – the power-constrainedness of embedded smart devices (like sensors and actuators), which will represent the vast majority of IoT nodes. As a consequence, additional efforts will need to go into the adaptation of existing protocols to the limited capabilities of these devices. This may well amount to the development of dedicated, IoT-specific security mechanisms.

Despite their crucial importance, security and privacy standardisation will not be considered in this chapter. For one, their inclusion would go beyond its scope; thorough discussions of the associated technical aspects and of ongoing standardisation activities are provided in e.g. [Keoh et al., 2014], [Sicari et al., 2015] and [Li et al., 2016]. Moreover, the socio-economic and policy ramifications of the topic are actually too important to be hidden in a chapter on general smart systems standardisation.

5.7 The Survey

5.7.1 Preliminary Explanations

CPS and IoT standardisation are of particular interest for two reasons. For one, both are becoming increasingly wide spread and will soon represent a major part of a smart communication infrastructure to support smart applications. Accordingly, and just like the process of developing standards for smart applications, the standardisation of a smart infrastructure will need to be multi-disciplinary. In fact, in the case of CPSs this multi-disciplinarity is twofold (which is one reason why CPSs appear in a separate category). For one, it comes from the link between the smart communication infrastructure and the smart applications that deploy it (see also Figure 5.15). Secondly, it relates to the standardisation of CPSs themselves, which represents a combination of the physical world and the virtual world.

At the end of the day the question of how to best do multi-disciplinary standardisation is at the heart of this study, with CPSs, smart infrastructure and smart applications serving as examples where multi-disciplinarity in standards setting is required.

5.7.2 Target Groups and Selection Criteria

According to Jansen [2010, p.3], a "*qualitative survey is the study of diversity (not distribution) in a population*". To achieve this, "*A qualitative sample should represent the diversity of the phenomenon under study within the target population*" [Jansen, 2010, p.8].

Accordingly, the survey covered the standardisation of a smart infrastructure and of smart applications[175]. CPSs, which are crucial constituents of a smart infrastructure, are covered from the research side simply because at the time of the study (second half 2016) their standardisation was still very much in its infancy (i.e. virtually non-existent); not that terribly much has changed since then[176].

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[175] The relevant SSOs covered included OneM2M's WG ARC and WG SEC, ITU's Study Groups 13, 15, 17, 20 and ISO/IEC JTC1's WG10 and WG11. This was not the full range ofrelevant SSOs, but those who made available the addresses of their WG/SG members.

[176] There may be two reasons for this surprising lack of standardisation activities. For one, there is still no clear distinction between CPSs and the IoT (see e.g. [Greer et al., 2019]); many see CPSs as part of the IoT (a view subscribed to by many

Therefore, the target group comprised three different, though overlapping communities. They included those active in (see also Table 5.9)

- research about CPSs (for their expert knowledge on existing or upcoming requirements on CPSs (and thus CPS standardisation) from the R&D sector);
- the standardisation of the smart infrastructure (for their expert knowledge on standardisation aspects);
- standardisation of smart applications (for their expert knowledge on existing or upcoming requirements on smart infrastructure standardisation from the application side).

Table 5.9: Communities covered by the survey

Topic / Activity	Standardisation	Research
CPS	–	X
Smart Infrastructure	X	–
Smart Applications	X	–

A dedicated questionnaire was developed for each group. Each questionnaire was accompanied by a cover letter explaining the goal of the overall study and the reasons that had led to the selection of the recipient. Questionnaires comprised seven (CPS research), ten (smart infrastructure standardisation) and twelve questions (smart applications standardisation), respectively (to be found in Appendix C).

Completing the questionnaire requires a potential interviewee's willingness to spend a certain amount of time on an exercise whose value to him/her is not necessarily immediately obvious. Thus, potential interviewees had to have an intrinsic interest in the study and/or the hope to benefit from its findings. In addition, interviewees had to have a certain level of relevant knowledge and experience in order to make reasonably educated comments. To make sure that only reasonably experienced researchers and standards setters, respectively, would take part in the survey some simple of criteria were applied, depending on the respective community.

- For researchers, membership in the Technical Programme Committee of one of the major conferences in the field or co-authorship of the respective AIoTI[177] report.
- For standards setters, either holding a leadership role (e.g. convenor, editor, etc.) or regular/frequent participation in group meetings.

In total, 37 responses (out of around 180) were received. Of those, 8 came from the application side, 13 from infrastructure research and 16 from infrastructure standardisation. The content analysis was structured similarly to the one described in sect. 2.5.3. The very focussed (sub)questions could be deployed for (implicit) categorisation of the responses for the subsequent qualitative context analysis. To this end, for each of the three groups of respondents the responses were integrated into one document, which showed all responses to each question at a glance.

For standards setters, the questions were subdivided into two main group, covering the current situation in and the envisaged future of infrastructure and application standardisation, respectively. One additional question covered the respondents' respective background. The document for researchers was structured similarly, with one group of questions covering their current deployment of

respondents as well). Moreover, the probably most important topics in CPS standardisation are communication and security; both are being deal with elsewhere.

[177] The Alliance for the Internet of Things Innovation was initiated by the European Commission in order to develop and support interaction among the European players active in the fields of smart infrastructure (IoT) and their applications.

and future need for standards in their work. The second group focused on their views of future development in the field and their ramifications for standardisation.

In the following, group-specific findings will be presented first, followed by a more general discussion of the overall outcome of the respective survey.

5.7.3 CPS – Researchers

5.7.3.1 Insights from the Survey

All respondents are long standing practitioners with seven to twenty years of experience with CPS and/or predecessor technologies. They come from very diverse backgrounds, including for example stand-alone and networked real-time/embedded/control systems for different application areas. In these contexts, software-related problems addressed cover, for instance, systems planning, simulation, design and verification from both theoretical and practical perspectives.

To start with, some respondents raised a number of more general issues in relation to CPSs and their standardisation that are worth mentioning. For one, what exactly constitutes a CPS does not seem to be entirely clear.

> *"In various academic and industrial research communities that I am a part of, there doesn't seem to be a precise agreement on what constitutes a CPS and what is not a CPS. ... we must be able to concretely state that these are the kinds of systems for which a (set of) standard(s) applies and there are the systems for which it doesn't"* (Respondent C4).

Another respondent who shares these concerns suggests that

> *"It is possible that by establishing a CPS standards body we can address this problem ..."* (Respondent C6).

There is no doubt that development and thus the standardisation of CPSs require co-operation of different disciplines or domains. According to the respondents, this holds for both the design of CPSs themselves as well as for the integration of CPSs into applications. For the former these domains are said to include:

> *"Physics based modelling, system and control theory, computer networks, embedded systems, real-time SW/HW integration, security and privacy, (wireless) communication theory, information theory and mathematics"* (Respondent C2).

In the latter case the disciplines that need to work together obviously depend on the respective application. Specifically, stakeholders from the application side also need to contribute to an (application-specific) CPS standard.

> *"The standards will necessarily depend on the applications. The disciplines involved in a specific application should contribute to the standard"* (Respondent C8).

This is further elaborated and stressed by another respondent who observes that

> *"Yes, it absolutely requires expertise in multiple domains to develop useful outcomes. Communication is a key to success across two or more domains, and it takes patience and extra time. Otherwise, the needs of the application area fall between the cracks and errors, sometimes huge errors, are the result. When CPS is exclusively done by computer engineering or science, it is usually a failure"* (Respondent C9).

Using an example from medical technology, a third respondent highlights not just the need for co-operation between disciplines, but for the need for (standards) developers to also have adequate knowledge about the respective application domain:

> *"A qualified developer for surgical robot must has strong background on both computers and surgery. The requirement on cross-domain qualifications will only become more*

> *challenging as each domain of expertise evolves. CPS has to find a way to mitigate this challenge"* (Respondent C1).

Yet, 'standardisation' does not just refer to the process itself as we know it. Rather

> *"I believe that a good CPS development process requires standardizing the process of specifying and eliciting requirements"* (Respondent C10).

This may imply the use of formal methods during the process. While this would certainly help decrease the degree of requirements' ambiguity it would also put an additional burden on those who work in standards setting as they would need to be familiar with these formal methods.

Given the apparently very low number of CPS-related standards actually used in development[178], it is little wonder that at least those respondents who actually do CPS-implementation work identify a range of aspects where they would consider standards to be at least beneficial if not crucial.

> *"Development of CPS apps require standard ways of development, which in turn require standardised frameworks, CPS programming lang, I/O formats and testing methodologies. No consensus on any of these till now"* (Respondent C3).

This lack of standards may have a lot of undesired and undesirable ramifications. For one, developers will be forced to develop their own 'private standards', which may or may not spread, thus potentially contributing to an even more confusing standards landscape.

> *"Yes, primarily centered around control and optimization system performance of software enabled control systems. Where I have needed metrics and standards I have developed them myself and claimed this contribution to the CPS community"* (Respondent C12).

On the bright side, some of these 'private standards' may also find their way into formal standardisation.

Deployment of and potentially resulting lock-in into proprietary de-facto standards is another potentially detrimental consequence of the current lack of standards for CPSs (not to mention the technical issues).

> *"CPS models are also specified using a plurality of formats. One of the most popular formats – Simulink – is a proprietary visual language from the company The MathWorks. The proprietary format makes the semantics of the model unclear, it makes the model inaccessible for external tools and processes, hampers traceability, and hinders application of formal reasoning tools. Clearly, specification of CPS models could be assisted by a standard syntax and operational semantics"* (Respondent C10).

In many respects, respondents' opinions vary when it comes to the issue of dedicated CPS standardisation. On the other hand, quite some level of agreement could be observed on other aspects. Starting with the latter, there is a agreement that CPSs do need standardisation, albeit for a variety of reasons. Among these, 'interoperability' is quite popular:

> *"CPS, more than any other system, need interoperability. Without standardization interoperability and modularization of CPS will never be achieved"* (Respondent C8).

Along similar lines, and highlighting the negative effects of a lack of standards in the e-health sector, another respondent observes that

> *"For example, due to lack of standardization, currently hundreds of thousands of different medical devices from different vendors cannot be organically integrated. A hospital is*

[178] The one standard mentioned by several respondents is ISO 26262 ('Road vehicles – Functional safety'). It is also the only 'formal' standard mentioned.

forced to purchase all devices from one single vendor to guarantee safety of an integrated medical device collaboration system" (Respondent C1).

A respondent who works more on the theoretical side offers a slightly different view regarding the need for dedicated CPS standardisation

"No... but if [dedicated CPS standardisation] *did exist, I think it could show itself to be more efficient than an approach where it didn't exist. That is, I think it's a good idea, and would be useful, but isn't explicitly required for progress to be made"* (Respondent C13).

Wide agreement may be observed regarding the option of a continuation of the current situation, i.e. to live with a rather loosely-coupled web of SSOs developing potentially overlapping and sometimes even competing technologies. This is not considered desirable in light of the potential alternatives of having "*a (new) SSO exclusively dedicated to CPS standardisation*" or to have "*a (very) close co-operation of existing SSOs, each contributing its specific expertise*". Yet, that's where wide agreement ends.

There is, however, still a certain level of agreement regarding the point in time at which standardisation should start or have started, respectively. For those who explicitly address this issue, "as soon as possible" is the latest point for CPS standardisation to start. As with the need for CPS standardisation as such, the underlying reasons differ here as well, though. One respondent observes that the starting point should be

"As soon as possible. I think to this point the community is young enough that it is still feeling out what it is. But it needs strong leadership that develops a unified vision as soon as possible" (Respondent C12).

Looking specifically at security and privacy aspects, another view is that

"Standardisation work should already have started. The longer standards aren't established, the less safe interoperability will be possible" (Respondent C13).

I does not come as a big surprise that views differ regarding the question of which aspects of CPSs should be standardised. It would seem that this very much depends on the field of work of the respective respondent. Still, many responses focus on the 'network' and 'security' aspects, which resonates with the importance of and need for (safe) interoperability.

"At the very least, secure real-time network standards for IoT and networked CPS should be developed" (Respondent C8).

The perhaps most interesting point relates to the most suitable structure of future CPS standardisation activities. Here, opinions were split regarding the best way forward. Some felt a "*(very) close co-operation of existing SSOs, each contributing its specific expertise*" to be the best option. Arguments in favour of this option typically were variations of

"Existing organizations have a long experience that must become part of any new standards" (Respondent C8).

That is, proponents of this option basically argue that the only – or at least the best – way to tap into exiting SSOs' vast expertise would be to establish close links between them and to make them co-operate and contribute their respective expertise.

A second option given was to establish "*a (new) SSO exclusively dedicated to CPSs*". One respondent felt that this would be the best way to deal with the fact that CPS standardisation is different from general ICT standards setting.

"CPS demands new thinking and approaching problems dedicated to a CPS as a whole rather than the sum of its parts" (Respondent C12).

This difference stems primarily form the multi-disciplinarity of CPS standardisation (see above).

Another respondent adopts a middle ground – co-operation of SSOs through a dedicated new one.

> *"I think that the most promising approach is to have close co-operation of existing SSOs, each contributing to its specific expertise. However, a new organization that includes members from the existing SSOs and develops standards through continuous discussion would be much more beneficial than having the separate SSOs draft their own standards and then present a patchwork standard"* (Respondent C10).

Along slightly different lines, some respondents consider the way standardisation should be organised to be domain specific. One aspect to be considered here is the maturity of the respective domain (which also links to the aspect of 'time' discussed above).

> *"Secondly, before we anything is standardized, we must know what the best practices are. These are often application-specific. Redundancy in the avionics domain might be handled in such a way that perhaps doesn't make sense in the smart grid application. Another challenge in terms of best practices is that in certain domains the best practices are not known yet because they are still emerging and evolving"* (Respondent C4).

One respondent even argues that the specific characteristics of different domains may require different structures for standards setting, to properly reflect these characteristics.

> *"The need may vary from domain to domain. For example Intelligent Transport System (ITS) would have more emphasis on cooperative properties and safety than Smart-Cities. For ITS, the second* [co-operative] *approach would be preferred. For Smart-Cities, the first option* [single SSO] *would be chosen"* (Respondent C11).

Such a mapping of domain characteristics onto the associated standards setting environment is certainly an interesting idea. However, it would seem that practical issues (e.g. cross-domain standardisation) stand in the way here.

Finally, an interesting comment that relates to the over-arching problem of the standardisation of privacy and information safety and security was made.

> *"One thought is to create an IETF like standards process that is driven by innovation rather than big bodies and see if we come to some conclusions with a grass-roots approach. We may still need experience bodies to overlay standards around safety and security to ensure the right qualities in developed solutions"* (Respondent C5).

This seems to suggest that the IETF process is considered to be substantially different from those of the other SSOs. At the same time, it should apparently not be entrusted with the development of standards that affect safety and security ….

Views on future developments are apparently much influenced by each respondent's respective background. Those from a more theoretical background mention e.g. online model checking, logical formalisms and other methods and approaches from realm of theoretical computer science, mostly to improve correctness reliability of the systems. Typical responses from the more practical side included

> *"Autonomous systems, next generation transportation systems, human-CPS interaction, (collective humans) society-CPS interaction"* (Respondent C2).

> *"Autonomous systems such as self-driving cars that carry passengers, and wearable/human-immersive/medical CPS such as cardiac pacemakers, neuro-robotics and actuated exoskeletons are things that come to mind as the next big wave of safety-critical CPS of the highest degree"* (Respondent C4).

However, the views on if and how these developments might affect standardisation were strikingly under-developed.

5.7.3.2 Initial Discussion

All respondents agree that multi-disciplinarity is a crucial factor in CPS development and standardisation. This holds despite the fact that not all respondents actually develop, implement or verify CPSs. Some are working on rather more theoretical aspects. Very much in line with the literature the respondents identify different levels of multi-disciplinarity in CPS standardisation. For one, the standardisation of CPSs themselves will require input from a number of disciplines. On top of that, different smart application domains will have different requirements on the underlying infrastructure. These will depend on the maturity of the respective domain and, of course, on technical aspects. In any case, these requirements need to be clearly communicated from the application side and understood by the CPS side. Eventually, mechanisms to address these requirements need to be incorporated into the standards. If this is not feasible (for e.g. technical reasons) this fact needs to be communicated back equally clearly. To successfully do so, a certain level of domain knowledge should be available on the side of those who standardise CPSs or, more generally, the smart infrastructure. From a managerial point of view this implies the need to have representatives in smart infrastructure standardisation who either share the necessary technical knowledge between them (and are capable of co-operating accordingly) or actually have the necessary multi-disciplinary knowledge and expertise individually (which would probably be the more efficient option).

Research and development (R&D) into smart applications and smart infrastructures in general and CPSs in particular has been ongoing for quite a while. In combination with a lack of relevant standards this has inevitably led to the development of numerous incompatible solutions. This, in turn, has contributed to very fragmented field in application areas like e.g. e-medicine. This is definitely a less than optimal situation per se, which needs to be remedied very soon if market fragmentation is not to prevail. However, it also offers the opportunity for a company with adequate expertise and R&D activities in the field to succeed in establishing (at least a close relative to) its proprietary technology as a standard. To this end, alliances may need to be formed both within and outside standardisation. Regarding the former, such an alliance will also need to extend to the level of individual standard setters in the technical WG(s) in charge. Moreover, care will need to be taken to ensure reliable information transfer from internal R&D into the WG(s). Here, the most simple and efficient way to achieve this may well be the direct participation of R&D staff in standards setting (following the necessary training and briefing).

5.7.4 Smart Infrastructure – Standards Setters

5.7.4.1 Insights from the Survey

In this field as well the vast majority of respondents are old hands, with experience in the topic for over ten years. The majority works with different ISO WGs.

A considerable number of SSOs or SSO entities have been identified. However, many of them work on more or less generic communication standards. These are of relevance for the CPSs and IoT, but in most cases they have not been developed specifically for them. Moreover, as one particularly knowledgeable respondent observed

> *“Existing standard developments are often re-positioned under the IoT label”* (Respondent I13).

This observation is further corroborated in [Barthel, 2015][179]

[179] At that time, Henri Barthel was Vice President GS1 System Integrity and Global Partnerships and Chairman of the CEN TC225 on Automatic Identification and Data Capture (AIDC) Technologies and Applications. We had a brief e-mail conversation about IoT-related issues. See also [Barthel, 2015], which highlights the same issue.

> *"IoT has become a buzzword that is used and misused to justify all sorts of initiatives in many areas including in the standardisation world"* (private communication in the context of the study).

This 'fraudulent labelling' aside (but keeping it in mind), there don't seem to be that terribly many SSOs active in 'true' smart infrastructure standardisation. Of those, the majority of respondents identified JTC1 and its various sub-entities as (one of the) most important players, with one interesting qualification

> *"JTC 1 has several relevant activities but its actual industrial reach is not always evident"* (Respondent I4; a long-standing contributor to JTC1).

The very strong overall impression the responses create is one of significant competition between SSOs, at different levels. This competition may have a strategic or a technical motivation. For the former

> *"Political competition between standards group is of course a reality especially when it comes to hype topics such as M2M or IoT, since every organization want to claim a dominant role in such areas"* (Respondent I1).

Regarding the latter,

> *"Competition occurs at various levels:*
> - *Physical and networking layers (although there is an increasingly clear understanding that several technologies will coexist, e.g. IEEE 802.15.4, Bluetooth, WiFi ...)*
> - *Application layer*
> - *Semantics/ontologies layer"* (Respondent I12).

Perhaps most importantly, there is also competition at the top-most, and perhaps most important level – the reference architecture

> *"A high degree of competition exists within efforts focused on developing reference architecture for the IoT"* (Respondent I13).

The first mover advantage will be particularly important at this level, as the 'winning' reference architecture is likely to have significant ramifications on the standards that are supposed to fit into it.

> *"This is a fast changing field, first movers will most likely set at least the defacto standards"* (Respondent I10).

On the brighter side, there is also co-operation between SSOs.

> *"Pre-existing co-operation/collaboration has had a carry-over effect into IoT areas. Examples would be ISO/IEC and W3C-IETF joint project"* (Respondent I13).

Existing formal liaisons and co-operations between the international SSOs and IEEE are especially stressed by many respondents. Probably at least as important is the informal co-operation that at the level of the individual standards setter, through people active in several entities.

> *"There is plenty of informal co-operation, and in many cases there are individuals involved in two or more activities"* (Respondent I6).

This form of co-ordination is effective and does not only happen in the smart infrastructure context. However, this also has its downside:

> *"… SC29 WG11 meets 3 or 4 times a year and WG10 3 times a year…6 weeks out of ones life plus travel means either need very accommodating employees or projects in the area with government/EU funding… For people to attend multiple meetings there really is a need for directed funding"* (Respondent I4).

The urgent need for co-operation, especially in the IoT sector, is quite convincingly highlighted by another respondent:

> *"... but in IT and even more so in IoT, there is overlap because the very nature of IoT means that two or more technologies are being connected which means that bits & bytes are being connected and exchanged in some manner, thus forcing collaboration of varying types, like it or not"* (Respondent I11).

Looking into the future of smart infrastructure standardisation it quickly becomes clear that most respondents consider CPSs as part of the IoT. Typical views would be

> *"CPS is just part of IoT. The current standardization efforts cover CPS at the general level. No one has stepped forward to identify specific gaps yet"* (Respondent I2).

> *"As mentioned, it seems that CPS standardisation can be placed under the umbrella of IoT standardisation"* (Respondent I3).

> *"CPS is just one part of the global IoT picture, with a strong focus on industrial systems"* (Respondent I12).

That said, a small minority of respondents felt differently. Asked whether or not they'd see, in principle, a need for dedicated CPS standardisation one respondent feels

> *"Absolutely; this is the only way to get to scale and the kind of cross-field innovation that IoT needs"* (Respondent I10).

Nevertheless, both 'minority voters' agree that the creation of a new SSO to cover this field would be counter-productive. How exactly a viable alternative should look like remains unclear, though.

> *"I see a need for dedicated CPS standardisation – just not sure of the model and "home" for it yet"* (Respondent I11).

In general, the respondents' feeling regarding a new entity may be summed up by

> *"It is the general feeling of the world and I tend to agree that there are already too many SDOs and I am not sure another would be helpful, even for a topic as important and needed as this"* (Respondent I11).

That said, the smart infrastructure standardisation environment is still considered as being in a status of flux.

> *"The landscape of influential organizations is still evolving"* (Respondent I1).

And despite the fact that almost all feel that the establishment of new, additional SSOs would not help there is also the belief that exactly this is likely to happen:

> *"I'm sure there will be additional SSOs but am not aware of any specific ones"* (Respondent I6).

Respondents' views show a clear tendency when it comes to the questions of increasing or decreasing importance of existing SSOs in the field of smart infrastructure standardisation, which may be summarised as

> *"I hope/believe that JTC1 work will take preference over all other work."* (Respondent I2).

Here again some interesting individual views deserve attention. Looking at future power shifts in CPS standardisation from an application point of view, one respondent speculates

> *"The IEC recently created a Systems Evaluation Group on Smart Manufacturing (SEG 7). This group will coordinate work with both other IEC groups and external organizations*

> *such as ISO, ITU or IEEE. It could be a good starting point to look deeper at CPS related standardization* (Respondent I12).

On the other hand, one respondent voiced doubts about the future relevance of specifications pushed by some industry consortium (termed 'pseudo standards')

> *"I have some doubts about the success of "pseudo-standards" e.g. OCF but difficult to predict for now" (Respondent I14).*

Taking a look outside the standards setting environment of respondents identifies a potential course of events that would be based on the market power of some individual companies.

> *"If Apple and/or Google expand their current home interface standardization initiatives into something industrial-grade they may very well be in a position to dominate the market despite what formal SSOs say"* (Respondent I10).

Finally, another respondent looks at the political dimension of standards setting in such an important field

> *"But since this organization* [OneM2M] *is perceived by vertical stakeholders as dominated by the ICT industry, it is not clear that they will adopt these standards. From this point of view, other organizations representing vertical industries such as the IIC may have a role to play"* (Respondent I1).

Perceptions were surprisingly split of the question of the importance of regional SSOs. One popular view, shared by several respondents was that regional SSOs are

> *"Not important other than identifying gaps. The work should move to the ISO/IEC JTC1 level"* (Respondent I2).

On the other hand,

> *"Standardisation activities of regional SSO would be very important given that they address regional/national issues which should be considered to achieve full system interoperability" (Respondent I3).*

In summary, respondents were frequently in comparably wide agreement, with frequent interesting individual or minority views thrown in.

5.7.4.2 Initial Discussion

'Competition' seems to be a major characteristic of smart infrastructure standardisation. From a standardisation management perspective this has several ramifications. For one, such competition implies that a strong company with deep pockets and relevant proprietary technology who is prepared to invest the necessary resources stands a good chance to influence the process to its benefits.

Such a company will need to identify the most suitable SSO(s) for its purposes. Criteria here include e.g. each SSO's membership base (with a certain focus on potential competitors and allies), its general relevance in the field (including co-operations and alliances) and its IPR policy. As different technical levels of competition exist, the most relevant ones (and the associated SSO(s)) will need to be identified up-front. In these SSOs the company will need to try and assume a leadership position. In addition, a less active role may need to be played in other relevant SSOs, not least for intelligence gathering (see chapter 2 for a more in-depth discussion of the associated aspects to be considered in this context). Being member in several SSOs and sending the same people to the meetings is a potentially very effective mechanisms not just to provide for some level of co-ordination, but also to influence parallel activities in different SSOs. The fact that existing co-operations from related sectors also play a role may be helpful here. All this is a costly exercise, so indeed only well-off companies will be able to act in this way. On the other hand, and since especially CPS standardisation is still in its infancy, some consideration should be given to the first mover advantage. While this advantage is not necessarily a guarantee for eventual success it might be an additional motivation for a company to make inroads into this field.

In such a comparably new, multi-disciplinary environment where ICT makes inroads into various more ‘traditional’ technologies additional, ‘soft’ aspects will also need to be taken into account. These include prejudices and scepticism on the side of stakeholders active in these traditional technologies who may well view an increasing importance of ICT in application areas with distrust. That is, alliances in smart infrastructure standardisation will need to extend to all groups of stakeholders if an ICT-related standards setting initiative is to be successful. Along similar lines, firms active in the field of (smart) applications may well be in a position to influence smart infrastructure standardisation through the definition of application requirements on the underlying infrastructure.

5.7.5 Smart Applications – Standards Setters

5.7.5.1 Insights from the Survey

Almost all respondents have been active in the field of Smart Cities, with two also working on the standardisation of ITSs and one on Smart Buildings. All respondents have been active in standards setting for smart applications for at least five years.

The standardisation of Smart Cities (SCs) is a fairly new and still developing field, with a very limited number of players in standards setting. Accordingly, it is not a big surprise that the respondents come from a rather homogenous background, namely ITU SG20 and JTC1/WG11. Neither will it come as a surprise that their views about the current importance of the different SSOs do not differ very much – SG20 and WG11 being almost unanimously named the most relevant players. ISO, IEC and oneM2M are also named[180]. A typical response reads:

> *“ITU-T Focus Group on Smart Sustainable Cities (FG-SSC) and its successor ITU-T Study Group 20. ISO TC268 / SC1. IEC SEG-1. ISO/IEC JTC1/SC on smart cities and its successor JTC1/WG11”* (Respondent A3).

Despite the respondents’ homogeneous standardisation background their views differ slightly when it comes to co-operation and competition between the SSOs. Views range from

> *“I’m not aware on the competition, but they are targeting similar things in some cases”* (Respondent A4),

to

> *“Of course, there is a natural conflict between the different organizations developing communication technologies”* (Respondent A2).

However, the latter qualifies that these conflicts are mostly about different business models by different companies, rather than between SSOs.

From a slightly different perspective, one respondent mentions the competition between communication protocols – all IP vs. telecommunication standards – or rather between their respective proponents

> *“Certainly. Specifically, in the area of sensor networks, where ITU, ETSI, and OGC have standards, whilst others strongly feel that all the communication should be over Internet Protocol – meaning that IETF (& W3C) would be relevant”* (Respondent A5).

[180] oneM2M develops a Common Service Layer on top of a number of communication protocols. This layer provides functions that M2M applications commonly need. Because of this generic nature oneM2M has not been included in the list of Smart City players.

In contrast to their diverging views about conflicts, all respondents agree that there is co-operation between SSOs. This co-operation, however, is exclusively identified for the SSO level, not at the level of the individual entities (e.g. WGs, SCs, SGs) working in the field.

The respondents are also largely in agreement about the most desirable structure of the future standardisation of a smart communication infrastructure. All observe that already today a number of entities are working in this field and assume that this situation is not going to change.

> *"There are several, I guess this won't go away"* (Respondent A5).

Yet, the (excessive?) number of standards that the different SSOs produce is seen as a drawback of this situation, specifically from a development perspective:

> *"Regardless the number of standards available, too much from my pov[181], there should be real efforts on the development of interoperability solutions. It represent one of the major barriers for system development"* (Respondent A4).

To improve co-ordination and thus to reduce the number of (possibly competing) standards developed in parallel by different SSOs in the future almost all respondents would prefer co-operation between existing entities over the establishment of a new, dedicated entity in charge of communication infrastructure standardisation. The same respondent as above states that:

> *"More than an entity this should be an agreement among SSO."* (Respondent A4).

The one diverging point of view that sees a need for a dedicated entity for smart infrastructure/CPS standardisation argues that

> *"CPS has strong relationship with other domain of IoT, such as IoT applications. Working in one SSO could make participants communicate more easily and closely"* (Respondent A1).

He continues that also the typical lack of resources (time and money) would make work in such a dedicated entity more efficient.

No views are offered with respect to any future changes of the importance of the SSOs currently working on smart infrastructure standardisation. However, some envisage an increasing importance of private standards consortia, albeit with the qualification that sometimes they lack a long term view. With respect to regional SSOs (like the ESOs) views differ and range from "… *regional SSOs will play very important roles* …" (Respondent A1) to "*The role of regional SSOs has become less important already* ..." (Respondent A2). The overlap of their respective activities is also noted.

5.7.5.2 Initial Discussion

The views offered by those looking at smart communication infrastructure standardisation from a Smart City perspective allow for some interesting observations. If the trend towards all-IP networks continued, power may eventually shift from the current incumbents to entities developing standards for the Internet or the WWW (i.e. the IETF and the W3C). On the other hand, a construction like oneM2M's Common Service Layer should decouple the communication sub-system form the applications deploying it. Nevertheless, this trend needs to be monitored by companies active in the field and early measures like moving activities to a more relevant SSOs will have to be taken if need be.

The observation that SSOs should focus on interoperability rather than on developing ever more new standards resonates with observations made in sect. 5.6.2. For firms with an interest in not just to develop but also to implement smart infrastructure standards (and the technical capability to actually do so) this may be an alternative/complementing approach to influence developments by offering

[181] Point of view.

products that either implement only parts of the standard or, probably more efficiently, implement the standard plus some proprietary additions, thus creating a lock-in situation[182]. The diverse views expressed regarding the importance of regional SSOs are understandable – after all, smart applications (like the smart infrastructure; see 5.7.4.1) are a global development. Nonetheless, their in-depth knowledge of their specific regional requirements and legal boundary conditions and their importance in their respective region are likely to keep regional SDOs on the list of relevant SSOs.

5.8 Implications and Issues

Ultimately, the goal of the discussion above was to get a better idea of how an environment for smart systems standardisation should look like. To this end, it followed two avenues. First, it took a closer look at past developments in this field, in the hope to be able to identify potential general future trends and developments. Second, it solicited expert opinions to obtain more detailed insights and views from those who are actually developing standards for smart systems. The resulting findings quite clearly show that the current standardisation system is not really fit for use for the development of adequate standards for smart systems. The discussion identified various issues that contribute to this situation and that are in need of further investigation. These issues may roughly be classified into three categories, which are, however, intertwined. One category relates to the standardisation timeline, one to the complexity of the current standards setting environment and the third to the standardisation process. In addition, some general aspects are considered.

Please note: From the outset, the research so far presented in this chapter was supposed to be practically oriented. Inevitably, the conclusions and recommendations presented in this section are also of a rather more practical nature.

5.8.1 Implications for the Research Agenda

5.8.1.1 The Standardisation Timeline

Looking at the establishment of standardisation entities (i.e. WGs, TCs or full-blown SSOs) over time for both smart applications (sect. 5.5.) and the smart communication infrastructure (sect. 5.6) certain similarities become apparent. For one, in almost all cases we find an entity standardising an early predecessor technology (smart cities being the exception); 'early' may be a decade, but it may also well be a century). More importantly, almost all share a roughly common timeline, typically comprising a comparably lengthy starting phase followed by two peaks of activity, with a short(ish) quieter period between them. The similarity of the timelines, specifically the more recent two 'waves' of new standards setting entities (and associated new activities) call for a closer look at this phenomenon. If such similarities of standardisation timelines could be observed in other (ICT-related) sectors as well this fact might perhaps be exploited for forecasting purposes, e.g. with respect to a likely increasing (or decreasing) popularity of a new technology.

It has also become obvious that the timelines of the standardisation activities on the application side are not in sync with those on the infrastructure side. In particular, the standardisation of smart applications frequently started earlier than those of the necessary underlying infrastructure. This raises some issues with respect to the co-ordination of these inherently intertwined activities. Apparently, such co-ordination is necessary not just in technical terms (e.g. with respect to application requirements and potential infrastructural limitations; see also sects. 5.3.1 and 5.5). This will be discussed in a bit more detail further below.

5.8.1.2 The Standardisation Environment

Over a decade ago, Cargill & Bolin [2007] observed that "[SSOs] *have lost sight of two fundamental principles of standardization: (1) the purpose of* [ICT] *standardization is to facilitate interoperability,*

[182] See [Egyedi, 2007] for a more in-depth discussion of surrounding issues.

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". Today, the situation has not changed.

Section 5.5 highlights the quite dramatic increase of the standards setting environment's complexity since the mid-nineties; this holds specifically for the field of smart systems. This increase may be observed for the number of SSOs and their respective sub-entities (TCs, WGs) as well as for the links that exist between them. The co-ordination of the activities of these individual entities still leaves much to be desired. This situation is highly unlikely to improve any time soon. This lack of co-ordination and the resulting competition between SSOs may have some highly undesirable consequences, including incompatible and competing smart application silos (see e.g. [Derhamy et al., 2015] or [Pereira et al., 2016]). How to avoid or at least reduce such competition largely remains an open issue (see also e.g. [Cantero Gamito, 2018]). In the EU, the regulator has been funding the current European standardisation system from the outset[183]. This affords a certain level of political influence (see also [EU, 2012]). This influence, however, first and foremost relates to requesting a new standard; it does not extend to its content. If this is indeed a desirable approach remains open for discussion, though. And whether or not it might be transferrable to the global level is unclear (not least as co-operation between European countries is more pronounced than in most other parts of the world); both issues require further analyses from different angles, addressing e.g. policy, economic and legal aspects.

The need for co-ordination between – and even within – SSOs represents a closely related aspect. Here as well political influence might be an option. The European Commission has established a new form of co-ordination mechanism – the Multi-Stakeholder Platform (MSP). It is tasked with guiding the European Commission on matters related to the implementation of ICT standardisation policy. This includes recommendations on which consortium standards should be approved for referencing in public procurement [Kallestrup, 2017]. The MSP might, therefore, be instrumental also for the co-ordination of the ESOs with international private consortia. Whether it may – and should – explicitly assume such a co-ordinating role[184] would be another issue in need of further analysis, as is the identification and analysis of other potential (top-down) co-ordinating mechanisms[185]. Wiegmann [2019b] identifies three modes of standardisation – committee based, market based and government based. It would appear that a mixture of these modes is used in Europe (the latter via 'standardisation requests' by the European Commission). A complementing, rather more low-level mechanism to co-ordinate the societally desirable with the technically feasible is presented in sect. 5.8.2.4 below).

Still looking at the aspect of soft regulation of standardisation the absence of private consortia in the field of grid standardisation has to be noted. It may at least be speculated that the heavy regulation of the power supply sector (certainly in Europe) contributes to this effect. Whether or not this is indeed the case, if this is a desirable situation or what could be done to change it are other aspects that warrant further studies. Fears of Chinese influence may be another contributing factor.

Leading entities have organically emerged in some sectors. The ITU-T, for example, has assumed a leading role for the IoT; the same holds for the IEC for smart manufacturing. Such leaders also imply some form of co-ordination, especially at the architecture level. The emergence of these two

[183] In 2019, funding provided by the EU and EFTA amounted to 21% of the total budget for CEN, 17% for CENELEC and 18% for ETSI (in 2018), according to the respective Annual Reports.

[184] Which would imply that not just consortium standards should be selected for approval, but also consortia (a much more demanding task).

[185] Wiegmann [2019] identifies three modes of standardisation – committee based, market based and government based. It would appear that a mixture of these modes is used in Europe (the latter via 'standardisation requests' from the European Commission).

organisations as leaders may in part be down to historical reasons (both had been active in predecessor technologies), but there may also be other reasons which should be identified.

Ballon & Hawkins [2007] offer a reason for the fragmentation of the ICT standardisation landscape that is worth considering: *"... in the ICT industry standards of every description play very significant strategic roles that coordinate technologies with markets as well as with other technologies. The fragmentation phenomenon may be an inevitable result of the needs of an ever increasing array of stakeholders ...*". To find out if there is indeed a causal relation between the number (and diversity) of stakeholders is another avenue worth following.

So far, the standardisation of smart applications and the communication infrastructure has been largely asynchronous. The major issue to be associated with this is the limited flow of requirements from the former to the latter. To improve the situation and to bring both strands of standards setting into synch would, among other aspects, require an alignment of timelines. If and how this can be done without hampering the standardisation process as such (like reducing the size of a window of opportunity) would be another aspect worth considering in more depth.

5.8.1.3 The Standardisation Process

So far, the assumption of largely mono-disciplinary work has implicitly been part of most standardisation processes (at least in the ICT sector); the same holds for the related conjecture of a rather homogeneous group of stakeholders (in terms of background, interests and technical expertise). The latter gas frequently been criticised, not least be EU legislators who call for "... *appropriate representation and effective participation of all relevant stakeholders, including SMEs, consumer organisations and environmental and social stakeholders* ..." EU, 2012, p.21] [186]. Today, this is rarely the case – in CEN, ISO and IEC participation of societal stakeholders is very limited; necessary consensus activities between stakeholders are supposed to occur at the national level, in ETSI, they are subsumed under the 'user' category with typically extremely limited voting rights (for lack of financial resources; see e.g. [Cuccuru, 2019], [Express, 2010]). Even liaisons with societal stakeholders are extremely rare – neither ISO/IEC JTC 1/SC 41 (Internet of things and related technologies) nor ITU-T SG20 (Internet of things (IoT) and smart cities and communities) list any on their respective web sites[187]. This situation is in urgent need of an overhaul. Interoperability *at all levels* is crucial for smart systems. To actually achieve it will in many cases require the co-design of applications and the supporting communication infrastructure and thus the co-operation of very diverse stakeholders. To do so will require to bridge several gaps, at both the technical and the cultural level (see e.g. [Bombieri & Pravadelli, 2016]); the latter probably being the more complex and time-consuming aspect. How exactly this bridging may be achieved requires additional research from a number of angles, including, but certainly not limited to, intercultural communication, negotiation theory and stakeholder theory. In any case, additional research will need to establish how a much higher level of multi-disciplinarity may be reached in standardisation work and if and how existing processes may need to be adapted to accommodate such integrativeness.

Responsible Research and Innovation (RRI) is a comparably recent trend that has recently gained momentum especially in Europe. V. Schomberg [2011, p.9] defines RRI as "*a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society)*". This quite nicely sums up the desirable situation in smart systems standardisation. Accordingly, a similar approach might be helpful in standards setting as well,

[186] For a research view of the issue see e.g. [Ho & O'Sullivan, 2017] or [Featherston et al., 2016].

[187] https://www.iec.ch/dyn/www/f?p=103:29:1216707054311::::FSP_ORG_ID,FSP_LANG_ID:20486,25#4
http://www.itu.int/net4/ITU-T/lists/representatives.aspx?Group=20&Period=16 (as of 8 May 2020).

depending on the non-technical (i.e. e.g. economic, legal, societal or environmental) ramifications of the technology to be standardised (see also [Wickson & Forsberg, 2015] and [Jakobs, 2021]). Further research will be required here as well.

5.8.2 Managerial Issues (for European Stakeholders)

Figure 1.3 shows the various influences that exist between the corporate environment and the standardisation environment, Figure 2.4 offers some more details about the standards setting side. The figures also show that external factors influence both environments. Based on the deliberations above this section aims to add an arrow to this figure – how corporate standardisation management may influence at least some of the external factors. Specifically, it will discuss a number of policy-related aspects that could be influenced, focussing on the European environment[188]. In addition, lessons that may be learnt from past developments in the field will be discussed.

5.8.2.1 General

ICT systems span the globe and, by definition, the associated standards need to be global as well. The task of regional standards then is to add regional[189] specifics (of e.g. regulatory nature) to international standards, while maintaining global interoperability. Alternatively, some such regional specifics may find their way into international standards. However, both cases require dedicated regional standardisation activities.

Firms need to identify the most promising candidate(s) for their standards-setting activities, taking into account the (nature of) links that exist between regional (European) SDOs and international ones on the one hand and those to relevant international consortia on the other, the relevance of these SSOs in their respective field and their general characteristics, rules and by-laws (see chapter 2).

A look at the relevant developments in Europe shows that ETSI's activities on smart systems are well positioned in the global context[190]. However, ETSI's focus is on rather more low-level wireless telecommunication services. The most notable activities in the field of smart applications are through CEN TC 278, which has been playing an active role in the ITS sector since 1992. Apart from that, however, CEN and CENELEC seem to have adopted a 'laggard' role, with CENELEC largely focussing on the transposition of international standards. Given the pioneering role that Europe in general and Germany in particular play in the field of Smart Manufacturing ('Industrie 4.0'; see e.g. [GTAI, 2014]), it seems strange that such a leadership position should not be translated into (indigenous) European standards that could eventually be adopted by ISO/IEC.

Against this background European firms need to carefully consider any national or regional activities in smart systems standardisation and the potential international impact they may have (as opposed to directly contributing to international standardisation, whether through SDOs or via consortia). An alternative approach would be to try to influence the ESOs and possibly the regulator to adopt a more pro-active role in smart systems standardisation, either through own activities or through close co-operations with relevant international bodies (specifically private standards consortia). Such an influence could only be exerted by an alliance of major companies active in smart systems development. Contributing to work of existing private consortia and even the establishment of a

[188] As an aside: In 1979, Siemens provided China with the full set of German standards and thus contributed quite considerably to the shaping of the Chinese standardisation system (according to private conversations with staff from both Siemens and CNIST; according to https://www.din.de/de/china-78866, this was done by DIN). If it was Siemens, this was a major achievement of Siemens' standardisation management as – despite all differences – the Chinese system is much closer to the European one than to the US system.

[189] Here, "regional" refers to any limited geographical region, also including national or even local.

[190] Through its smartM2M TC and its Partnership Projects (3GPP, oneM2M).

dedicated private (European?) standards consortium would also be options[191]. This holds particularly for large companies; for S(M)Es the benefits of reduced travel costs, national networking opportunities and language issues may well make national activities more attractive[192].

Standardisation is a costly business (see also sect. 1.2). It would, therefore, be beneficial if the market relevance of a standard were ensured from the outset. After all, the development of functionally similar standards is a phenomenon that is not unheard of in the ICT sector (IEEE 802.3/4/5, IEEE802.11/HomeRF/HiperLAN, ISO's ODF/OOXML). Today, the ESOs' associated requirements are rather limited[193]. It would be in the potentially involved firms' best interest if they prepared a joint market relevance study before engaging in a costly activity that runs the risk of producing a standard that will not be implemented on a sufficiently broad scale. Especially in the realm of smart systems such a study should not be limited to technical and economic aspects, but should also cover the societal dimension.

The issues of speed and inclusiveness present related problems. Here, an ex-ante evaluation of the optimal timing and an identification of the stakeholders that should be involved in the process should be most helpful. Such information could then be used to guide the process. This holds all the more as the recent Regulation [EU, 2012] highlights the need for speed and inclusiveness. Indeed, speed in the sense of 'timely standards' is important. The same in standards setting holds for inclusiveness, especially in the field of smart applications, which will have a considerable impact on everyone's lives. However, one size does not fit all. Neither speed nor inclusiveness are necessarily important for all kinds of ICT standards; the respective necessary and desirable levels of inclusiveness and speed vary between standards. A standard for the interconnection of a PC with peripheral devices does not require the same level of inclusiveness as one for data protection in Smart Cities. And a standard for a probably long-lived infrastructural technology should not be rushed, running the risk of ending up with a less than optimal solution.

In addition to the above, the recommendations made to European governmental and administrative bodies in [ProSE, 2011, p.42] can only be seconded here. Originally they relate to embedded systems (the not necessarily interconnected predecessors of CPSs), but they are equally valid and relevant for the standardisation of smart systems.

- "*Recognise the need to value standardisation and to take leadership of standardisation (in appropriate domains).*
- *Recognise the need to co-operate on standardisation across competitive boundaries and to reconcile and manage the differences that presently inhibit such co-operation.*
- *Invest in the efforts required to bring about standardisation, allowing staff the time and support to bring about long-term benefits.*

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[191] With a projected size of the smart manufacturing market alone of $205.42 Billion by 2022 (https://www.marketsandmarkets.com/PressReleases/smart-factory.asp) or $395.2 Billion by 2025 (https://www.grandviewresearch.com/press-release/global-smart-manufacturing-market) active participation in relevant standards setting activities may well be a promising avenue for many companies.

[192] This holds for both national mirror committees through which a certain international influence may be exerted and for purely national activities; the respective national market is highly relevant for very many SMEs.

[193] CEN, for instance, only requires a rather informal "Purpose and justification for the proposal" to determine if a proposal for a 'New Field of Technical Activity' (i.e. work to be done by a new technical body) or for a 'New Work Item Proposal' (i.e. new work to be performed by an existing technical body) corresponds to real market needs; the latter at least also requires the identification of "stakeholder categories immediately affected by the proposal" and information on environmental aspects.

- *Invest in people and RTD*[194] *in order to feed the technology pipeline that provides the basis for standardisation*".

5.8.2.2 The Standardisation Timeline

The standardisation environment for a smart infrastructure and smart applications has changed considerably over the past 20 years. During this period, the developments in the individual application sectors discussed above show similarities, but also differences. Regarding the former, the number of entities has mushroomed during this period, as have the links that exist between them. Standardisation in all sectors emerged from comparably humble beginnings around the mid-1990s to the fairly complex webs of SSOs we see today. The main reason for this increased complexity is the emergence of new and sometimes highly specialised SSOs, many of which are private consortia. Likewise, in all cases formal SDOs initially led the way; consortia and other 'non-traditional' entities joined only at a later stage. It could be argued that their emergence – and increasing importance – , in turn, eventually triggered the foundation of numerous new entities within the SDOs (TCs, WGs, etc.).

A closer look at the timeline of these developments reveals that the establishment of standardisation entities relevant for the IoT, ITS, Smart Manufacturing (SM), the Smart Grid (SG) and Smart Cities (SC) show a fairly similar pattern. The first wave of new entities appeared in the early-mid 1990s (for SM and SG; SC was not a topic for standardisation back then), followed by a second one during around 2008 – 2015 during which new entities were established at an almost explosive rate. For SC and the IoT, the first wave so far also emerged during that period. ITS standardisation followed a similar path, albeit a bit earlier and with less pronounced waves. The same picture emerges for mobile communication systems, where the peaks were in the late 1980s and mid-1990s, respectively. In all cases, we can observe a considerable drop in the creation of new entities after 2014/15.

Additional similarities may be found for SM and SC. In both cases, standardisation of simple 'predecessor technologies' started rather early and a notable agglomeration of SSOs may be observed over the past eight years. In the case of SG, this comes in the wake of the attempt (mostly of the industrialised countries) to reduce their dependence on fossil energy sources [EC, 2016]. Similarly, the trend towards SM may be seen as an attempt to maintain or improve competitiveness[195] (possibly versus emerging economies; see also e.g. [GTAI, 2014]).

Looking at the differences between the application areas, the comparably 'homogeneous' development of ITS standardisation is obvious. This *may* be attributed to the fact that lobbying entities and an overarching EU programme preceded (and perhaps helped trigger) the two 'waves' of SSOs creation. This sector has the most advanced integration of telecommunication with applications. In contrast, this integration is largely non-existent in smart manufacturing. Also, the rather dominant role of SDOs for smart grid standardisation is worth noting. The fact that this is a highly regulated area *may* at least be part of the explanation.

Considering the above, it may be expected that the number of specialised standardisation entities (SSOs, TCs, etc.) working on individual aspects of (e)merging applications and the IoT will continue to increase for a while, albeit a much slower pace (a fairly steep decline in the number of newly founded standardisation entities may be observed since around 2015).

The commonalities of the timelines of such different technologies like mobile communication and smart manufacturing (two waves of new standards setting activities and entities, with roughly 15 years in between) may suggest that a similar pattern can be found in other ICT areas as well; this would need to be verified, though. If such a common pattern could indeed be found, it would simplify the medium and long-term planning of a firm's standardisation activities. At the same time, however, the

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[194] Research and Technical Development.

[195] See e.g. https://ec.europa.eu/digital-single-market/en/smart-manufacturing.

dramatic increase of the number of standardisation entities will further complicate the decision to which SSOs' activities a firm should contribute. This is further aggravated by the fact that, for the time being, each SSO coordinates mostly internally (and even that is not necessarily always the case); co-ordination with other SSOs working in the same or in a relevant adjacent is mainly through more or less loose liaisons. Specifically, there hardly seems to be any formal cross-SSO coordination[196] (see sect. 5.8.1 for suggestions for possible remedies).

5.8.2.3 The Standardisation Environment

Already in 1995[197] Blumenthal & Clark [1995, p.431] observed that "*current processes for setting standards are facing increasing pressure from the pace of technological advance, the growing number of industry sectors involved, and the lack of coherent leadership to set a long-range direction for emerging standards*". It is quite remarkable that these problems still prevail after almost 25 years.

Smart systems standardisation requires input from a variety of disciplines with very different cultures, approaches to standardisation, technology life cycles and stakeholders. Moreover, it would be most beneficial if application and infrastructure were standardised under one roof (or at least in very close co-operation between the entities in charge) in order to better communicate requirements (top-down), technical constraints (bottom-up) and potential regulatory issues. Not least the European Commission has identified the need for such truly multi-disciplinary standardisation [EC, 2016b; see also sect. 5.3)]. They call for such standardisation in several application areas, including Smart Grid and Smart Cities. This could be exploited by interested companies to lobby for a dedicated platform for multi-disciplinary standardisation of smart systems in general. Such a platform could help bundle European expertise from the different relevant fields and thus eventually lead to a competitive advantage for the firms involved. In general, lobbying and forming an alliance to pro-actively move towards a dedicated standards-setting entity for smart systems appear to be the major options for corporate standardisation management in this field[198].

To bundle (European) activities would be desirable in several respects. For one, such a 'centre of gravity' would help to reduce the number of competing standards. If established at the European level, it could also help strengthen the European voice in international standardisation. Moreover, and from a more general point of view, the multi-disciplinary nature of smart systems standardisation and these systems future omnipresence imply that not just technical aspects need to be considered, but also e.g. societal and environmental issues; there as well smart applications' ramifications will be massive. This almost mandates an involvement of, on the one hand, stakeholders representing the non-technical aspects (e.g. societal, legal, environmental, ethical) and, on the other hand, of policy makers. The latter would suggest an entity under the umbrella of the ESOs[199]. A dedicated new (European) entity could cover all these aspects. Especially the need to enable active participation of the non-technical stakeholders also suggests that this new entity should deploy a standards setting process that provides for more inclusiveness and caters for a greater diversity of stakeholders than the current processes do. (for more details see e.g. [Jakobs, 2019], [Jakobs, 2021]). Such inclusiveness would also increase credibility and thus acceptance of the ensuing standards (see e.g. [Iversen et al., 2004], [Werle & Iversen, 2006], [EU, 2012])

[196] Private communication with Henri Barthel, a long-standing and high-ranking expert in the field.

[197] In that year the NSFNET Backbone, an important part oft he Internet, was switched off (as part of NSF's privatisation policy). Also in that year, the W3C was founded (see also [Leiner et al., 2009]).

[198] Another way forward in this context would be the improvement of the link from R&D and standardisation. After all, quite a bit of research on smart systems has been going on in Europe over the past years; e.g. by the ECSEL Public-Private Partnership and the ARTEMIS Industry Association (https://artemis-ia.eu/ for CPS and by e.g. IMS in the area of smart manufacturing the http://www.ims.org/). But in the context of this thesis this is considered a company-internal issue (see Figure 1.2) and is thus outside its scope.

[199] The CEN-CENELEC-ETSI Sector Forum on Smart Cities and Communities could be such an entity. Yet, so far it has been acting solely in advisory and co-ordinating capacity; see https://www.etsi.org/technologies/smart-cities.

In the ICT sector in general and in the case of a smart infrastructure in particular interoperability is the one overriding requirement. And while interoperability, in turn, requires underlying standards, it also requires the existence of interoperable implementations of these standards[200]. This simple observation suggests that some entity should also look at implementation-related issues. These include the specification of functional standards[201] as well as the actual implementations and possibly a subsequent certification. The creation of such an entity should also be considered by European policy makers and companies. After all, being able to demonstrate both standards-compliance and interoperability through e.g. a certified reference implementation or interoperability tests would definitely constitute a competitive advantage.

In summary, an extension of the current (European) standardisation system would appear to be a viable option to address the specifics of smart systems standardisation outlined above. Figure 5.21 provides a rough sketch of how such an extension might look like.

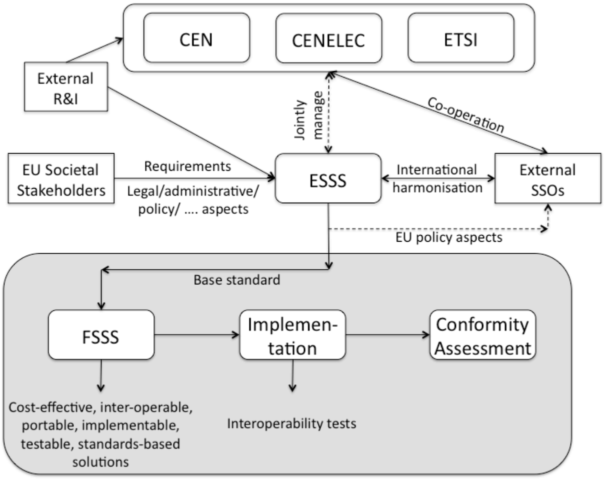

Figure 5.21: A proposal for an extended European Standardisation System for smart systems (adapted from [Jakobs, 2017a])
ESSS = European Smart Systems Standardisation, FSSS = Functional Smart Systems Standardisation

The grey shaded part in the Figure is specific for interoperability standards. The remainder, i.e. a dedicated, specialised organisation with an inclusive process and managed by the ESOs, might well be a model for the standardisation of other emerging technologies with major e.g. societal, environmental and/or ethical ramifications.

5.8.2.4 The Standardisation Process

Prior to any active involvement in the standardisation process all stakeholders, from large multi-nationals to small NGOs (or perhaps individual citizens), need to address some basic questions. They

[200] For the difficulties to provide interoperability despite existing standards see e.g. [Egyedi & Dahanayake, 2003].

[201] This is not necessarily done (see e.g. [Egyedi, 2007]). In the 1980s/90s the European Workshop on Open Systems (EWOS), therefore, developed functional standards (then based on ISO's OSI suite of standards) in close co-operation with CEN/CENELEC and with support from the EC. While functional standards are not the same as implementations, they represent a step towards them.

include: why, what, how, where, and when to participate? Looking specifically at societal stakeholders, the questions they will need to answer are[202]:

- Why should we participate (if at all)?
- How could we participate most effectively and efficiently?
- What could we contribute?
- Which would be the best entity/entities[203] to contribute to?
- When, i.e. at which stage of the process would our contributions best serve our interests?

First, why participate at all? After all, such commitment implies major expenses, with a very uncertain 'return on investment'. In fact, only companies with an interest in the technology to be standardised may hope for an economic gain through participation in the standards setting process. Societal stakeholders, on the other hand, will need to recognise that they stand to suffer from standards that only reflect the technically feasible or the economically desirable (from a corporate perspective, as opposed to a societal one). Whether or not many companies will be prepared to adequately take into account environmental or ethical aspects, for instance, remains to be seen, all the more so if these aspects are at odds with their respective economic deliberations. Yet, the 'why participate' question has more dimensions to it. 'Funding' would be one. Within limits, European stakeholders' organisations (ANEC[204], ECOS[205], ETUC[206] and SBS[207]) receive funding from the European Union for their contributions to standardisation. Yet, to have these organisations' voices adequately heard in all relevant fields, notably including smart systems standardisation, will require considerably more (public) funding. Whether or not these organisations actually have a widely accepted mandate[208] may become another open question. For example, the organisation to "*represent social interests in the standardisation process*" [EU, 2012, p.31] almost exclusively focuses on cases where "*standardisation projects impact the health and safety of workers*" [European Trade Union Institute, 2018, p. 47].

For the time being, the answer to the question how societal stakeholders (should) participate in standardisation would be "*through the above stakeholder organisations*"[209]. Yet, two issues are associated with this approach. Looking at the participation of SME user companies in standards setting, Jakobs [2005] reports that WG members would particularly welcome their delegates if they represented a relevant umbrella organisation (as opposed to their respective individual employer). On the other hand, requirements on a standard (and on a technology) are "*closely linked to the particularities of the respective local environment*" within which it is to be implemented [Jakobs, 2006, p. 35]. An analogue argument may be made for the contributions of societal stakeholders. Obviously, this makes the contribution of more general requirements via an umbrella organisation, representing a wide range of diverse stakeholders, much more difficult if not impossible.

What could societal stakeholders contribute? At a very general level, they should establish whether or not a standard to be developed would be desirable form a societal perspective. Aspects to be considered in this context would include, among others, social, environmental and ethical ones. These

[202] The following discussion is only supposed to provide food for thought. Getting comprehensive answers to these question would require (at least) another thesis.

[203] I.e. e.g. SSOs, TCs, WGs.

[204] The European consumer voice in standardisation.

[205] European Environmental Citizens' Organisation for Standardisation.

[206] European Trade Union Confederation.

[207] Small Business Standards.

[208] See [EU, 2012] for the selection criteria.

[209] At least according tot he European Commission.

deliberations should result in a set of requirements that could be fed into the technical standardisation process and which the eventual standard would have to meet. 'Communication' would be an inherent problem here, as would be the different perceptions of technology held by the 'technical' side (e.g. engineers or computer scientists) on the one hand and societal stakeholders on the other. These different perceptions would need to be aligned, which would require a learning process on both sides; the 'technical side' will need to gain some understanding and appreciation of the (potential) non-technical ramifications of their work, societal stakeholders will need to get at least some idea of what technology can do and what it cannot. Yet, this is not just about mutual learning. In an environment with such diverse actors, many of whom have never co-operated before, communication problems are highly likely to occur. That is, an initial lack of mutual common understanding may be assumed and so trust will become all the more important for a meaningful collaboration. Rosenkopf et al. [2001, p. 754] note that "*frequent and sustained face-to-face meetings among firm representatives engender trust and collaboration among alliance partners*". The importance of face-to-face meetings is further corroborated, albeit from a slightly different angle in [Kramer & Cook, 2004], who note that "*Trust theorists have long argued the benefits of face-to-face interaction and direct experience with others in the trust-building process*" [p. 12].

The literature frequently views the standardisation process as something akin to an atomic unit, which cannot be subdivided any further (see e.g. [Foray, 1994], [Iversen et al., 2004]). Yet, a variety of very different organisations are active in the standardisation arena. Thus, 'where to participate?' is another relevant question, and perhaps the most complicated one. This complexity is caused by the almost impenetrable web of SSOs, which is characterised by nodes with very different characteristics (in terms of e.g. membership base, technical competency, credibility, by-laws, IPR regulations; see [Wiegmann, 2019] for an in-depth discussion) many of which are interlinked by a rather bewildering variety of co-operation agreements and liaisons (see also Figs. 2.1 and 2.2). Adequate knowledge of these characteristics and agreements will be most helpful. For instance, consider the link between EPCglobal and JTC1 in Fig. 2.2. The EPCglobal consortium is widely considered as being largely driven by users. This is not normally the case for other SSOs, where users typically are dramatically under-represented. Utilising the co-operation between EPCglobal and ISO, user companies may be able to (indirectly) influence the process within ISO by submitting their proposal via EPCglobal (where exerting influence is easier for users), as opposed to a direct contribution to the ISO process [Jakobs, 2014].

Figure 5.22 shows the different stages of a standard's life cycle of, from requirements elicitation to removal. This suggests the final question: At which stage(s) of the overall standardisation process ('when') should societal stakeholders participate? This problem is closely related to the question of what societal stakeholders can contribute to standardisation. The most obvious answer would be 'at the requirements elicitation phase' (Figure 5.22, left). In ISO terms, that would mean during the first three project stages). Moreover, they could contribute to an evaluation of a standard that has been implemented and used for a certain period of time. This evaluation would be part of the 'Maintenance' phase and could lead to a revised version of the standard, depending on the input from all stakeholders.

Project stage	Task
Preliminary	New standard proposed to relevant TC
Proposal	
Preparatory	WG of experts prepare a Working Draft
Committee	First WD shard with TC and Secretariat
Enquiry	Draft shared with all ISO national members
Approval	Final Draft sent to all ISO members
Publication	Standard published

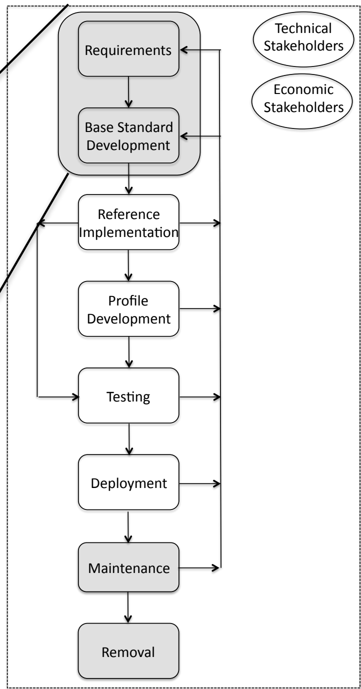

Figure 5.22: A standards life cycle (right)
The ISO project stages that relate to the first two phases (left) (the shaded phases denote typical SDO activities)

The above has highlighted some of the problems to be associated with the diversity of stakeholders that are, or rather should be, active in the standardisation of smart systems. These include, among others, communication problems, likely (initial?) lack of mutual trust, different and possibly contradicting interests and very different competencies. Considering the potential societal, environmental and ethical ramifications especially of smart systems (see sect. 5.8.1.3 and e.g. [Wickson & Forsberg, 2015] and [Jakobs, 2021]) and the importance of social capital in standards setting (see sect. 3.4.2), this is an untenable situation. A modified standardisation process could be a potential way to at least reduce some of these problems. This process would largely decouple requirements elicitation and compilation from the primarily technical work[210] that would aim at building a system that meets as many of these requirements as possible. The right hand side of Figure 5.23 again shows the 'traditional' standards life cycle. Most SSOs' activities focus on the grey-shaded stages at the top[211]; societal stakeholders input would mostly be fed into these phases. Their tasks and required input are depicted on the left hand side[212]. Ultimately, they would recommend to proceed with the planned activity or to stop it[213]. Once the process has started, societal stakeholders would contribute requirements to the technical part of the process.

[210] This technical work would, of course, still be influenced by stakeholders' economic interests.

[211] Exceptions include e.g. the IETF and the W3C, both of which require interoperable reference implementations as part of their process.

[212] This is pretty much in line with ETSI's Recommendation to "*Ensure that for new topics, there is a clear assessment of who are the interested stakeholders and involve them fully in the process, and do so in a collaborative way between the interested SDOs in advance of the work starting*" [ETSI, 2020, p.29].

[213] Obviously, this process would need some refinements like perhaps a moderating entity that could become active in case of a no-go decision by the societal stakeholders. But elaborations here are outside the scope of this thesis.

One benefit of this approach would be that the technical part would remain unchanged. Moreover, the communication between the technical and the societal world would mostly occur via one well-defined interface. Benefit number three would be that the level of involvement of the societal stakeholders in the 'classical' part of the process (and thus the associated costs) would be significantly reduced. This, in turn, might encourage a broader variety of these stakeholders to become active in 'their' part of the process. Overall, this should contribute to a stronger societal representation.

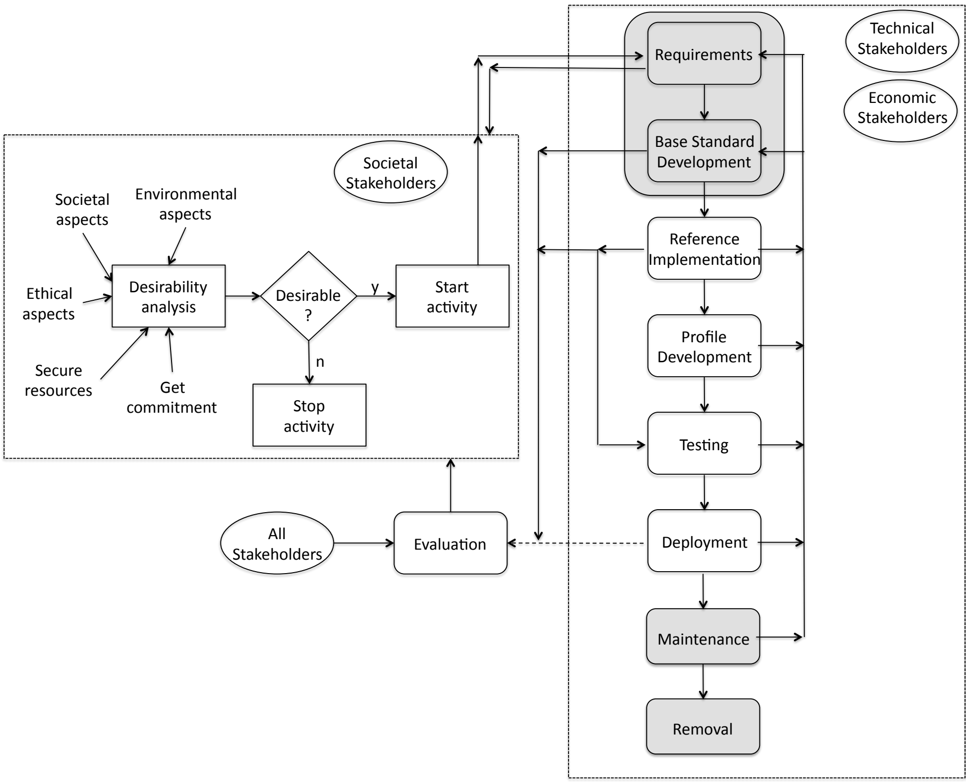

Figure 5.23: An adapted standardisation process

It may be expected that this addition to the standards setting process would prolong the overall process. The need for speedier standards development has frequently been emphasised, not least by the European Commission [2012]. On the other hand, several authors have put speed into perspective and argued that it must not be overriding aspect (see e.g. [Mähönen, 2000], [Rada, 2000], [Sherif, 2003], [Sherif et al., 2007], [van Wegberg, 2004]). Along similar lines, Biddle [2019] observes that e.g. in hardware standardisation organisational consensus is more important than development speed, while Shin et al. [2017] highlight the dichotomy of speed and co-ordination and note that the latter typically leads to higher quality technology. Specifically, for ubiquitous technologies like smart systems, with huge ramifications on virtually all sectors of society, speed should take a back seat; aspects like sustainability, interoperability and true added societal value of the technology should take precedence.

The evaluation (following a period of deployment) is another element added to the process. These days, the one related activity is the potential revision of a base standard, following a review process (e.g. every five years for ISO standards). The proposed evaluation is similar but has a broader scope in that it also covers profile and implementation/interoperability aspects. Moreover, a standard's societal and socio-economic dimension shall be considered as well, as shall be any issues that have emerged with respect to the interworking with other standards

5.9 Final Remarks

This chapter aimed to sketch how the standardisation environment for a smart communication infrastructure and for (e)merging applications may look like in the future. To this end, it described in detail the current environment, including its actors and the co-operation between them (if any) and how it has developed of the past 20 years. This environment's complexity has grown considerably during this period, in terms of both number of players and of number and type of links that exist between them. It appears highly unlikely that this development will be reversed any time soon. Accordingly, the deliberations how to optimally support their goals has become more complex as well for stakeholders. In many cases it will be necessary to contribute to (or at least observe) the ongoing developments in an ever larger number of SSOs.

In addition, new skills and expertise will be required from those who will need to actively contribute to multi-disciplinary smart systems standardisation. This is particularly bad news for Small and Medium-sized Enterprises (SMEs), who frequently struggle with both inadequate knowledge about the standardisation environment and very limited resources (see e.g. [Riillo, 2014], [EU, 2012]). On the other hand, if the projections for the market for smart applications and for smart infrastructures are anything to go by, the potential revenues to be made should easily warrant an extra effort.

The timelines of SSO formation across the different applications and infrastructure technologies show some similarities. The same may be said about the increasing (over time) complexity of the respective standardisation landscape. It is too early to judge – and outside the scope of this thesis anyway – whether a company can bring itself in a favourable position through early participation in the process (when the web of SSOs active in the field is still comparably simple) or if jumping the bandwagon during the second wave of newly established standards setting entities is the preferable strategy (and under which conditions).

Not just the individual standardisation landscapes become increasingly complex. The need to align the standardisation of the different smart applications with that of the underlying smart communication infrastructure (and possibly also with each other) will complicate the situation even further. The example of e-medicine shows that a lack of globally accepted standards (as opposed to a number of proprietary and/or competing ones) may lead to a very fragmented field with massive interoperability problems. Such an environment favours those with strong R&D who wish to a proprietary technology as a standard.

Despite the above, in the realm of smart systems competition between standards occurs mainly at the infrastructure level, where money stands to be made by selling standards-based communication equipment (just think IEEE 802.11; see Chapter 3). Here, the necessary alignment between applications and infrastructure standardisation may allow to shape the latter through requirements emerging from the former. However, the timelines show that these two levels of standardisation still proceed rather independently. The uncertainty on the application side about the future dominant infrastructure technology, i.e. whether or not everything will eventually be IP-based is a case in point. A development towards smart all-IP networks would also cause a power shift between SSOs, with e.g. the IETF and the W3C becoming more important. Likewise, large companies like Google or Apple may play succeed with proprietary technologies.

The previous sections have already pointed to the various socio-economic, societal, legal, environmental and ethical ramifications of smart systems, which are primarily rooted in their sheer ubiquity and, indeed, likely inescapability. This true ubiquity virtually mandates that societal and ethical issues also have to be taken into account during standards development. To this end, the need to represent especially societal stakeholders' interests will lead to the involvement of 'exotics' (in the standardisation world) including citizens, environmentalists, NGOs, unions as well as politicians and perhaps also sociologists and philosophers will have to have a say in one way or another.

To accommodate this need and also to bundle European smart systems standardisation activities a dedicated new entity may be a way forward[214]. The ESSS/FSSS depicted in Figure 5.21 might be seen as an example; the former could be implemented as a TC jointly managed by the ESOs, the latter could be an adapted 'reincarnation' of the European Workshop on Open Systems (EWOS), which produced functional standards for the OSI environment in the 1980s/1990s. This entity should, on the one hand, deploy a process that accommodates the participation of a much broader variety of stakeholders, the incorporation of the related equally diverse expertise and requirements. On the other hand, it should minimise the communication problems likely to emerge given the diversity of the stakeholders to be involved in the standardisation process. It should also be noted that such a new platform would, in all likelihood, subsume a number of existing entities and would thus ultimately reduce the standardisation environment's complexity.

[214] This holds despite the fact that practitioners' views on such an entity vary but tend to negate the need for it.

6 Discussion

So far, literature has paid comparably little attention to the topic of standardisation management. This holds with the one major exception of standards wars, which have been studied extensively, mostly from an economic perspective, but also from a managerial point of view. In the late 1990s, the idea of strategic standardisation management generated a certain level of interest, albeit more among practitioners than in the academic literature. Moreover, a number of papers discuss aspects that relate to standardisation management without making this link explicit, whether intentionally or not. In the past couple of years the topic has gained some momentum; whether or not it is sustainable remains to be seen.

Economics continues to be a highly popular discipline in the field of standardisation research[215] and standardisation management is no exception (see above). In contrast, and to complement economic insights, the previous chapters look at the topic from a decidedly non-economic vantage point. They aim to identify important but frequently overlooked aspects of standardisation management. Specifically, these include elements of the cultural, procedural, technical and temporal dimensions (see Fig. 1.7). These have been addressed in chapters 2 – 5. The following discussion will be structured in an orthogonal way around three levels and will also address some more recent developments:

- The internal corporate environment (sect. 6.2).
- The specific standards setting activity (sect. 6.3).
- The wider standardisation environment (sect. 6.4).

First, however, the key outcomes will be summarised in sect. 6.1. The managerial implications of the thesis' findings will be discussed in sect. 6.5 and the resulting implications for research in sect. 6.6. Of course, this study has its limitations; they will be addressed in sect. 6.7. Finally, some brief concluding remarks will be made in sect. 6.8.

6.1 Summary of Key Outcomes

6.1.1 General Framework

The overall goal of the thesis has been to

Discuss important, but frequently overlooked dimensions of standardisation management and incorporate them into a general framework.

To this end, five, rather more abstract, dimensions – temporal, cultural (for both firms and SSOs), procedural and technical – have been discussed in depth. These discussions led to the identification of five factors (along with sample constituting elements) that (may) exert an influence on standardisation management and/or directly on standards setting. These factors, along with their respective links to corporate standardisation management (CSM), form the framework that is depicted in Figure 6.1. This is a far cry from the still visible 'technicalistic' view of standardisation, which highlights conformance, compliance and performance. It also represents an elaboration and refinement of the Strategic Standardisation Management approach (see sect. 2.3.1.4).

The nature of the links between the individual factors and CSM differs. The 'Individuals' who, on their part, influence standardisation are under the control of CSM (at least to a certain degree; this differs between own employees (sect. 3.5.4) and others (see sect. 3.4.2). Influencing the 'Standardisation Context' will occasionally be possible, albeit difficult. Here, a certain influence may be exerted at two levels: For one, it may be possible (for powerful firms) to influence e.g. by-laws and

[215] It is also the one with the longest tradition in this field.

IPR regimes of an SSO[216]. Complementing this, the context of any new individual standardisation activity may be influenced from the outset by the choice of SSO. 'Competing/Complementing Activities' may also be influenced up to a point, e.g. via alliance forming, buy-outs or acquisitions.[217] To influence the 'Corporate Characteristics' will in most cases be next to impossible for CSM; it will typically need to adapt and/or to implement. The same holds for the 'Exterior' factor, which CSM will only be able to influence in very exceptional cases (see sect. 5.8.2).

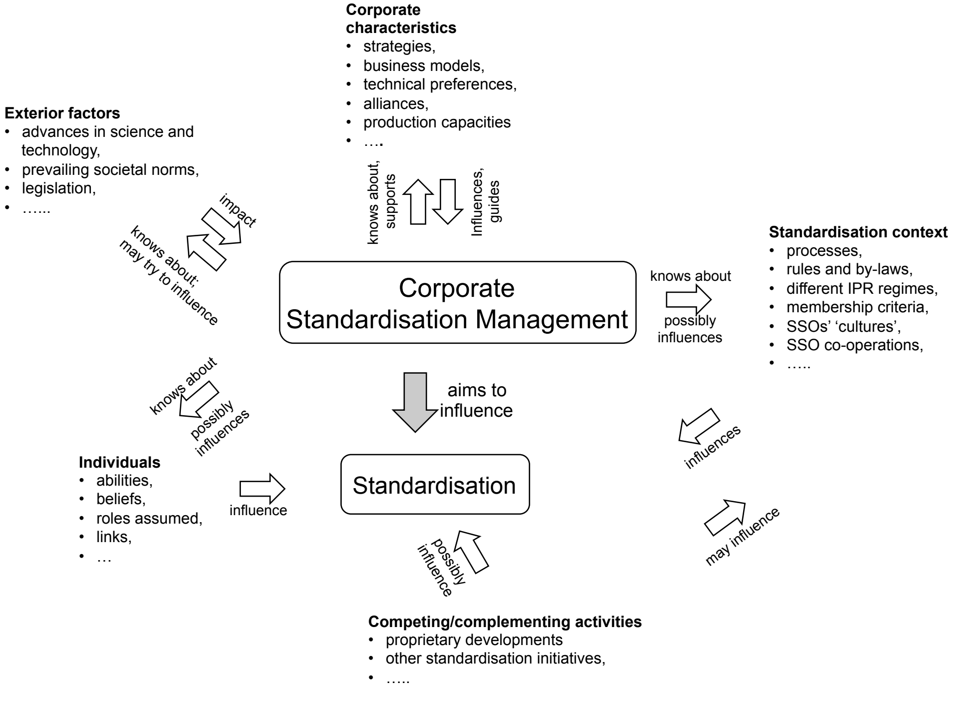

Figure 6.1: A framework for corporate standardisation management

6.1.2 Specific Key Findings

The overall discussions so far suggest that a firm's awareness and appreciation of the strategic importance of standards is the 'sine-qua-non' that underlies any standardisation management. Without this awareness, standards setting will remain a largely technical exercise despite its potentially enormous strategic (and economic) ramifications. In addition, the standardisation management function needs to have the means and the power to actually transpose this awareness into concrete action.

In the following, the key findings (from a firm's perspective) that result form the discussions so far will be listed, along with a brief explanation. They appear roughly in their order of importance, as perceived by the author[218].

[216] Baron et al. [2019, p.39] observe that firms with a strong IPR portfolio are also "… *more likely to devote more resources (personnel and financial) to engaging in and seeking to influence policy debates through activities such as public advocacy, lobbying, research support, and the like*".

[217] That happened e.g. to the company discussed in sect. 2.7.

[218] That is not to say that any of them is not truly important.

- It is crucially important to align the (external) standards setting activities with corporate criteria and goals [Chapter 2].
  Standards setting is not an end in itself. Rather, it is a means towards the realisation of corporate goals. Unless standardisation does not serve to reach these goals, it is little more than a waste of resources[219].

- Clear goals for a firm's involvement in a particular standardisation activity need to be defined up-front (and subsequently acted upon accordingly) [Chapter 2].
  This relates to the above. All corporate goals must be identified up-front for each individual standards setting activity. Moreover, they need to be clearly communicated to all corporate representatives that contribute to these activities.

- In almost all cases it will be necessary to form alliances in order to impact standards setting [Chapter 4, 5].
  Few firms have the power to push a proprietary technology towards a (committee) standard. Accordingly, allies need to be found. This holds for both the corporate and the individual level. The latter is necessary as corporate alliances to not necessarily translate into the according actions of individuals. Some form of monitoring may be advisable.

- The availability of capable individuals and their social capital within a WG are essential for effective and efficient standardisation work [Chapter 3].
  This links to the above. Social capital is crucial in order to form alliances at the individual level and thus to get support for proposals and, ultimately, to influence votes. Representatives need to be adequately trained and informed about the nature and background of their tasks. Moreover, their loyalty towards their employer needs to be assured.

- It is a good idea to try and learn from the past and to apply this knowledge to ongoing activities [Chapter 4].
  Many lessons may be learnt from past standards setting activities, mostly from failures, and care should be taken not to repeat earlier mistakes. This may imply the need for preparatory actions and measures to accompany the actual standards setting activity. Specifically, for any standardisation activity it is important to ensure that potentially necessary underlying or complementing standards are available in time.

- Multi-disciplinary standards setting will become increasingly important [Chapter 5].
  Smart systems development involves numerous different disciplines. The same holds for the standardisation of these systems. On the one hand this will require an approach to standardisation that caters for such multi-disciplinarity. On the other hand individual standards setters will need to acquire new skills and knowledge in order to successfully continue their work.

- It may well pay to try and influence policy making [Chapter 5].
  European policy makers have a considerable influence on the ESOs. If a (European) firm considers changes within the context of the European Standardisation System lobbying the European Commission may, therefore, well be a way forward. This may particularly help strengthen or initiate indigenous European standardisation efforts, e.g. in the field of smart manufacturing ('Industry 4.0').

[219] There may be 'semi-exceptions'. A company may leave it to its representatives in a WG to decide about the best technical solution to be standardised. But even then the resulting increased market size is a strategic goal and in the best interest of the company (thus the 'semi'; see also sect. 2.5.3).

- The alignment of standardisation activities with internal development capacities will be beneficial [Chapter 2].
  A company that aims to capitalise on a first-mover advantage will need to be able to ship standards-based products as early as possible, ideally even before the final version of the standard has been published. To be able to do so it will be necessary to ensure that adequate production capacities are available in time. This, in turn, may imply the need to speed up or defer the process.
- One needs to remember that different SSOs have different 'cultures' [Chapter 2, 3].
  These different cultures need to be taken into account when selecting the most suitable individual(s) for an assignment to a given SSO. A high degree of assertiveness may be more important in the IETF than in ITU-T, for instance and language skills may be less relevant in purely technical discussions than in more strategic ones.
- A formal leadership role may be a double-edged sword [Chapter 2].
  Generally, leadership roles (chairperson, editor, rapporteur, etc.) provide the opportunity to influence the standardisation process in one way or another. This may be beneficial if, for instance, a firm needs to adapt the speed of the process. However, a chairperson has to adopt a neutral position (as opposed to represent e.g. a company). This 'loss' of a typically well-qualified person may well be considered a downside, certainly for a smaller company with a typically small number of qualified employees.
- Generally, it is important to monitor the standardisation environment to identify – at the strategic level – the most suitable SSO(s) for each potential activity [Chapter 5].
  The ICT standardisation landscape is rather dynamic – new entities and links are established, others vanish and SSOs' by-laws and IPR rules may change. These changes may well have an impact on ongoing activities as well as on those about to be initiated.

6.2 The Internal Corporate Environment

The probably one single most important aspect to be observed in standardisation management is the alignment of the (external) standards setting activities with corporate criteria. The criteria may be manifold. They may include, for example, corporate goals and strategies as well as internal timelines, production capacities and, last but not least, the available human resources. Moreover, the requirements of business partners on a potential future standard may need to be considered as well as the presence of any potential allies and opponents in the process. Even very powerful firms with deep pockets will find it difficult (if not impossible) to reach the desired outcome of a standards setting activity without any allies. This implies the frequent need for compromises as the allies' needs and requirements will also have to be taken into account. Accordingly, it is highly unlikely that, for example, one firm's proprietary technology will be 'elevated' to become a standard without significant changes.

Related to the above is the importance of well-defined goals for a firm's involvement in a particular standardisation activity. These goals[220] need to be very clear from the outset and also need to be communicated to the firm's representatives in the process. Such goals may be both 'hard' and 'soft'. The former include e.g. (in decreasing order of complexity of achieving it)

- push a proprietary technology (with the associated problems; see above);
- incorporate essential patents into a developing standard;
- make sure that the standard meets certain corporate requirements;
- intelligence gathering.

[220] See also [Wiegmann et al., 2022].

Each of these goals will require a different approach, from passively joining an existing activity via actively contributing to an existing one to, ultimately, the establishment of a new standards consortium to standardise a firm's proprietary technology.

'Soft' goals may include;

- credibility improvement;
- marketing aspects (appear as competent and leader in the field);
- establishment and/or maintenance of business relations (with e.g. customers, suppliers, peers).

Once the corporate criteria (including the goals) have been established the decision which role to assume in the process should be rather straightforward. This will mostly depend on the perceived strategic importance of the activity, but the availability of suitable staff any other criteria will also play a role. In general (though not necessarily), a certain type of organisational strategy will be associated with a certain role in standards setting.

There are other related aspects that need to be considered as well. These include a clear definition of what exactly should be considered as 'success' for each individual activity. Clearly, 'success' relates – or rather, should relate – to the role assumed (see chapter 2) and thus to the corporate goals that underlie each standards setting activity. These goals may differ widely (see above), even if each activity is aligned with the overall business strategy.

Similarly, a 'micro-strategy' and 'micro-tactics' need to be defined for each individual activity. They will need to be within the framework of the overall strategy, but boundary conditions may – and will – vary between activities. Specifically, they will also need to take into account the characteristics of the respective standardisation activity (see sect. 6.2) and the standardisation environment (see sect. 6.3).

In this context, the availability of adequately capable individuals also plays a crucial role. What exactly makes a person 'capable' of successfully completing a certain task in standards setting depends on the respective task and the environment within which it needs to be performed. Typically, the necessary skills will comprise a combination of technical expertise, procedural knowledge, diplomatic, rhetoric and presentation skills, deal-striking capability, assertiveness and amiability. A suitable combination of these skills will enable standards setters to accumulate social capital in the respective groups they are working in. If need be, such social capital may also be brought in from outside, e.g. by employing external consultants for particular activities or by hiring people. In any case, to make sure that capable and well-respected people represent the company in standards setting is a crucial yet frequently overlooked task. On top of that, and probably most importantly, all representatives need to know what they are supposed to do, and why. That is, they need to have an in-depth understanding of the corporate goals underlying each standards setting activity.

6.3 The Specific Standards Setting Activity

Typically, the technical standardisation work takes place in working groups (WGs). Each individual WG is a micro-cosmos of its own. Its work is shaped, on the one hand, by the rules and by-laws of its respective parent SSO (covering e.g. membership aspects, voting rules, IPR policy, etc.). On the other hand, the interests of the firms and other organisations represented in the WG and the links that may exist between them (e.g. ally, competitor, supplier, customer) are of relevance. The needs of the wider market also play a role, as do external forces that may be of e.g. regulatory, cultural, ethical and technical nature.

Typically, a WG works on a specific task (which may have sub-tasks). For each such task, a firm will need to establish a dedicated strategic approach, which takes into account its own goals as well as the shaping factors discussed above. Once this has been done, the more 'tactical' aspects need to be addressed; these will then need to be implemented by the firms' representatives in the WG. In fact, when it comes to a firm's successful participation in standards setting, the perhaps most important and certainly the most frequently overlooked aspect are the people who populate the WG[221].

In this context, social capital is an aspect of overriding importance. In a consensus-oriented process (with eventual voting) like standards setting it is next to impossible, even for the most powerful companies, to succeed without any allies. And while alliances may have been established at firm level up-front, they do neither necessarily translate into the same alliances at the personal level ('just because my company trusts your company I do not necessarily trust you') nor to the intended voting behaviour (see below).

Accordingly, a WG member's most valuable (soft) skill is the ability to accumulate social capital. To be able to do so an adequate level of trust is a crucial pre-requisite. Trust, in turn, can only be gained over time, so long-standing, continuing involvement in a standardisation activity is important (as opposed to showing up only occasionally). Figure 6.2 shows (some of the most important) constituents of social capital.

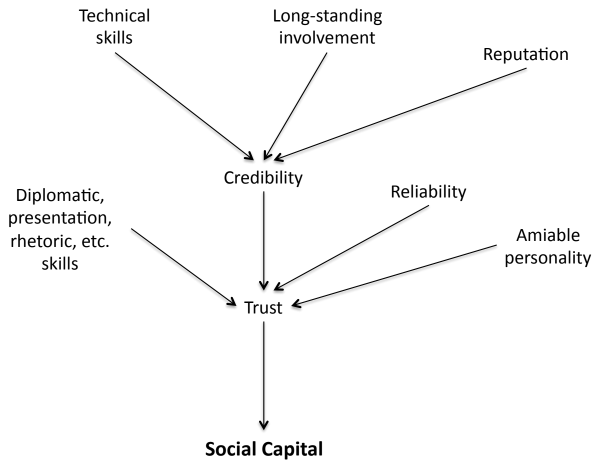

Figure 6.2: Some important constituents of social capital

'Credibility' is an important contributor to trust and thus to the ability to build up social capital. To acquire its elements – technical skills and reputation – typically takes a long time. One solution to this problem has been the recruitment of external experts specifically for this purpose[222].

In some respect social capital is a double-edged sword, though. The bonds that may be established between long-time co-workers in a WG may eventually become stronger than the loyalty towards the employer. As a result, informal alliances may be formed that may or may not be in any firm's best interest. Apparently, this does not happen too frequently, though (see also sect. 3.3.4). Moreover, and depending on their respective character and abilities individuals' behaviour in a WG will differ and

[221] The rules of numerous SSOs (e.g. CEN/CENELEC, ISO, IEC) require WG members to act in their capacity as technical experts, not as national or company representatives. For a more realistic account see chapter 3 and e.g. [Henrich-Franke, 2008], [Isaak, 2006], [Jakobs et al, 2001]).

[222] See [Jakobs, 2016] for some evidence. Moreover, it could be observed that some of the big names in standardisation, especially those active in the standardisation of the Internet, gravitated to the big players. For instance, Harald Alvestrand was hired by Cisco in 2001, three months after he had become Chair of the Internet Engineering Steering Group. Vint Cerf, 'Father of the Internet' and co-designer of the TCP protocol, went to Google in 2005 when he was Chairman of the Internet Corporation for Assigned Names and Numbers (ICANN).

different roles may be assumed. In any case, from a firm's perspective it would be a good idea to monitor its representatives.

The goals underlying a firm's participation in standards setting will differ between activities. Moreover, the characteristics of the individual activities differ as well – the standardisation of, say, an extension of an existing programming language is a much more technically-oriented exercise than the development of, for example, initial standards for smart cities and communities. Along similar lines, the existence of Standards Essential Patents (SEPs), held by different players, may add a strong economic dimension to a standardisation activity. Accordingly, the necessary skill sets of the respective representatives will differ as well. In the examples above, technical expertise will play a dominant role for the extension of a programming language. In the case of initial smart city standards, presentation and rhetoric skills will be more important. When SEPs join the game, abilities like deal striking and even alliance forming will become more relevant.

Related to the above, and also depending on a firm's goals, it may well be helpful to try to assume a formal leadership role (e.g. chairman, editor, convenor, rapporteur). This will be particularly important (albeit not strictly necessary) if a firm either generally aims to adopt the role of a 'Leader' or if the process needs to be aligned with the firm's internal developments. While the role of the chairmen may potentially have its drawbacks, that of the editor appears to be more important and powerful than one might initially assume.

'Cultural' differences between SSOs also play a role. ITU-T, for example, with its rather formal procedures will hold appeal to a different type of person than the slightly chaotic proceedings within the IETF. This also relates to the rather more mundane aspect of language skills – not fully adequate proficiency in English is highly likely to be less of a disadvantage in a more formal setting (as it is for purely technical discussions). This may at least in part explain the apparent attractiveness of the ITU for e.g. Chinese companies.

6.4 The Wider Standardisation Environment

Looking at today's standardisation environment and its development over that past decades, 'complexity' is a term that immediately springs to mind. This complexity has several dimensions. For one, the global standardisation environment itself has become highly complex. A couple of hundred SSOs (both 'formal' SDOs and consortia of different types) are now actively developing ICT standards. Cargill [1999] describes how primarily large US companies started forming private standards consortia in the early/mid-1990s to bypass the formal SDOs' slow processes and, more importantly, to increase their impact on standards development. At least initially, these consortia resembled those alliances companies formed to be successful in a battle for dominant design to be fought in the market (see also chapter 4). SDOs had been marginalised in the crucial fields 'Internet' and 'World Wide Web' (by the IETF and the W3C, respectively). This may at least partly explain the mushrooming of new SDO entities in field of the smart systems, which may be seen as an attempt to regain relevance in an important emerging field.

The huge differences between SSOs represent a second dimension of complexity. They differ widely in terms of e.g. technical relevance, membership base, available levels of membership (this is mostly relevant for consortia), membership fees, by-laws, financial situation, embeddedness in the overall system (e.g. links to other SSOs) and, typically most importantly in the ICT field, the respective IPR rules. Differences also exist in term of 'soft' aspects like (perceived) credibility and 'popularity' in the field.

For the above reasons, convergence to one set of standards for smart systems, ideally developed by one entity, is most unlikely. Rather, a complex network of links (both formal and informal) between SSOs has evolved, contributing another dimension of complexity. The nature of the formal links differs widely, from purely informational ones to others that provide for a one-to-one adoption by an

SDO of a standard typically developed by a private standards consortium (such links may be exploited strategically, see chapter 2). This variety thus establishes another dimension of complexity.

Many standards developed by SSOs cover similar ground and (may) even compete with each other (see also chapter 4). Certainly in the field of smart systems such competing (sets of) standards (are about to) create silos of standards for individual smart applications (see e.g. [Butt, 2021] or [Li, 2019] and also chapter 5), between which inter-operability will be (very) hard to achieve ex-post. Such silos have already been created even within individual application sectors of smart systems (see e.g. [Sovacool, & Del Rio, 2020] for the case of smart homes). This is, for one, highly undesirable from an economic point of view; competing standards decrease interoperability, fragment the market and increase transaction costs [Egyedi, 2014]. Moreover, those stakeholders wishing to contribute to standardisation need to decide up-front to which development(s) to contribute.

The implementability of standards, or rather the lack thereof, also embodies a dimension of complexity. History provides us with ample examples of standards that were overly complex, thus hard to implement and, as a result, not implemented on a sufficiently broad scale (see also Chapter 4). This is a problem that those developing the standard should keep in mind. It links to the originating SSO's 'philosophy' – ISO, IEC and ITU-T still prefer to develop 'jack of all trades' standards[223], the IETF prefers a more modular approach[224]. Typically, the former yields more sophisticated standards, the latter simpler ones that can be implemented more easily.

No communication standard is an island – each one is based on services provided by the layer below and/or offers services to the layer above. Accordingly, the implementation of a standard at layer (n) requires the implementation of standards at layers (1) – (n-1). This, in turn, implies that all required standards need to be available at the time of implementation. Chapter 6 discusses an example where such an unavailability caused problems; similar problems may easily occur in the field of smart systems (see also sect. 5.3.1). This dependency creates another dimension of complexity which is related to the dimension of multi-disciplinarity (see below).

The increasing need for multi-disciplinarity in standards setting will represent yet another dimension of complexity. For smart systems' standardisation it comes in four types. 'Horizontal technical multi-disciplinarity' relates to the standardisation of a smart communication infrastructure. This used to be the domain of telecommunication engineers, but this is changing. For example, AI-based methods and tools will increasingly be deployed in communication systems; expertise from these sides will also be required. 'Horizontal technical cross-domain multi-disciplinarity' refers to the integration of today's smart systems silos, each of which has very limited or no links to others. This is not a sustainable situation; interfaces between e.g. the smart gird and intelligent transport systems and smart buildings will be necessary. To break up these silos, expertise from different application domains will be needed to ensure e.g. semantic interoperability. 'Vertical technical multi-disciplinarity' deals with applications' potentially hard requirements on the underlying communication infrastructure (like guaranteed levels of latency, resilience, reliability and predictability). As a consequence, application design, communication technology, operating systems and control loops will need to be extremely closely coupled from the outset. 'Vertical non-technical multi-disciplinarity' will perhaps be the most relevant type. It represents the main link between the societal and the technical world. The non-technical requirements on the (smart) technology to be standardised will be identified and discussed (see also Fig. 5.23). These various forms of necessary multi-disciplinarity will cause problems, at least initially. Perhaps most prominently, there will be a communication problem. Experts from very different backgrounds and with equally different expertise will need to co-operate. They will need to

[223] Or 'Swiss army knife' standards ('Eierlegende Wollmilchsau' in German); meaning one tool/standard able to address all problems (which results in extremely complex tools/standards).

[224] Not to mention the problem of ensuring a) standards compliance of and b) interoperability between different implementations; this is part of the 'exterior' dimension of standardisation management.

learn from each other and to align their respective concepts and terminologies to establish some form of common ground.

The various dimensions of complexity discussed above are interlinked, but there will hardly be a single solution to address them all. Over the past decades, the standardisation environment has become increasingly distributed. The highly complex environment that has resulted from this development is likely to be here to stay (and possibly to become even more complex). It is very unlikely that the complexity caused by too many SSOs will be significantly reduced or even disappear in the foreseeable future (if at all); the prospect of being able to influence the direction of a (newly founded) standards consortium will be too tempting (see also e.g. [Teubner et al., 2021] for a more recent study on why companies participate in standards consortia active in the field of mobile telecommunications).

For reasons very similar to the above, the diversity of SSOs is most unlikely to be reduced any time soon. Neither will existing SSOs be prepared to align their respective rules, by-laws, etc., nor will companies about to form a new standards consortium forfeit this consortium's major benefit of having tailor-made characteristics to best suit their needs. At least in theory it would be possible to regulate private standards setting, although this also appears to be unlikely[225].

All sorts of links may exist between SSOs. The formal links (e.g. liaisons or MoUs) are typically well documented, so it should not be too difficult to obtain detailed information about the exact nature of these links. Informal links are mostly established by individuals who are active in different SSOs working on the same or closely related topics. The exact nature of such links, let alone their respective impact, may be identified only with hindsight (at best, if at all).

The three dimensions of complexity discussed above are primarily of relevance for those who (wish to) actively participate in standards setting. Basically, the emergence of standards consortia in the mid-1980s created them. Accordingly, at least large companies have since been used to closely watch the standardisation landscape. Updegrove [2003b] reports how carefully large companies scrutinize SSOs' characteristics to identify those that best suite their needs. As a result, this dimension of complexity is typically covered anyway (this will look different for most SMEs, though; see also e.g. [Abdelkafi at el., 2021 and chapter 4.4.4]).

The emergence of competing standards is the direct result of the situation outlined above. Here, complexity is mostly experienced on the side of potential users, who will have to decide up-front which (set of) standard(s) to incorporate into their existing environment, i.e. which one will prevail and will best suite their respective needs. To a lower degree, complexity will also affect those companies who wish to implement the eventually most successful (or the only surviving) (set of) standard(s) as part of their portfolio. Several indicators may be identified that at least suggest certain developments, including e.g. a standard's backward compatibility and flexibility, the number and market power of the companies supporting the (set of) standard(s) and the availability of suppliers willing and able to actually implement it (see e.g. [Suarez et al., 2004], [van de Kaa, et al., 2011], [van de Kaa & de Vries, 2015] or [van de Kaa, 2022], [Rogante et al., 2022]. Applying the frameworks developed by these authors to a particular (set of) standard(s) may thus allow an educated guess, but a guess it will in all likelihood remain (see also chapter 4 for the initially highly unlikely failure of a set of urgently needed standards). The most simple but probably also most unrealistic solution, however,

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[225] Discussion inside the WTO have been ongoing since 2005, but with little progress [McMahon, 2022]. That said, "*WTO jurisprudence does not rule out the possibility that the actions of private standard- setting bodies may be subject to WTO law, ...*" [McMahon, 2022, p.16]. He admits, however, that *"... private standards may escape scrutiny under the TBT Agreement as it seems unlikely that Members could be held accountable for the activities of non-governmental bodies as result of dispute settlement activity*" [McMahon, 2022, p.17]. To resolve this, Du [2018] proposes that the WTO should develop a Code of Good Practice for how to deal with private standards and hopes that "… *voluntary compliance* [by some countries] *may serve as a catalyst for a snowball effect, ...*" [Du, 2018, p. 901]. These discussions were triggered by concerns about private food standards, not ICT standards, though.

would be a close co-operation and co-ordination between the SSOs involved to either develop a joint standard or to align the eventual different standards ex-post. The specification of a dedicated gateway to cater for interoperability between different approaches would be another option. Specifying such a gateway would be doable process-wise within today's standardisation environment, but might introduce new technical issues (see e.g. [Abdulrahman et al, 2021]).

A standard's implementability is one of the factors that are crucial with regard to its success or failure in the market. It affects the same two groups of stakeholders as above – those who actually do the software development and, to a much lower degree, those who wish to deploy the implementation in their ICT environment. The former will get a reasonably good idea about the standard's degree of complexity either by following the standardisation process or by studying the specifications[226]. For the latter, the complexity is primarily related to the need to integrate the standard's implementation into an existing environment and the subsequent mutual adaptation. The most promising way to improve the implementability of a standard will be to take this aspect into account during standards development. This, however, will have to be left to the individual working groups. Some SSOs (e.g. the IETF) require the availability of interoperable implementations prior to publication of the final standard. Others (e.g. ETSI) organise Plugtests, which serve a very similar purpose but are in no way part of the standards setting process. Both shall primarily determine interoperability but implicitly they also demonstrate a standard's implementability (albeit without providing any information about the implementation's complexity). Still others (like ISO, ITU, CEN) stay clear off any implementation aspects. To improve specifications' implementability it would help if they – and other SSOs – extended their idea of what a standards setting process should cover to also include the white boxes in Fig. 5.22 (i.e. 'Reference Implementation', 'Profile Development' and 'Testing').

The issues linked to the unavailability of necessary underlying or complementing standards (in the case of smart applications that would e.g. be the IoT and security standards, respectively) are related to those of implementability. They may render the implementation of a standard technically impossible (the former case) or at least much more complicated legally and/or in terms of user acceptance (the latter case). If and when such problems occur the lack of inter-SSO co-ordination and co-operation may be considered a major reason. The same holds for a possible lack of alignment of intra-SSO activities (again; see chapter 4 for an example). In such a situation many stakeholders will suffer – implementers will not be able to develop full working implementations and, accordingly, users will have nothing to work with. Moreover, the originating SSO(s) will lose some credibility. Depending on the intended functionality of the standard (if e.g. security or privacy aspects are addressed) the general public will be affected (reduced privacy/security) as well as governments (who may e.g. not be able to meet legal requirements). Here once more, co-ordination and co-operation within and between SSOs will need to be improved.

The need for multi-disciplinarity at different levels is perhaps the most pressing issue in the standardisation of smart systems; it also quite considerably increases the complexity of the process. SSOs are the immediately affected stakeholders. The three types of 'technical multi-disciplinarity' identified above will certainly complicate and prolong the standards setting process. This is, on the one hand, due to the number of technical disciplines that will be involved (leading to communication problems; see e.g. [Ramirez & Choucri, 2016]) and, on the other hand, to the larger number of people who will be involved in the process. It may, however, be assumed that the communication problems between the different technical disciplines will be overcome over time. And a prolonged process is not necessarily a bad thing if it benefits the quality of the final standard[227]. Eventually, however, virtually everyone will be affected by the outcome of the standardisation process and involvement of standards

[226] The original SMTP specification had less than 50 pages, the 1984 version of the X.400 series of recommendations had four parts with over 200 pages, the 1988 version had seven parts with over 500 pages.

[227] For discussions about 'quality vs. speed' see e.g. [Sherif, 2003] and [Sherif et al., 2007].

setters from different relevant disciplines as well as of societal stakeholders would help to push this outcome in a more desirable direction (from both the technical and the societal) perspective). To this end, sect. 5.8. discusses an approach to solve part of the procedural aspect of this (addressing the involvement of societal stakeholders, i.e. the 'vertical non-technical multi-disciplinarity'; within SSOs).

Winston Churchill is quoted with "*Those that fail to learn from history, are doomed to repeat it*"[228]. This holds not just for politics, but also for standards setting. The lack of security features in today's Internet standards is frequently explained by the fact that in the earlier days of Internet protocol development security was not a major issue – capability building was. Today, in the times of the IoT and of smart applications, Churchill is proven right – security and privacy aspects once more take a back seat compared to e.g. the development of dedicated applications and ecosystems. There is no overarching security framework in sight and the resulting piecemeal approach is unlikely to yield outcomes that are sustainable in the increasingly complex world of smart systems[229].

While all non-proprietary standards emerge through rather similar consensus-based processes they may fare very differently in the market. Some have been hugely successful (e.g. GSM, TCP/IP, IEEE 802.11), some lost out against direct competitors (e.g. ETSI's HiperLAN against 802.11), some have simply been ignored by the market (e.g. the Open Document Architecture (ODA; ISO 8613)) and others that should have been huge successes (because they were desperately needed) but were not (e.g. ITU-T's X.400/X.500 Series of Recommendations). Analysing these (and other) cases yields at least some insight into the reasons why some standards succeed and others do not and thus helps prevent future standards' failure in the market. For a company, knowledge about the factors that contribute to success or failure and application of this knowledge to ongoing activities will be a major asset.

One thing that can be learnt from history is that in the vast majority of cases installed base hostility[230] should be considered a show-stopper. After all, said installed base represents a – possible considerable – sunk investment and unless the implementation of a new standard promises exceptionally huge benefits a company will not normally be prepared to replace it.

Related to the above it needs to be observed that 'no standard is an island'. That is, to fully reap the benefits a standard could offer other, underlying or complementing standards may be necessary. Given the ongoing trend towards all-IP networks the former will be less relevant. However, complementing standards, most notably those that provide for security and privacy, are still crucially important; the lack of such standards may well hamper the broad uptake of e.g. cloud services and the IoT. Here, attention has to be paid to the timely development of adequate such complementing standards. If need be, their development may need to be triggered pro-actively.

A similar effect may be observed in the standardisation of smart applications, for which standards have been developed without a dedicated underlying communication infrastructure. Without such an infrastructure that has been designed to meet applications' requirements it has to be expected that the 'piecemeal-type' result will be far from an optimal solution. Ultimately, this may hamper (or at least delay) the uptake of smart applications on a broad scale.

'Timing' is another important aspect, which has two facets. For one, the 'absolute' timing is important, i.e. a window of opportunity has to be met. While this holds more for the actual technology than for the underlying standards, at least telecommunication technology simply could not work on a broader scale without these underlying (interoperability) standards. Such windows of opportunity may be opened by e.g. technological progress or external events. With respect to the former, the timelines

[228] See e.g. http://www.age-of-the-sage.org/history/quotations/lessons_of_history.html.

[229] See [Spring, 2016] for a more thorough discussion.

[230] A system is 'installed base hostile' if it is incompatible with widely implemented technology and cannot, or only with major difficulties, be integrated with it.

of the establishment of entities working on standards for emerging technologies (e.g. the IoT and smart applications) show that apparently technology in these fields was considered ripe for standardisation from around 2008 onward[231]. Regarding the latter, the eventual development of the wireless IEEE 802.11 standard, for example, was made possible by a US Federal Communications Commission's (FCC) 'Report and Order' (adopted in May 1985) that made unlicensed spread spectrum available in the ISM (Industrial, Scientific and Medical) spectrum bands[232].

The second facet is the 'relative' timing. Depending on a firm's underlying goals it will be most beneficial to try and align standardisation activities with the internal development capacities. This direction of alignment is particularly important if the available development resources are limited. Otherwise, the simpler approach of aligning internal development with standardisation might be adopted. If done properly, both cases will yield a first mover advantage once the standard has been finalised (and probably even a bit earlier).

Related to the above, the time it takes to develop a standard also needs to be taken into account. Especially in a fast moving sector like ICT the speed of a standardisation process will in many cases be a decisive factor. This is rather old news, though. But there are additional qualities that a standard setting process should also possess. These include flexibility and adaptivity to emerging external developments. If, for example, new technical developments rendered the technology to be standardised obsolete, either the scope of the activity should be adapted accordingly or it should be terminated and a new activity be set up. In the case of the emergence of a competing standard a liaison with the responsible SSO should be established to avoid a situation potentially leading to a standards war.

Typically, the scope of a new standardisation activity needs to be precisely defined up-front[233]. That is, the technical programme of work, its impact on existing work and the affected stakeholders need to be identified along with any wider societal, economic and environmental aspects. It will thus remain to be seen if this is adequate to prevent a 'paradigm shift' during an ongoing activity, which may change the whole thrust of an activity (for better or worse).

Standardisation may also be triggered by policy making. This holds particularly, though by no means exclusively[234], for regulated sectors (e.g. for Intelligent Transport Systems and Smart Grids). This influence may take on different forms, though. For ITS, it appears reasonably safe to say that a policy-led initiative at least helped trigger the foundation of the major European standardisation entity in the field (CEN TC 278). Similarly, the FCC's decision to make unlicensed spectrum available initiated more intensive work on wireless networks that eventually led to the standardisation activities of the IEEE 802.11 group (see above). On the other hand, standardisation of the Smart Grid, which is heavily regulated in Europe (and to a lower degree in e.g. the US), shows a conspicuous absence of private consortia. Formal SDOs have always been closer to – and more subjected to – regulation than private consortia (not least exemplified by the fact that SDOs need to observe the WTO's Technical Barriers to Trade (TBT) Agreement). These comparably close links may well have contributed to the almost complete absence of consortia in the field; traditionally, they are not formally accountable to any public interest and have thus forgone the associated legitimacy in favour of being able to accommodate specific business and product models[235].

[231] Please note that this aspect is very different from the one discussed in the preceding paragraph, although both relate to the same development.

[232] See [Lemstra, et al, 2010] for a detailed account.

[233] See e.g. [ISO, 2017]; Annex C: 'Justification of proposals for the establishment of standards'.

[234] The Regulation (EU) No 1025/2012 [EU, 2012] quite clearly shows the influence European regulators have on standardisation in Europe.

[235] See [Hawkins, 1999] for a thorough discussion of this matter.

6.5 Practical Findings and Managerial Implications

6.5.1 Strategic Level

It has already been said, but the importance of aligning the standardisation activities with the overall corporate strategy can hardly be overstated. From a firm's perspective, standardisation is not an end in itself, but a means to an end, a tool that may help to reach corporate goals.

Over the past decades the importance of ICT standards has increased and this trend will continue. This is mostly due to two closely related ongoing developments. These include, for one, the emergence of smart applications. Their 'smartness' is enabled by the integration of ICT into 'traditional' technologies like manufacturing, transport systems or power supply. These applications, in turn, will deploy new infrastructural technologies like the Cloud, the IoT and Big Data; this is the second development. For both, the existence of adequate (interoperability) standards is a sine-qua-non.

From a managerial perspective, the crucial importance of standards in these major future technologies[236] implies the need to look very closely at the development of these standards and how to actively contribute to it in a way that is beneficial for the company. In fact, a number of general managerial implications of the developments in ICT standards setting and of the changing standardisation landscape may be identified. It is highly likely that these implications will remain very real throughout the next decade and beyond.

Two major aspects in (ICT) standardisation may be identified that require particular managerial attention and action. One is the increasingly complex standards setting landscape, with ever more entities becoming active. In the absence of any overall co-ordination this implies a rising risk of competing technologies being developed in parallel by different entities, possibly resulting in standards wars. Standardisation management will need to identify ways how to deal with such developments in the best interest of the company. This is not a new phenomenon, but the considerably increased complexity of both the standards setting environment and the technologies to be standardised, along with the more diverse technologies that need to be considered makes this task more and more complicated. This increasing complexity and the resulting need for improved co-ordination may (should?) lead to a strengthening of committee-based standardisation (as opposed to market-based and government-based processes). However, in this mode as well co-operation between SSOs and co-ordination of the individual activities is limited (see also sects. 2.2.4 and 6.4). Accordingly, a stronger involvement of governmental entities may be called for, to provide for such co-ordination and co-operation. This would then lead to an expression of multi-mode standardisation [Wiegmann, 2017b].

The second aspect is caused by the fact that increasingly standardisation will require multi-disciplinary work and a greater diversity of stakeholders. This holds particularly for smart applications, but also for the underlying infrastructural technologies (like e.g. the IoT). Even for an ICT company it will in many cases hardly suffice anymore to just employ ICT specialists for research, development and, particularly, the standardisation of smart systems. Rather, the interaction of ICT with and its integration into 'traditional' technologies will trigger the need for having relevant know-how from these 'traditional' sectors available in-house – in terms of technology as well as standardisation. Moreover, management will need to ensure that employees from these different backgrounds can co-operate and represent and defend the company's interests. This is not exclusively a standardisation management task; other management functions will need to be involved as well. But

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[236] According to [PWC, 2016] firms from nine industries (Aerospace, defence & security; Automotive; Chemicals; Electronics; Engineering & construction; Forest, paper & packaging; Industrial manufacturing; Metals; Transportation & logistics) planned to invest US$ 907 billion globally in Industry 4.0 applications alone from 2016 – 2020.
IDC forecasts "*worldwide spending on the Internet of Things (IoT) to grow 16.7% year over year in 2017, reaching just over $800 billion. By 2021, global IoT spending is expected to total nearly $1.4 trillion …*" https://www.idc.com/getdoc.jsp?containerId=prUS42799917 (accessed 19 January 2018).

with standards setting representing an important interface between in-house R&D and the market, standardisation management will play a particularly important role here.

The above developments relate to the 'procedural' and, in part, to the 'cultural' and 'exterior' dimensions of standardisation management. With respect to the former two, standardisation management needs to be aware of the fact that each individual standards setting activity has its own specific 'micro climate', which is influenced by a variety of factors. These include not only the rules and by-laws of the parent SSO, but also the respective economic and/or technical interests of the represented firms and any resulting alliances. In fact, 'alliances' are a crucially important aspect. On the one hand, there will be cases where the decision whether to try and get the entire cake or at least a bigger piece of the cake (i.e. to go it alone and push a proprietary technology) or to try and make the cake bigger (i.e. to form alliances and create a larger market) will have to be made (at least for large and powerful companies). If history is anything to go by, in most other cases it will rather more be the question "Which allies do I need?" than "Do I need to form an alliance?". Here, a classification of stakeholders will be helpful (see sect. 1.2).

Moreover, for each activity the skill sets of the individual representatives need to be identified and taken into account. Subsequently, the exact composition of the individual skill sets of a team of corporate representatives needs to be adapted to the requirements of each single activity, always with a view towards the underlying corporate goals. In addition, rather more intangible aspects like personal preferences and attitudes need to be considered. They may well collide with – or be considered more important than – corporate goals (if these are known in the first place, that is). On top of that, alliances may also be formed at this level ('social capital'); they as well will not necessarily be in line with any corporate alliances. This may trigger the need for some form of monitoring of each representative's performance. For standardisation management these aspects are crucial, but quite hard to grasp and to cope with.

In this context, the still limited level of education about standardisation and the rather specific skill set necessary for efficient active participation in standards setting imply that graduates will possess (some of) these skills only in very exceptional cases. This, in turn, implies the need for firms to pro-actively improve the situation, e.g. through direct interaction with academic institutions. In addition (or as a (temporary) substitute), in-house training may be provided, covering both general and specific topics. The former would cover the necessary soft skills (diplomatic, rhetoric, negotiation etc.) and background knowledge (importance of standards in general, SSOs' processes, IPR issues etc.). The latter would address the specifics of each individual standardisation activity, including e.g. the technical aspects and, more importantly, why this activity is important, how it supports the corporate strategy, which potential allies might be available and what the expected outcome would be. Specifically, for each such activity it needs to be made very clear from the outset which outcome would count as 'success'. The standardisation management function would be responsible for both in-house training and contact with academia.

From the standardisation management point of view the 'temporal' and the 'technical' dimensions are intertwined in different ways. A look back in history yields numerous insights into potential pitfalls. Any major standards setting activity needs to ensure from the outset that the necessary underlying (communication) standards will be available in time; the same holds for complementing standards[237]. Likewise, an overarching architecture is extremely helpful to ensure sustainability and adaptability of

[237] For example, for the – comparably well advanced – field of Urban ITS CEN [2016] identifies a number of issues that still need to be addressed by standardisation, including e.g. standards relating to mixed vendor environments; autonomous/ automated vehicles; traffic management system status, fault and quality as well as for data models and interfaces; ITS communications and information protocols and emissions management in urban areas.

an initiative (despite its eventual failure, OSI[238] is a case in point here; it's underlying idea remains valid until today).

Other aspects to be addressed relate to the complexity and implementability of standards. Again history provides ample examples of standards that were overly complex, thus hard to implement and, as a result, not implemented on a sufficiently broad scale[239] (see Chapter 4). Here, standardisation management will need to, on the one hand, co-operate very closely with internal R&D to ensure an acceptable level of complexity (as opposed to the development of an overarching solution, taking into account all possible aspects that my be technologically beautiful, but most likely a commercial failure due to its complexity; this also links to the 'exterior' dimension of standardisation management). On the other hand, it will need to try and exert influence on SSOs (notably on consortia; corporate influence on an SDO's internal matters is very limited) to perhaps shift its overall approach towards the development of less complex and modular standards that are easier to implement.

'Path dependencies' is a well known phenomenon. In the standardisation of electronic messaging systems they had rather negative ramifications in the long run. In the mid 1980s – early 1990s the X.400 series of electronic messaging standards, along with the complementing standards of the X.500 series (directory services), failed to be adopted on a broad scale (or indeed on any scale worth mentioning). Instead, the IETF's comparably simple, but easy to implement SMTP, along with some later enhancement and additions, has since been deployed almost exclusively. Yet, and despite said enhancements today's e-mail functionality is extremely limited compared to what X.400/X.500 would have to offer (among others, there is still no such thing as a global directory service and no equivalent to e.g. registered mail). Basically, a very function-rich and useful, albeit hard to implement system was sacrificed for easy implementability. This was a comprehensible decision at the time, but with negative long-term ramifications. The lessons learned from these developments will hopefully make sure that standardisation managers will take the implementability of standards into account during standardisation and thus avoid to repeat mistakes from the past.

To this end, the question remains how to incorporate migration paths into standards to make them more sustainable and better adaptable to future requirements. This is not just a technical question; for instance, SSOs' guidelines could prescribe the integration of mechanisms to enable such migration paths. In such cases, however, backward-compatibility may become an issue. To address this issue systematically, an overall architecture should be designed first and the necessary individual standards second (OSI would be a case in point). To be able to do so may well require some pre-normative research. However, even then the integration of specifications submitted by third parties via e.g. the PAS process[240] and of consortium specifications may become problematic. Moreover, this may well create an additional battlefield – between reference architectures (as may be witnessed for e.g. the IoT; see sect. 5.7.4 and [Rogante et al., 2022]).

The complex web of SSOs and the frequently very limited co-ordination of the individual activities implies that competing standards may well be developed by different SSOs (and sometimes even within one). This is not a new phenomenon, but it is becoming increasingly prominent in the field of smart systems (see above and chapter 5). As a result, standards wars/battles/skirmishes may emerge. In the past, most of these standards wars have been fought between products that implement one of the available standards, i.e. in the market, rather than between proposed standards specifications, i.e.

[238] Open Systems Interconnection; a reference model that subdivides communication software into seven independent layers, with well-defined interfaces between them [ISO, 1994].

[239] Not to mention the problem of ensuring a) standards compliance of and b) interoperability between different implementations; this is part of the 'exterior' dimension of standardisation management.

[240] Publicly Available Specifications are typically submitted to ISO, IEC or ISO/IEC JTC1 by third parties (the so-called Approved PAS Submitters, who need to meet certain criteria; in May 2021, JTC1's list comprises of Approved PAS Submitters 14 entries <https://jtc1info.org/wp-content/uploads/2021/12/Approved-PAS-Submitters-December-2021.docx>. These PASs eventually be transformed into an International Standard.

in committees or working groups[241]. There are exceptions, though. Examples include Ethernet vs. Token Ring (vs. Token Bus; IEEE 802.3/5/4, respectively) and IEEE 802.11 vs. HomeRF vs. HiperLAN. In both cases the standards were developed more or less in parallel. Standardisation management has got several tasks at hand to deal with such competing standards. Careful observation of ongoing developments is a sine-qua-non. This includes the evaluation whether one standard will prevail (and if so, which one) or whether similar standards are likely to exist in parallel. Criteria here include, among others, suitability for potential application scenarios, market needs and size, strengths and weaknesses of supporting and opposing entities (firms and alliances), the supporters' manufacturing capabilities and possibly associated IPR issues; technical superiority does not necessarily play a role. To this end, participation as an 'observer' in selected, promising activities is advisable. To identify the 'promising' bit, own requirements and preferences (in terms of both technology and SSO characteristics) need to be identified up-front. Alternatively – or in addition – active participation in ongoing activities, the formation of a special WG under a relevant SSO or even the establishment of a dedicated consortium may be considered. For the latter two options, technically competent and well-educated and -trained staff will need to be available. Likewise, staff will be required for the more strategic level, from where technical activities may be steered in the desired direction.

Additional staff will also be required to cope with multi-disciplinarity in standards setting. Specifically, this holds for staff with cross-domain expertise ('horizontal technical cross-domain multi-disciplinarity'), expertise in both an application domain and the underlying infrastructure ('vertical technical multi-disciplinarity') as well as with relevant non-technical expertise ('vertical non-technical multi-disciplinarity'). Similarly, available staff will need to be trained to be better able to deal with the different types of multi-disciplinarity.

In the past, most standards wars[242] were fought in the market (e.g. HD-DVD vs. Blu-ray; see e.g. [den Uijl, & de Vries, 2013]). Yet, it may be argued that many lessons learnt from these cases are valid for battles between competing proposals inside a standards setting entity as well (e.g. the importance of alliances at firm/individual level, the need to engage as many groups of relevant stakeholder as possible, the need for complementing standards/ products/services and meeting the window of opportunity). Standardisation management will need to make sure that these lessons have indeed been learnt and that they are applied in ongoing or planned activities.

6.5.2 Tactical Level

Obviously, the more strategic level of standardisation management discussed above has ramifications for the tactical level. Specifically, these include the need for

- More standardisation staff.
  To be able to contribute to (and/or observe) the increasing number of (potentially) relevant standardisation activities.
- Better trained standardisation staff.
  Asian countries (most notably China and Korea) have recognised the importance of education about standardisation. Many standards setters from these countries are now well-trained and educated. To maintain a level playing field similar educational and training levels need to be attained for Europeans as well.
- The creation of multi-disciplinary teams.
  Typically, ICT standards are developed by working groups comprised of mostly engineers and computer scientists. For converging technologies, like smart systems, such 'mono-disciplinarity'

[241] See [v.d.Kaa et al., 2011] for a discussion of what the authors call "interface format battles".

[242] Actually, these were rather more battles for a dominant design (see also e.g. [v.d.Kaa et al., 2001]).

will be inadequate. Accordingly, in many such cases a company will need to send multi-disciplinary teams of standards-setters to WG meetings in order to be able to adequately address the technical challenges[243].

The above aspects are company specific. Looking at the standards setting process a number of other 'tactical' issues may be identified.

- Which relevant standardisation activities to either join or launch (or perhaps obstruct).
  This requires the consideration of diverse aspects, including applicable IPR rules, membership (allies, competitors, suppliers, customers; their respective power and importance). Also, it needs to be kept in mind that attempts to prevent the emergence of an unwanted standard should not be made too often, as it may affect the company's reputation as a reliable and constructive partner.
- An SSO's culture needs to be taken into account.
  SSOs differ not just in terms of IPR rules, by-laws and voting procedures. Rather, each has developed its own culture. The ITU-T, for instance, is very formal, which sets it apart form e.g. the IETF. For the latter, inadequate language skills may well represent a major disadvantage.
- Pros and cons of assuming a leadership position.
  Such positions have their pros and cons; this holds particularly for the role of a chairperson (who, in many cases, is required to assume a neutral role). On the other hand, editors are quite important (e.g. for speeding up or delaying a process).
- The importance of social capital.
  Alliances are not just important at the firm level. Representatives with a wealth of social capital are crucially important for any important standards setting activity (that is, social capital is hardly important if e.g. the role of an observer shall be assumed). If need be, such individuals should be hired.
- The importance of language/presentation skills is in inverse proportion to the respective level of 'technicality'.
  Purely technical aspects – and thus expertise – are typically much more important at the 'lower' levels of technology (e.g. programming languages, operating systems or the physical layer of a communication system). Soft skills become much more important at the 'higher' and more strategic level. That said, a (perceived) economic importance of a standard may well turn this on the head.

Depending on the characteristics and the environment of an individual standards setting activity, many other aspects may need to be taken into account by the standardisation management function. The above, however, will be relevant in almost all cases.

6.6 Theoretical Findings and Implications

Literature about standardisation management is still extremely limited. Plus, much of the literature that directly covers the corporate management of standardisation has been written by practitioners with a long-standing track record in standards setting, including e.g. Carl Cargill[244] (see e.g. [Cargill, 1997], [Cargill, 2017], [Cargill, 2019]) and Alice de Casanove[245] (see e.g. [Casanove et al., 2015], [Casanove et al., 2023]). This seems to suggests that 'pure' researchers (i.e. those without any practical background in standardisation (management)) are either not interested in the associated issues or are not in an adequate position to undertake research in this field. To address at least the latter, i.e. to better enable researchers to look into matters related to standardisation in general and

[243] If the SSO's regulations allow it.

[244] Formerly Director of Standards with DEC, Netscape, SUN and Adobe.

[245] With Airbus; see also https://youtu.be/TmqCjbmQM-U.

standardisation management in particular, stronger links between research and standardisation would have to be established. Specifically, this includes a better information flow between practice and research. A discussion of how this could be achieved is way outside the scope of this thesis. In any case, a solution would need to involve research organisations (to better appreciate and support standardisation research), research funding organisations (to put research *about* standardisation on the agenda) and the editorial boards of many journals (to pro-actively solicit and adequately review standardisation research papers).

This thesis' point of departure was the assumption that the current academic understanding of standardisation management is in urgent need of extension. To this end, the study has identified 14 dimensions of standardisation management (see Table 1.1). Each dimension represents a lens through which standardisation management may be analysed.

Eight of them have been discussed (at different levels of detail), most of which have so far been either massively under-researched or ignored altogether. Yet, that is not to say that the other dimensions are well understood. Neither does it mean that the set of dimensions is now complete. Considerably more work will be required in order to get at least a reasonably full picture of the factors that influence standardisation management (and may be influenced by it). Insights from the thesis strongly suggest that such future research will have to leave the trodden paths of the economic and technical dimensions, though[246], proceed along the identified dimensions and be based on the findings discussed in this thesis in order to gain both deeper and broader insights. This will require co-operation between different disciplines, few of which have so far been associated with technical standardisation and its management. For example, with respect to the 'cultural' dimension in general and to the role of the individual in particular, the relevance of negotiation theory and conflict resolution theory still needs to be discussed. It remains to be seen if and how these theories can be deployed in order to increase efficiency and effectiveness of a) the working group activities in general and b) a firm's representatives and how management may put them to good use (e.g. through dedicated training). In any case, the findings suggest a much more complex picture of technical standardisation (and its management) than it has so far been assumed.

Orthogonally to these dimensions, five factors have been identified[247] (along with sample constituting elements, which may belong to different dimensions). These factors (may) exert an influence on standardisation management and/or directly on standards setting (see Figure 6.1 above). The level of impact each of these factors (and it respective constituents) exerts will differ widely between standards and may change over time. Nevertheless, research based on (a possibly extended list of) these factors and involving disciplines like, among others, technology forecasting, decision sciences, sociology and engineering, may come up with a model to calculate (at least roughly) the respective impacts. Such a model would then be one step towards a better understanding of e.g. longer-term technology trajectories[248]; after all, today's standards are tomorrow's technology.

In this context, two more aspects will need to be studied more extensively. For one, it remains unclear if and how these factors also exert any mutual influence (as opposed to influencing CSM). The rough initial overview presented in Table 6.1 suggests that, for example, envisaged standardisation activities may be influenced by the 'standardisation context', i.e. e.g. individual SSOs' characteristics (for instance, an SSO's IPR rules by attract or deter a company planning a new standardisation activity)[249] (see Table 6.1). However, the 'Exterior factors' are most influential in this respect. They may

[246] Both of which are still far from being fully understood as well.

[247] There may well be more. But these five have been discussed, at different levels of detail.

[248] The resulting knowledge would also contribute to a clearer picture enable CSM to react proactively. Along similar lines, more in-depth knowledge about factors influencing standards setting would also help policy makers' long-term planning.

[249] See e.g. [Updegrove, 2003b]

influence 'Individuals' (through e.g. societal norms) and 'Competing/complementary activities' (through e.g. technological advances). Most notably, though, they influence the 'corporate characteristics' (e.g. through legislation and prevailing societal norms). The impact e.g. national cultures and norms may have on firms has been studied quite extensively[250]. Yet, this thesis' findings raise questions like "how do cultures and norms impact CSM (and do they do so in the first place)" and "how can a globally acting CSM function align such diverse national and regional specifics (at both the strategic level and that of the individual) with typically global standards setting activities". These questions (and probably others) remain open for research in e.g. Organization Studies and Management Studies.

Table 6.1: Mutual influences between factors that (may) impact corporate standardisation management (➔ denotes '(may) influence')

	Exterior	**Corporate Characteristics**	**Standardisation Context**	**Competing Activities**	**Individuals**
Exterior	X	➔	➔	➔	➔
Corporate Characteristics		X			(➔)
Standardisation Context			X	➔	
Competing Activities			(➔)	X	(➔)
Individuals				➔	X

Second, so far only the impact that exterior factors may have on CSM has been addressed. The other way round, i.e. the question whether or not CSM may influence the exterior environment and if so, how, still needs to be addressed. Sect. 5.8 discusses how (alliances of) large firms may directly influence certain policy-related aspects of standardisation. Yet, what may or may not be done beyond that still needs to be analysed; there may well be opportunities[251]. For example, the unrestricted availability of additional frequency bands would probably trigger massive new standardisation activities for services operating in these bands[252]. Moreover, industry trying to exert influence on the responsible regulatory entities is not unheard of (see e.g. [Lemstra & Marcus, 2010]). A newly developed technology is also likely to trigger – possibly competing – standardisation activities (see e.g. [Parameswaran & Chaddha, 2009]).

Given the strong links that exist between standardisation and innovation[253], equally strong links may be may be expected to exist between standardisation management and the management of innovation (especially of open innovation). After all, both share important characteristics, including e.g. their pre-

[250] Albeit mostly some time ago, see e.g. [Hofstede, 1984], [Nelson & Gopalan, 2003], [Tayeb, 1994], [Whitley, 1991]. See [Manders, 2014] for a more recent study.

[251] As an aside: In 1979, the German NSO Deutsches Institut für Normung (DIN) provided China with the full set of German standards. This contributed quite considerably to the shaping of the Chinese standardisation system (in the sense that the Chinese system, despite all peculiarities, is still closely related to the German/international system, as opposed to e.g. the much more uncoordinated US system). According to private conversations with staff from both Siemens and the China Electronics Standardization Institute, this was initiated by Siemens (or at least the company had had a major say in it). If this were indeed the case, it would be a clear example of standardisation management successfully influencing the 'exterior factors'; see Fig. 6.2.

[252] As was the case with WiFi, the development of which was only made possible by an FCC Report and Order deregulating certain frequency bands [Lemstra & Marcus, 2010].

[253] See e.g. [Blind, 2013], [Bridgit, 2014], [Ho & O'Sullivan, 2015], [Lemstra & Hayes, 2009], [Maxiquest, 2003], [Swann, 2010], [Swann & Lambert, 2010], [Hawkins et al., 2017].

competitive nature and the need for alliances[254]. Accordingly, insights from research into the management of innovations may be assumed to also be of relevance to standardisation management. This assumption, however, seems to be wrong. Researchers in innovation management seem to be interested in standards *for* their subject[255] (see also below), but hardly in the role standardisation may play for (the management of) innovations. Pretty much the same may be said for e.g. the field of Organization Studies[256]. Here, bridges will need to be built between the individual disciplines. This is thesis will (hopefully) contribute to that (e.g. through its multi-disciplinary approach).

The need for stronger links between research and practice has long been identified[257], albeit almost exclusively for research *for* standardisation, i.e. how research findings could best be fed into, and be deployed by, standards setting. This kind of pre-normative research is purely technical in nature and is supposed to contribute to technically better standards (which is not necessarily the same as 'more useful standards'). In contrast, research *about* standardisation (as in this thesis) is more concerned with the non-technical aspects of standards and standardisation (i.e. e.g. socio-economic, legal, ethical and historic aspects and with the non-technical impact standards may have). With especially ICT standards becoming ubiquitous, companies and society need to develop an adequate understanding about the various issues surrounding standards and standardisation (including e.g. standards' diffusion; adoption; technical, economic and societal impacts; why they emerge the way they do and how they can be managed) [258]. Ultimately, this is about 'more useful standards' and thus complements research *for* standardisation. However, and with the exception of the economic aspects, this strand of research is still pretty much in its infancy. This holds all the more for research *about* standardisation management.

This thesis will (hopefully) contribute to the development of more useful (for society at large) standards by making a strong point for the involvement of a broader variety of stakeholders in the standards setting process and by suggesting a way forward that would be comparably easy to implement. By identifying these problems it will also contribute to more theoretical research into e.g. stakeholder management (theory), technology assessment and the ethics of smart systems.

To meet the window of opportunity for a certain technology is an important aspect in standards setting. However, what exactly opens such a window is far from being clear. Technical developments, policy actions, changes in the legal framework and social processes may all be contributing factors. For example, the formation of the ERTICO Public-Private Partnership and the establishment of CEN TC 278 (Intelligent Transport Systems) happened almost in parallel (in 1991; preceding the foundation of it's international counterpart, ISO's TC 204, by around two years). ERTICO is supported by the European Commission and aims to bring "*intelligence into mobility of people and goods in Europe*"[259]. ITS America, which may be regarded as the US equivalent to ERTICO, was also created in 1991[260]. It may at least be speculated that in these cases policy makers had realised that the time was ripe for improved and intelligent transport services. They were prepared to (co-)finance associated activities that would throw open a window of opportunity also for standardisation.

To get a better understanding when such a window of opportunity is likely to be opened, by whom and through which actions would be of relevance way beyond standardisation management. The analysis of the timelines of different standardisation activities in the field of smart systems (chapter 5) may provide a basis for the identification of windows of opportunity.

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[254] See e.g. [Dittrich & Duysters, 2007] [Grøtnes, 2009], [West, 2016].

[255] Not unlike researchers in the ICT sector.

[256] There are exceptions, though. See e.g. [Brunsson et al., 2012] and other papers by the first author.

[257] In e.g. [Blind & Gauch, 2009], [Copras, 2007], [Interest, 2007a], [Interest, 2007b], [Jakobs, 2009], [Jakobs, 2011b].

[258] See also [Jakobs, 2011b].

[259] http://ertico.com/vision-and-mission/.

[260] See [Nowacki, 2011].

Standardisation management is not an end in itself. Rather, for a company it is ultimately a means to the end of being successful in the market[261]. In the 1900s, Strategic Standardisation Management (SSM; see sect. 2.3.1) became popular for a while: "*Several of the most successful U.S. businesses credit the strategic adoption of standards in processes and products, or strategic standardization, with helping them achieve industry leadership. Strategic standardization is how business leaders leverage standards to build and sustain a competitive advantage*"[262]. However, despite this claim so far no conclusive links between good standardisation management and market success have been demonstrated[263]. On the other hand, an intermediate yet more relevant step towards this end (in the context of this study) would be a company's success in setting standards that meet its needs and requirements. After all, this is one of the major goals of corporate standardisation management[264]. For further insights, a definition of what establishes 'good' standardisation management should be a first step (SSM would be a good starting point here). This should to be followed by (historic) case studies that link the performance of a firm's representatives in a certain standards setting activity to the degree to which the final standard met the firm's initial goals.

The skills and competencies of the individual standards setters are important (albeit widely underestimated) assets for any CSM function. The literature suggests that not their technical competency is most important, but that their soft skills are, including e.g. negotiation and presentation skills and their ability to accumulate social capital (see e.g. [Cargill, 2011], [Jakobs, 2011a], [Dokko & Rosenkopf, 2010] and also sect. 3.2.2). In contrast, this study suggests that a representative's necessary skill set will very much depend on the characteristics of each individual activity. Specifically, there may well be cases in which the technical expertise of a representative is the decisive factor. This seems to hold particularly for activities that are of limited economic interest at least for the larger players (see sect. 2.6 and also e.g. [de Vries, 2006]). To the best of my knowledge, this distinction has so far not been made in the literature. Which skill set is best suited for which kind of standards setting activity would thus be another topic for future research,

Along similar lines, current literature highlights the importance of the WG chairman and the importance of assuming this position for any firm that seriously wants to influence a standardisation process[265]. This study does not question this importance, but it suggests that some qualifications may apply (e.g. for smaller companies). It also suggests potential alternatives (e.g. the role of an editor). The respective pros and cons would need to be analysed.

All in all, it seems safe to say that standardisation management continues to offer a rich variety of relevant open topics that are in need of further insights. This holds all the more if standardisation management is looked at from an innovation perspective.

6.7 Limitations of the Study

Just like almost every study, this one as well has its limitations. The most severe ones will be discussed in the following. Roughly speaking, they relate to the research approach and the scope of (parts of) the study, respectively. The former is primarily of relevance for the qualitative studies

[261] Which may include the desire to just increase the size of the market or to create a new one, without any technical preferences; see e.g. [Updegrove, 2003b].

[262] According to [Forselius, 1998b, p.3].

[263] It may be assumed that large companies calculate the benefits of participation in a given standards setting activity (see e.g. [Updegrove, 2003b]. Yet, to the best of my knowledge and no such calculations have been published. And even if some had been, it would be difficult to transfer any results from one case to another. A methodology to enable such analyses was devised in [de Vries & Veurink, 2017]. Apparently, this methodology has been applied by some companies.

[264] Other departments, including e.g. R&D and marketing, are responsible for actual market success.

[265] See e.g.[Spring at al., 1995].

described in chapters 2, 3.5 and 5, respectively. Here, the issues of 'validity' and 'generalisability' need to be addressed.

6.7.1 Limitations of the Research Approach

Robson [2002] summarises three phenomena that represent threats to a (qualitative) study's validity: reactivity, researcher bias and respondent bias. Very generally, reactivity occurs if the object under investigation behaves differently due to the presence of the researcher. Researcher (and/or) respondent bias occurs if either brings his/her personal views and ideas into the study, thus affecting its outcome.

By their very nature, the three qualitative studies might have suffered from these phenomena. However, a closer look suggests that reactivity will hardly be an issue. This is due to the design of both studies, which were conducted asynchronously, via e-mail. Accordingly, researcher and respondents were separated in both time and space, so mutual behavioural impact should have been marginal at most.

Researcher bias, i.e. e.g. preconceived assumptions, views and prejudices, however, is hard to exclude. Here as well I feel that the asynchronous nature of the study helped, though (see also sect. 1.3). Moreover, I applied elements of reflexivity to at least reduce the impact of underlying taken-for-granted assumptions. Also, I took care to cite relevant quotes from as many different respondents as possible (as opposed to favour those who share my assumptions). Nevertheless, I cannot claim that I could fully eliminate any researcher bias.

Respondent bias was even harder to avoid. In fact, I feel it was quite visible in some cases and could be suspected in others. It was visible, for example, in chapter 5, where respondents who were active in standards setting exhibited an overall more positive attitude towards the process and its elements than others did. Along similar lines, I could frequently observe a very positive perception of the work and the relevance of the SSO(s) a respondent was affiliated with. Similarly, a certain bias towards the own employer may be assumed for the case studies discussed in chapter 2. Here, I used triangulation to reduce this effect. Yet, in both studies a certain level of remaining respondent bias may be assumed. That said, I believe that the counter measures applied were sufficient to reduce this to an acceptable level, with no impact worth mentioning on the findings.

Other types of bias also need to be assumed. For one, the 'self-selection' of respondents in chapter 5 suggests that primarily rather more motivated and interested individuals were prepared to participate in the study, leading to a certain selection bias. The same holds for the study described in sect. 3.5, where most respondents had initially been selected and contacted by the former WG chairman (who knows them personally and had picked the most experienced ones). Likewise, I cannot fully exclude the possibility of a certain procedural bias. I tried to avoid leading questions, suggestive wording and question-order bias, but perceptions may differ in this respect. Here as well, however, I believe that both impacts, if any, are minimal at most.

Finally, the comparably small number of respondents represents an issue. This holds for all three studies mentioned above, but particularly for the survey on smart system standardisation presented in chapter 5 and especially for the limited numbers of respondents per category. Given the number and variety of smart applications, this relatively small number of responses not least enhances the effect of any respondent bias (regarding the importance of certain SSOs, for example).

The small(ish) number of participants leads up to the generalisability problem. Lack of generalisability has long been the major point of criticism of the case study method; it is indeed an issue for both the surveys discussed in sect. 3.5 and in chapter 5, respectively, and the multiple case study reported in chapter 2. With respect to this study, however, it has to be noted that it is, by its very nature, an exploratory study, the goal of which was to investigate the comparably new and still vastly under-researched field of corporate ICT standardisation management. As such, the goals of the study did not include any generalisable findings, but the formulation of new research questions, propositions and hypotheses. To this end, a number of propositions have been defined (sect. 2.10); these will be further extended in sect. 6.8.

A similar argument may be made for the two surveys. While the role of the individual in ICT standards setting has occasionally been discussed in the literature, still much needs to be learned to fully comprehend all facets of this role. Here, both theoretical analyses from different angles as well as further studies in different settings will be needed to eventually understand all ramifications for ICT standardisation management and to perhaps arrive at testable hypotheses.

With very few exceptions the standardisation of smart systems is still a very young and emerging field. The survey of researchers and standards setters presented in chapter 5 can thus only be a snapshot. As the standardisation environment evolves, further similar studies will be necessary over time to form part of the basis for better informed managerial decisions in this field.

6.7.2 Limitations in the Scope of the Study

In addition, the methodological aspects discussed above a number of limitations with respect to the scope of the overall study may be identified. At the same time, these are potential areas for future research.

For one, the study has a certain European focus, i.e. it does not really address the 'spatial' dimension of standardisation. This may be considered a bit problematic – after all, the times when Europe and the US were the two powerhouses in ICT standardisation are gone. Asian countries, most notably China, are now playing a much bigger role than they used to. Already in 2011, it was observed[266] that "*Only a few years ago, China's approach to innovation and standardization barely played a role in international economic diplomacy. With its economic power on the rise that assessment has changed dramatically*". In the late 1990s China initiated the development of its first major 'indigenous' telecommunication standard (TD-SCDMA). Until then, China had mostly limited herself to implement international ICT standards (as opposed to developing her own as contributions to the international ICT standardisation). In 2003, China became the world's largest market for mobile telecommunication systems[267]. For foreign companies the combination of these facts (market size and internationalisation of her standardisation) makes Chinese standardisation working groups a place to be represented in. Yet, at least until 2017 the Chinese standardisation system was perceived as alien and overly complex by European firms, which are used to a system that aims to provide contradiction-free standards. Until then, a Chinese standard belonged to at least one of the four levels of standards ('national', 'industry', 'local' (or 'provincial') and 'enterprise', with both voluntary and mandatory standards at all levels); standards from different levels could have been contradictory (e.g. between regions). Moreover, different testing and certification requirements might have been associated with these standards. Companies that (planned to) do business in China had to navigate through this highly complex and virtually inscrutable network. The new Standardization Law of the People's Republic of China[268], in force since 2018, has simplified the situation. Today, 'National' standards may be either mandatory (those focussing on issues of health, safety, security and environmental protection) or recommended (the others; see [Ziegler, 2016] for a more detailed discussion). All 'Industry' (or 'Sector'), 'Local' and 'Association' standards are voluntary. This will probably simplify participation of foreign firms in the process. However, it remains to be seen to what degree foreign companies will actually be allowed to participate[269]. In any case, to successfully contribute to standards development in China the differences between the Chinese system and the European one need to be taken into

[266] By Ernst [2011], p.2.

[267] See e.g. [Shen et al., 2015].

[268] https://www.cfstc.org/en/2932583/2968817/index.html.

[269] See http://www.npc.gov.cn/englishnpc/Law/2007-12/12/content_1383927.htm.

account. Clearly, this would be under the responsibility of a corporate standardisation management function for any company active in the Chinese market.

A number of dimensions of standardisation management have been identified in Table 1.2. Of these, only some have attracted scholarly attention and research and those that did have so far barely scratched the surface. By introducing some new dimensions this study has not helped improve this situation. That is, one of the major tasks for future research in the field will be to look more thoroughly at the individual dimensions as well as at any potential mutual influences. For example, the Chinese market (see above) has become more and more important for non-Chinese firms. One result of this increasing importance is the need to adhere to Chinese standards and, ultimately, the need to actively participate in the Chinese national standards setting process. Another result has been a comparably strong interest on the research side in the Chinese national standardisation system and in associated relevant developments[270]. This interest, however, focuses largely on national policies and economic aspects. That is, how and to which degree the specifics of the national standards setting system and its individual institutions influence participation of foreign firms in the process and how firms should react or adapt to these specifics remains largely unexplored. Moreover, this needs to be considered in conjunction with the underlying national culture[271].

The 'ethical' dimension may perhaps be considered as slightly 'arcane' by some. But smart systems will – in all likelihood – eventually penetrate all spheres of our lives to a degree unheard of so far (just think Smart Cities). Major issues of privacy, security and trust will emerge in conjunction with this true ubiquity. To adequately address them the necessary protective mechanisms will need to be incorporated up-front into many standards; a piecemeal-like approach of integrating them at a later stage did not work properly for the Internet in the long run (see also sect. 6.4 above) and it will be entirely inadequate for smart applications. An ethical standardisation management will need to make sure that such aspects will be fully integrated into future smart system standards.

It has been said before – the economic perspective has always been the most popular one in standardisation research. Economic considerations (including those relating to IPR) underlie many (probably most) activities of a standardisation management function. Nevertheless, exactly which role these considerations play for e.g. a decision process whether or not to initiate – or to actively contribute to – an activity remains unclear. The same holds for the revers direction – costs and benefits (economically and otherwise) of a specific standardisation activity remain unclear[272]. Insights related to these aspects would certainly be of interest and relevance, especially for practice.

One major omission of this study is its negligence of company-internal aspects. These include particularly the nature of the links between standardisation management and the legal and R&D functions (see Fig. 1.2). The necessity for such links is obvious – insights from R&D need to be channelled into relevant standardisation processes and R&D needs to be kept up to date about the outcome of these processes[273]. The former, however, may be problematic – R&D outcomes may have been patented or be patent pending. In many cases this calls for an involvement of the legal department, which may have to advise or decide about any IPR-related aspects. How exactly these links look like, who ultimately assumes responsibility for what and which other departments[274] may possibly be involved remain open issues.

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[270] By e.g. Ernst [2011], Ernst et al. [2014], Kennedy et al. [2008], [Kwak et al. [2012], Lee et al. [2009], Murphree & Breznitz [2011], Ziegler [2016].

[271] This would represent a combination oft he 'cultural' and the 'spatial' dimension.

[272] Numerous studies exist on the economic benefits of standards (see also sect. 1.1), though.

[273] In most cases members of the R&D department will also contribute to standardisation.

[274] The marketing department would be a candidate; standardisation may well also be deployed as a marketing tool; see sects. 2.5.3/4 and 2.6.

The other identified dimension could be discussed analogously. However, the general thrust should be clear – while this study has helped to get a more complete picture of the different dimensions standardisation management entails, the individual dimensions still require additional research efforts.

In addition to the above, more content-related aspects parts of the study also suffer from some methodological limitations, which will need to be overcome by follow-up research. These limitations apply primarily to chapters 2 and 5.

With respect to the study discussed in chapter 2 on the management of corporate participation in international ICT standardisation, one such limitation is the fact that none of the standards considered in the study had any IPR attached to it (according to the SSOs' IPR data bases). Whether or not the study's findings are limited to this class of standards should be subject to further study.

Another problem was the limited access to potential respondents (mostly for the study described in chapter 2), which was partly due to confidentiality issues, either perceived by potential respondents or by their superiors. One consequence of that was that the original idea to triangulate via information from third-party WG members on the success of failure of the respective case study firm's representatives did not work out in full; triangulation was possible only to a certain degree . The study also had to find a trade-off between breadth and depth. This lead to the selection of three companies with a number of similarities, but also with considerable differences. For a deeper understanding of the respective issues at hand studies of similar companies from the same sector will need to be conducted.

6.8 Summary and Concluding Model

This thesis aims to contribute to a better understanding of the different facets that, taken together, make up standardisation management. After having discussed the necessary general background to set the scene it looks at five (plus three) dimensions of standardisation management that have so far been largely neglected or not discussed at all in the literature: 'Procedural', 'Cultural' (for both firms and SSOs), 'Temporal' and 'Technical' plus, albeit more implicitly, 'External', 'Ethical' and 'Distributive'. These dimensions may also be applied as lenses through which standardisation management may be analysed. The analyses draw upon literature from a variety of field, including primarily Standardisation Research, but also (in alphabetical order) Computer Science, Economics, History, Science and Technology Studies, Strategic Management, Technology Management and Telecommunication.

The 'procedural' dimension relates to the processes, guidelines and by-laws of the different SSOs. These may have a considerable impact not only on the working of an SSO, but also on firms' decisions which one to join (or whether or not to establish a new one). Looking through this lens I show how different firms that nevertheless share some common characteristics deal with standardisation management. This is done on the basis of three case studies. The findings suggest a number of aspects that need to be taken into account. These aspects have so far either been mostly ignored by the literature or are in contrast with established perceptions. The latter includes the two levels (individual and corporate) of altruism that may be observed as well as the importance of the editor (as opposed to the more 'popular' – and more visible – role of the chairperson, which is shown to be a double-edged sword). The former include the need to be enthusiastic about standardisation as a prerequisite for success. It also includes the importance of a clear communication of the corporate goals and, related to that and perhaps most importantly, an equally clear definition of what establishes success (for each individual activity). This has to come along with the knowledge of what is takes to actually be successful; the associated criteria may differ between activities and SSOs.

In some way, each SSO is a small world of its own. This world is governed by its various formal rules and guidelines. However, in addition – and related – to that, each SSO has developed a certain specific culture over time. This culture and the attitudes, views and actions of the individuals that populate the SSO's WGs mutually shape each other. This makes up the 'cultural' dimension (for both SSOs and companies). Looking through this lens reveals that corporate representatives channel aspects of corporate cultures (values, for example, but also technical preferences) into the WGs. This may be one of the reasons why a match between corporate culture (and the 'underlying' national one as well as a representative's personality) and an SSO's culture is highly beneficial[275] – most will feel more comfortable (and perform better) if among like-minded people. Focussing further on the role of the individual in standards setting, I show that this is still a widely under-estimated aspect. Importantly, and slightly at odds with common wisdom[276], findings suggest that a firm's representatives' skill sets need to be in line with both the nature of the specific activity and the SSO's characteristics. This implies that in-depth technical expertise may very well be a representative's most relevant and important trait. Nevertheless, adequate training beyond technical aspects is crucial. The same holds for the provision of the necessary information (on e.g. the corporate goals underlying the activity). This also implies empowerment of the representatives and reflects the need for identification with their respective employer. Nevertheless, a certain level of monitoring also seems to be advisable since WG members do not necessarily actually represent their respective employer's interests (this does not happen too often, though).

Lessons from history can also be learnt in standards setting. Perhaps a bit surprisingly, this 'temporal' dimension may be closely linked to the 'technical' one. After all, both are in a constant state of flux. I analyse the case of the ill-fated X.400 series of standards for an electronic messaging system through the 'temporal' lens, This analysis reveals a number of aspects and developments that contributed to the eventual failure of X.400 in the market. The findings are in stark contrast to the widely held belief that the increasing popularity of the Internet was the sole reason for X.400's failure (as a victim of the 'religious war'[277] between the Internet and OSI). Specifically, I show that a number of relevant parallel developments at the time had been ignored by the powers in charge (notably in ISO and the ITU-T). This ignorance came in conjunction with unwise changes to the direction of the standardisation process (from the pragmatic to the all-embracing). Analogous developments may occur any time again, as may be similarly poor decisions regarding a standards setting activity's major thrust. The case thus teaches lessons relevant also for the standardisation processes of today and of the future.

The 'external' dimension is arguably the most important (and the most extensively studied) one. Its influence shines through in many cases. This holds specifically in the context of smart systems standardisation (where it also links to the 'ethical' dimension). For one, smart systems will integrate artefacts and sub-systems from very diverse fields[278]. Standardisation needs to take that into account. One resulting important aspect here is the necessary multi-disciplinarity of the associated standardisation activities. More importantly, the likely future ubiquity of smart systems (that will easily dwarf that of today's Internet), along with their non-technical (e.g. societal, economic, environmental and ethical) ramifications, calls for the involvement of a broad range of non-technical stakeholders. Very few (if any) of these stakeholders are currently represented in a typical standards setting activity in the ICT sector. To address both issues – the necessary technical multi-disciplinarity of smart systems standardisation and, in particular, the need to better integrate more societal stakeholders, I make a recommendation for a modified standardisation process. This process also

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[275] It may be a bit of a cliché: The ITU is well known for strict procedures, the IETF for being slightly chaotic at times. Two (out of 11) ITU-T Study Groups have Chinese chairs, along with 10 (out of ca. 100) vice chairs. In contrast, two (out of 34) IETF WGs have Chinese co-chairs.

[276] Which has it that rhetorical, diplomatic and negotiation skills are more important than technical expertise.

[277] As Hanseth [2001] puts it. See also [Russell, 2006].

[278] Just think of smart cities, which will comprise, among others, smart buildings, intelligent transport, smart energy supply and e-health. Each of these individual smart technologies will, in turn, comprise of a number of more 'traditional' constituent technologies.

takes into account the 'distributive' nature of the process, which still remains at the heart of several problems like parallel developments of similar, yet incompatible standards.

Based on the findings discussed in the thesis, the conceptual model of the factors that influence the standards setting process (as shown in Figure 1.6) could be considerably refined, yielding Figure 6.3. It shows the five factors that influence corporate standardisation management (and may be influenced by it), along with (a number of) the respective constituting factors. It also shows the possible mutual influences between the individual factors.

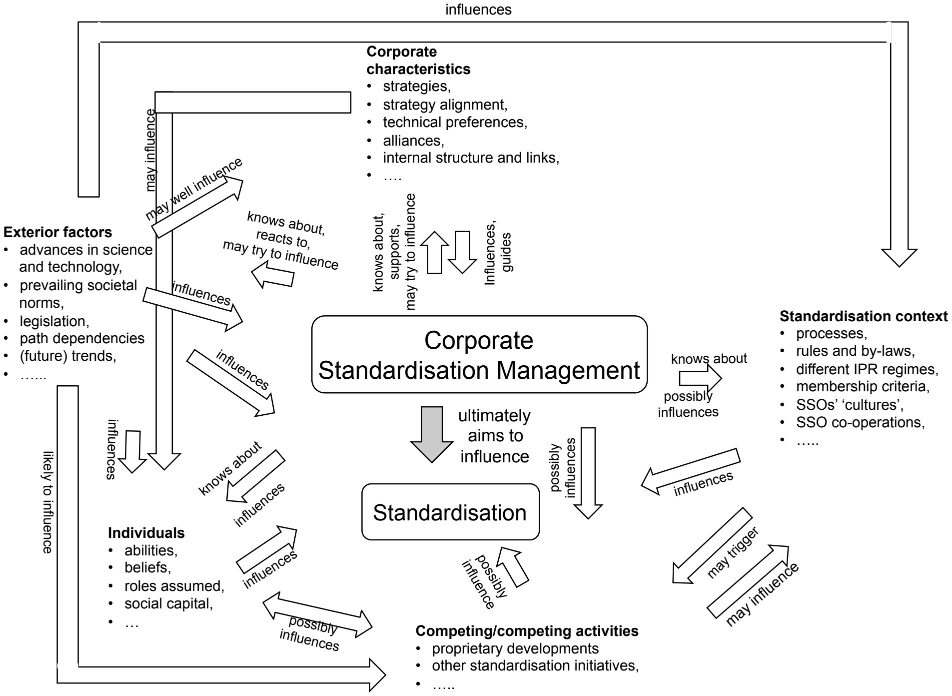

Figure 6.3: Corporate standardisation management – activities and influencing factors

The picture has become more comprehensive, but, inevitably, also rather more complex. Nevertheless, it is safe to say that it is far from being complete. There will be more influential factors and additional lenses (dimensions) through which to look at standardisation management. I do hope that other researchers will base their work on the findings discussed in this thesis and that they will further advance the field of standardisation research in general and deepen the insights into corporate standardisation management in particular.

You will have noticed that I like the idea of learning from history. So, just as a final note: Charlemagne's empire comprised a considerable number of ethnic groups with different religions, languages and cultural identities (not unlike the realm of international standardisation today). As a pragmatic, he limited standardisation (i.e. centralisation[279]) to the truly important aspects (like salvation). And even in such cases, "*efforts to encourage* [standardisation] *almost inevitably left room for some degree of local variation*" [Davies, 2015, p. 301]. We see similar phenomena in

[279] Today, these are not the same. In Charlemagne's times, 'standardisation' meant to apply the views and ideas of the emperor across the empire, i.e. some form of centralisation.

standardisation today (just think of the ESOs[280] or the US standardisation system[281]). I am pretty certain that this will become much more visible in the standardisation of smart systems, where many aspects beyond the technical and economical will play a role. So, perhaps there is more to be learnt from history than meets the eye – even from medieval history[282]. One might be to be just a that little bit more pragmatic ……..

[280] CEN and CENELEC do co-operate closely with their international counterparts (ISO and IEC, respectively). However, there are qualifications "*Wherever appropriate priority is given to cooperation with ISO provided that international standards meet European legislative and market requirements* …" (see https://www.cencenelec.eu/european-standardization/international-cooperation/iso-and-iec/). Regional specifics continue to exist and so do regional standards.

[281] Here, standards may indeed differ between individual states, see e.g. [Alshareef, 2019], [Muto, 2017] or [Toth, 1996]

[282] The medieval guilds, for instance, took care of sector-specific standardisation (for e.g. product quality and education; see e.g. [Epstein & Prak, 2008] or [Richardson, 2001]), not unlike the US standardisation system of today.

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About the Author

Kai joined RWTH Aachen University's Computer Science Department as a member of technical staff in 1985. Since 1987, he has been Head of Technical Staff at the Chair of Communication & Distributed Systems. He holds a PhD in Computer Science from the University of Edinburgh and is a Certified Standards Professional.

His research interests and activities focus on various aspects of ICT standards and the underlying standardisation processes. Over time, he has (co)-authored/edited a text book on data communication networks and, more recently, 30+ books on standards and standardisation processes, with a focus on the ICT sector. Over 250 of his papers have been published in conference proceedings, books and journals. He has been on the programme committee and editorial board of numerous international conferences and journals, respectively, and has served as an external expert on evaluation panels of various national and European R&D programmes, on both technical and socio-economic issues.

Kai is member of the Board of the European Academy for Standardisation (EURAS). He is also the founding EiC Emeritus of the 'International Journal on Standardization Research' and the 'Advances in Information Technology Standards and Standardization Research'; he still edits the 'EURAS Contributions to Standardisation Research' book series.

Curriculum Vitae

Education

1994 – 1998	PhD, Computer Science The University of Edinburgh, Scotland
1975 – 1985	Electrical Engineering RWTH Aachen University, Germany
1967 – 1975	Highers Certificate City Grammar School, Porz, Germany

Employment

Since July 1987	Head of Technical Staff, Computer Science Department, ComSys, RWTH Aachen University
May 1985 – June 1987	Member of Technical Staff, Computer Science Department, RWTH Aachen University

Portfolio

Journal Papers

Invited

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Appendix A: Questionnaires from Chapter 2

Other WG-Members
Standardisers
Standardisation Management

The survey was conducted during the 2nd half of 2013.

Questionnaire 'WG Members'

Background

Many companies have a well-defined standards strategy, others don't. Some have an influential central standardisation department; for others, it's more of an un-coordinated and distributed activity. While some manage, monitor, and track the standardisation activities of their staff, others haven't got a clue of who is doing what in their name, at which standards bodies. And moreover, earlier research suggests that those active in standards working groups do not necessarily represent their employers' interests.

The survey

Against the above background the survey aims to

- take stock of different organisations' approaches to standardisation and standardisation management,
- compile information about success factors in individual standards-setting activities.

To this end, I'm doing a number of case studies on different companies. For each case study (different) questionnaires are sent to people who have been involved – in different roles – in a particular standards-setting activity. These people include standardisation managers and active standards-setters from the company under study. Moreover, questionnaires are sent to people like you – members of standards working groups within which said company has been active.

And this is where I need your help. That is, I would like to ask you to complete the attached questionnaire. I appreciate that it may take some time to complete the questionnaire and I'll be happy with whichever information you are prepared to provide. It goes without saying that all information will be treated confidentially and will only be used for academic purposes. Names of companies and individuals will not be revealed unless so desired.

There is little I can offer in return. Of course, I can send you a report about the outcome of the study. Please let me know if you are interested.

And if you liked to receive any further information about this project, please do ask. I will be more than happy to help.

It would be great if you could complete and return the questionnaire by mid-November.

Thank you very much in advance.

Kai Jakobs.

1. Please provide some information about yourself; your background, your tasks and responsibilities in your organisation, and about your role and activities in XXXXX
2. Frequently, companies have different goals in standardisation. In XXXXX, roughly how many did participate to
   a) gather intelligence ('Observer');
   b) understand the intricacies of the implementation of the standard, but not to strongly contribute to its content ('Adopter');
   c) make active technical contributions, but without an interest in, or resources for, influencing the overall direction of the process ('Contributor');
   d) make many active technical contributions and to control the overall direction of the process ('Leader');
   e) try to prevent the emergence of a new standard ('Opponent')?

   If possible and acceptable, please also assign company names to each goal.
3. If a 'Leader' and/or an 'Opponent' were present:
   a) How did each of them try to achieve its respective goal (e.g. rely on market power, send technically capable representatives, send good negotiators, make superior proposals/contributions, build a strong alliance, etc.)? Please try to identify the most important approaches and list them in descending order of importance.
   b) Specifically, how important was the performance of the respective representative(s)?
4. What – or who – actually steered the process (e.g. general consensus and a common (technical) goal, the convenor or the editor, an individual without a formal role, a group of people from one company, etc.)?
5. Do you think the activity was a success, from the perspective of
   a) the XXXXX
      i.e. did it result in a standard that is (likely to become) widely implemented?

   b1) of the 'Leader(s)' (if any)
      i.e. did it succeed in getting most of its major contributions accepted?
      or

   b2) of the 'Opponent(s)' (if any)
      i.e. did it succeed to prevent or excessively delay the development of a new standard?

   Please briefly explain why.
6. In your view, which characteristics are important to be a successful standards-setter (please rank from 1 – 6; '1' being the most important one):
   a) a strong sense of purpose,
   b) in-depth technical knowledge,
   c) rhetoric capabilities,
   d) diplomatic skills,
   e) familiarity with procedures,
   f) other, please specify.

   Please briefly explain your view.
7. Again, in your view, does it increase a company's chances to get its contributions accepted if its representative assumes a formal role in the process (e.g. convenor, editor)?

If you've got any other comments, information, whatever – please write them down below.

THANK YOU VERY MUCH INDEED!

Questionnaire ‘Standardisers’

Background

Many companies have a well-defined standards strategy, others don’t. Some have an influential central standardisation department; for others, it’s more of an un-coordinated and distributed activity. While some manage, monitor, and track the standardisation activities of their staff, others haven’t got a clue of who is doing what in their name, at which standards bodies. And moreover, earlier research suggests that those active in standards working groups do not necessarily represent their employers’ interests.

The survey

Against the above background the survey aims to

- take stock of different organisations’ approaches to standardisation and standardisation management,
- compile information about success factors in individual standards-setting activities.

To this end, I’m doing a number of case studies on different companies. For each case study (different) questionnaires are sent to people who have been involved – in verious roles – in a particular standards-setting activity. These people include standardisation managers as well as active standards-setters from both the company under study and other companies involved in this activity.

And this is where I need your help. I would like to ask you to complete the attached questionnaire; it should not take overly much time to do so. It goes without saying that all information will be treated confidentially and will only be used for academic purposes. Names of companies and individuals will not be revealed unless so desired.

There is little I can offer in return. Of course, I can send you a report about the outcome of the study. Please let me know if you are interested.

And if you liked to receive any further information about this project, please do ask. I will be more than happy to help.

It would be great if you could complete and return the questionnaire by the end of August.

Thank you very much in advance.

Kai Jakobs.

1. Please provide some information about yourself; your background, your tasks and responsibilities in your organisation, and about your role and activities in **<insert WG here>**.
2. Did you receive a special training before becoming active in standardisation? If so, in which form and what did it cover?
3. Why did you contribute to **<insert WG here>** in the first place (e.g. technical interest, part of the job, boss told me to go, career move, etc.)?
4. Have you been informed about your employer's interests (e.g. technically or economically) in **<insert WG here>** prior to joining the working group? If so, did these interests imply to
    - a. influence the standard,
    - b. push an own standard,
    - c. prevent emergence of the standard,
    - d. compile intelligence,
    - e. exploit IPR,
    - f. create/extend a market through the standard,
    - g. other (please specify)?
5. Have you been asked to provide reports about the work done in **<insert WG here>** and/or about your activities in the group? If so, which information were requested and did any of these reports lead to changes in your tasks?
6. Typically, companies have different goals in standardisation. In **<insert WG here>**, which role were you supposed to adopt:
    - f) 'Observer' (gather information about the standard);
    - g) 'Adopter' (understand the intricacies of the implementation of the standard, but no contributions to its content);
    - h) 'Contributor' (make active technical contributions, but without an interest to influence the overall direction of the process);
    - i) 'Leader' (make many active technical contributions and try to control the overall direction of the process);
    - j) 'Opponent' (try to prevent the emergence of a new standard)?
7. Did you see yourself (and act accordingly) as a
    - a. Company representative;
    - b. National representative;
    - c. User advocate;
    - d. Promoter of a superior technical solution;
    - e. Other (please specify)?
8. Do you think the activity was a success, from the perspective of
    - a. **<insert WG here>**
      i.e. did it result in a standard that is (likely to become) widely implemented?
    - b. your employer
      i.e. did it achieve its goals?

   Please briefly explain why.
9. In your view, which characteristics are important to be a successful standards-setter (please rank from 1 – 7; '1' being the most important one):
    - a. a strong sense of purpose,
    - b. in-depth technical knowledge,

c. rhetoric capabilities,
d. diplomatic skills,
e. ability to form alliances,
f. familiarity with procedures,
g. other, please specify.

Please explain your view briefly.

10. Again, in your view, does it increase a company's chances to get its contributions accepted if (one of) its representative(s) assumes a formal role in the process (e.g. convenor, editor)?
11. Finally, please name a few people from other companies who also worked on **<insert WG here>** and who might be prepared to complete a shortish questionnaire or do a short interview.

And if you've got any other comments, information, whatever – please write them down below.

THANK YOU VERY MUCH INDEED!

Questionnaire – ‘Standardisation Manager’

Background

Many companies have a well-defined standards strategy, others don’t. Some have an influential central standardisation department; for others, it’s more of an un-coordinated and distributed activity. While some manage, monitor and track the standardisation activities of their staff, others haven’t got a clue of who is doing what in their name, at which standards bodies – earlier research suggests that those active in standards working groups do not necessarily represent their employers’ interests.

Against this background, I’m trying to find out whether or not there is a link between an organisation’s success in standardisation and its internal standardisation management. Subsequently, I will try and develop initial recommendations for organisations on how to improve performance in international standards setting.

The survey

This questionnaire is part of a survey that aims at taking stock of different organisations’ approaches to standards setting as well as to compile information about success factors and perceived outcomes of individual standards setting activities. It is sent to people like you – standardisation managers. Ideally, and with your help, a related questionnaire will be sent to two or three people in your organisation who have been active in a recent standardisation activity. Yet another questionnaire will be sent to other former members of the Working Group / Committee in charge of this activity.

I appreciate that it may take some time to complete the questionnaire (one could probably write whole essays in response to some of the questions) and I’ll be happy with whichever (partial) information you are prepared to provide. I’d also be happy to extract these information from any written material you can make available. In any case, all information will be treated confidentially and will only be used for academic purposes.

There is little I can offer in return. Of course, I will send you a report about the outcome of the project (which will, hopefully, be published as a book). Please let me know if you are interested. I would also be happy to try and help in cases where you could use assistance from academia

And if you liked to receive any further information about this project, please do ask.

It would be great if you could complete the questionnaire by mid-December.

Thank you very much in advance.

Kai Jakobs.

Please Note

'Standardisation management' refers to the overall management of an organisation's standards setting activities (in either a 'formal' body like ISO, IEC, ITU, CEN/CENELEC or a private standards consortium like W3C or OASIS). Specifically, it does <u>not</u> refer to activities like internal process standardisation or the introduction of standard software in an organisation or one of its departments.

A. General

1. Please provide some information about your organisation – it's core areas of activity, number of employees, branches/departments/subsidiaries, etc.
2. And a bit about your department.
3. And finally, some information about yourself, please; your background), tasks, and responsibilities.

B. Standardisation activities

1. Please explain briefly why your organisation actively contributes to standards setting, in which areas and in which organisations.
2. On a scale from 1 (not at all) – 10 (crucial), how important is active participation in standards setting for your organisation, and why?
3. On the same scale from, how important are the motivations below for participating in a standards setting activity:
   a) influence an emerging standard,
   b) push your own standard,
   c) prevent emergence of another standard,
   d) compile intelligence,
   e) exploit IPR,
   f) create/extend a market through development of a standard,
   g) other (please specify).
4. Typically, which role(s) does your organisation assume in standardisation? Please try and assign a percentage to each role.
   k) Observers (participate to gather intelligence);
   l) Adopters (strong interest in understanding the intricacies of the implementation of the standard, but no strong contributors to its content);
   m) Contributors (active participants, but less interested in, or lack resources for, influencing its strategic direction);
   n) Leaders (participation is business critical; aim to control the strategic direction of the process);
   o) Opponents (active participants who try to prevent emergence of a new standard)
   p) Other role. Please specify
5. Which of the below does your organisation do to reach its goals in standards setting (please mark) and how important would you consider each of these activities (again on a scale from 1 (completely unimportant) to 10 (absolutely crucial))?
   a) Assume a leading role in the process (e.g. editor, rapporteur, WG leader, etc.).
   b) Send excellent technical people.
   c) Send good communicators and diplomats.
   d) Provide general training/education for the standardisers.

e) Inform them about the business goals underlying the standardisation activity.
f) Monitor their activities.
g) Other (please specify).

C. Standardisation Strategy & Management

1. Does your organisation have a dedicated standardisation strategy?
   - If so, please outline briefly
     - which elements the strategy comprises,
     - who developed it, and who maintains/updates it.
   - If not – why not? Please explain briefly.
2. Who manages standardisation-related activities in your organisation (e.g. dedicated department, group attached to another department – which one?, etc.)?
3. If there is dedicated staff in charge of standardisation management:
   - Roughly how many are there?
   - To whom does their manager report?
   - What are their primary tasks?
   - What are their backgrounds (e.g. engineering, management/business, social sciences)?
4. How does your organisation stay informed about new relevant standardisation activities?
5. Has your organisation established dedicated communication channels to disseminate information relating to standardisation to potentially interested internal stakeholders? If so, how do they work?
6. Has your organisation established a dedicated link between innovation (R&D) and standardisation (e.g. to exploit the former via the latter)? If so, how is this link institutionalised (if at all)?
7. Who proposes a (potential) new standardisation activity (e.g. CEO, CTO, standards department, R&D, other departments / business units, customers, etc.)?
8. Which formal requirements does such a proposal need to meet (e.g. proof of technical relevance, business case)?
9. Do you do any 'performance evaluation' of your standardisation activities? If so, what are the criteria?
10. Do standardisation activities have their own budget line item (per business unit or centrally)?

D. About People

1. Roughly how many people in your organisation are actively contributing to technical standardisation activities? From which areas do they typically come (e.g. R&D, business units, management, marketing? How are they selected, by whom and based on which criteria?
2. Are there any incentives for prospective 'standardisers'? If so, which ones (e.g. a dedicated career path)?
3. Are they briefed for each individual standardisation activity they will participate in? If so, which information are provided? ´

4. Are they monitored (e.g. by keeping track of who goes where for which activity, collecting reports, etc.)?
5. Do you try to ensure continuous participation by the same people in each activity? If so, how?
6. Are standardisers trained for their job? If so, which aspects are considered necessary (e.g. technology, business strategy, legal/IPR issues, diplomacy, negotiation techniques, rhetoric)?
7. Does your organisation specifically hire people for certain standardisation-related jobs? If so, which capabilities/experiences/knowledge do they need to have?

E. Specific Standardisation Activities

1. Please identify one or two completed standardisation activities during the past two years into which your company has invested major efforts. Please name standards body, Working Group / Committee and standardisation project name for each activity.

Please answer the questions below for the above activity(ies).

2. What were your organisation's goals in the respective activity (please be as specific as possible)?
3. Please answer for each activity: Would you consider it a success or a failure for your company? Please rate on a scale from 1 (total failure) to 10 (complete success; all goals reached). Please explain your rating briefly.
4. Which criteria does your organisation apply to measure success in standardisation?
5. What were, in your opinion, the most important factors that contributed to the respective activities' success/failure?
6. What is, in your view, the 'overall success rate' of your company in standards setting, in cases where you wanted to
   a) influence an emerging standard,
   b) push your own standard,
   c) prevent emergence of another standard,
   d) compile intelligence,
   e) exploit IPR,
   f) create/extend a market through development of a standard,
   g) other (please specify).
7. Can you think of any improvements to your organisation's approach to standardisation management? If so, please explain briefly.

F. And Finally

1. Please provide contact information for some people in your organisation that had been active in the activity(ies) identified in question E.1 above.
2. Please provide contact information for some people from other organisations that had been active in the activity(ies) identified in question E.1 above.

If you've got any other comments, information, whatever – please put them down below.

Appendix B: Questionnaire from Chapter 3

The survey was conducted during the 2^{nd} half of 2007.

Hello,

Together with Vic Hayes and several others I am currently working on a book entitled ‘The genesis of Wi-Fi and the road towards global success’. My job is to contribute an academic perspective on standards making in general, with some links to the 802.11 activities. In this context, I’m particularly interested in the role of the individual committee member in the process. And here I’ll need your help. I would be most grateful if you answered the questions below. I appreciate that this may take some time (one could probably write whole essays in response to some of the questions), and I’ll be happy with whatever (partial) information you are prepared to provide. In any case, all information will be treated as confidential, and will only be used for academic purposes.

There is little I can offer in return for your efforts. I can offer an electronic version of the final paper. Please let me know if you are interested. And if you need any further information – please do ask.

Thanks a lot in advance, and greetings from Aachen.

Kai Jakobs.

Your Background

During which period have you been active in IEEE 802.11?

Around how many meetings did you attend?

Did you have voting rights? If so, roughly at how many meetings?

What was (were) your job title(s) during this period?

Did you have any prior experience in standards setting? If so, for how long?

Your Motivation and Role

Why did you attend the meetings in the first place (e.g., boss told me to go, interested in topic, part of the job, etc)?

Did you take over any special responsibility in the process (i.e., e.g., vice chair, secretary, technical editor)?

How would you characterise your role in the process (e.g., company representative, users' advocate, promoter of technically superior solutions, etc)?

Your Views and Experiences

What kinds of organisations (e.g., manufacturers, service providers, government entities, users, research institutions, etc) were represented in the committee, and which were the most influential ones (if any)?

Where did the respective influence come from (e.g., powerful organisation, deep pockets, strong technical proposals, active/respected representatives, etc)?

Did a company's representatives typically act in unison (i.e., were they likely to represent their affiliation's point of view)?

Did you notice individuals likely to follow their own personal agenda (as opposed to that of their respective employer/affiliation)? If so, was this a frequent phenomenon, and were these individuals successful (as far as you can tell)?

Did you observe committee members change their stance when changing employment? Can you give examples?

Did you see any coalitions of committee members being formed, pushing solutions independent from their respective employer's/affiliation's interests. Can you give any examples?

Did you observe any clashes of egos (e.g., over technical issues)? If so, were they exceptions or frequent phenomena?

What were the main factors influencing the technical decisions taken (e.g., supporters/opponents present during discussion, reputation of supporters/opponents, purely the technical merits of a proposal, solution already implemented somewhere, company/national/group interests/individual interests, anything else)? If possible, please indicate their relative importance as well.

Appendix C: Questionnaires from Chapter 5

Researchers – Applications.

Researchers – Smart Infrastructure

Standardisers – Applications

Standardisers – Smart Infrastructure

The survey was conducted during the 2nd half of 2016.

Dear Expert,

RWTH Aachen University has recently launched a small project that aims to get an idea how applications deploying a smart infrastructure (comprising e.g. M2M communication, the Internet of Things (IoT) and Cyber-Physical Systems (CPSs)) will be standardised in the future.

The cyber world and the physical world will (have to) converge for the development of smart applications. And this will need to be reflected in the associated standardisation activities. In effect, this will imply the need for co-operation in standards setting between rather diverse disciplines. Depending on the application area these may include, for example, computer science, telecommunications, civil engineering, architecture, traffic engineering, electrical engineering (and probably several others). To the best my knowledge, such inter-disciplinary standardisation activities are in only their infancy today, but will need to become 'standard' in the future.

To get a better picture of the associated issues I'll need expert help. I would thus be most grateful if you completed the questionnaire below and returned it to Kai.Jakobs@cs.rwth-aachen.de, preferably by *****.

I appreciate that this may take some time (one could probably write whole essays in response to some of the questions) and I'll be happy with whatever (partial) information you are prepared to provide. In any case, all information will be treated as confidential and will only be used for the purposes of this project.

There is little I can offer in return for your efforts. Our work will hopefully help to improve standardisation of a smart communication infrastructure and make the eventually emerging standards more useful for everyone. Obviously, this would be a benefit in itself. Apart from that, I can offer to send you the final report of the project (if you are interested, that is). Just let me know.

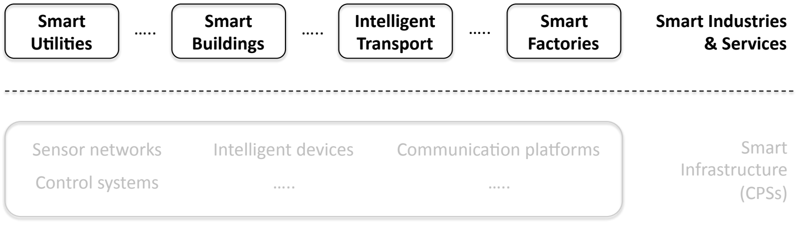
If you liked to receive any further information about this project, please do ask. I will be more than happy to help.

Many thanks in advance, and greetings from Aachen.

Kai Jakobs.

Future Standardisation of Smart Applications Deploying a Smart Communication Infrastructure

A Little Bit of Background



1. For how long have you been involved in R&D activities on smart applications (those targeting the upper layer in the Figure)?

Current status

Standards organisations

1. Which Standards Setting Organisations (SSOs) are the major players in the area of smart applications (e.g. Smart Grid, Smart Cities, Intelligent Transport Systems, etc.) today? Please explain why.
2. Are you aware of any **competition** between these entities? If so, on which topics?
3. Are you aware of any **co-operation** between these entities? If so, on which topics?

Future developments

Standards organisations

1. Do you, from an application perspective, see a need for dedicated smart infrastructure standardisation to establish an adequate infrastructure?

   If so, please state

   – When should such standardisation activities start?
   – Should there be a dedicated standards setting entity for the smart infrastructure? If so, please explain why?
   – Should that entity be a new SSO or be placed under the umbrella of an existing one? Please explain your preference.
   – Would close co-operation between relevant existing SSOs also be a viable option? Please explain why / why not.

   Otherwise, please explain why you don't see a need for dedicated mart infrastructure standardisation.
2. Will any of the SSOs currently active in the standardisation of smart applications become **more** important? Please state which ones and why.
3. Will any of the SSOs currently active in in the standardisation of smart applications become **less** important? Please state which ones and why.

4. Are any additional SSOs likely to become active in in the standardisation of smart applications? If so, which ones, will they be important and why (not)?
5. How would you rate the future importance of regional SSOs in in the standardisation of smart applications. Please explain your views.

Stakeholders

1. From your point of view, which stakeholders should be actively involved in the standardisation of smart applications (e.g. users, manufacturers, service providers, research organisations, consumer organisations, government entities, etc.)? Please explain why.
2. If you had to give the widest possible range of stakeholders a chance to influence the standardisation of smart applications – which SSO would you consider to be the most suitable ones in terms of its overall importance in the standardisation of smart applications?

Thank you very much!

Dear Expert,

RWTH Aachen University has recently launched a small project that aims to get an idea if and how Cyber-Physical Systems (CPSs) will be standardised in the future.

I believe that the emergence of CPSs will have major ramifications for the world of (ICT) standardisation. This is due to CPSs' inherent multi-disciplinary nature - designing and implementing them will require co-operation between various sub-fields of computer science, different fields of engineering and possibly also some natural sciences. My premise now is that this will need to be reflected in the underlying standardisation activities. Yet, to the best my knowledge a platform for such inter-disciplinary standardisation activities does not exist today.

To get a better picture of the associated issues I'll need expert help. I would thus be most grateful if you completed the questionnaire below and returned it to Kai.Jakobs@cs.rwth-aachen.de, preferably by **14 December 2016**.

I appreciate that this may take some time (one could probably write whole essays in response to some of the questions) and I'll be happy with whatever (partial) information you are prepared to provide. In any case, all information will be treated as confidential and will only be used for the purposes of this project.

There is little I can offer in return for your efforts. My work will hopefully help to improve standardisation of CPSs and make the eventually emerging standards more useful for everyone. Obviously, this would be a benefit in itself. Apart from that, I can offer to send you the final report of the project (if you are interested, that is). Just let me know.

If you liked to receive any further information about this project, please do ask. I will be more than happy to help.

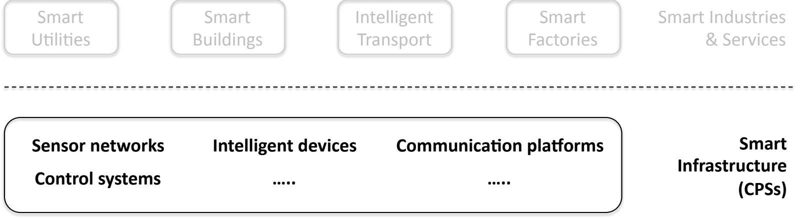
Many thanks in advance, and greetings from Aachen.

Kai Jakobs.

Future Standardisation of Cyber-Physical Systems (CPSs)

– For Non-Standards-Setters –

A Little Bit of Background



1. For how long have you been involved in CPS-related (R&D) activities (those targeting the lower layer in the Figure) and on which aspects specifically?

Standardisation

1. Judging by your experience: Would you agree that CPS development (and thus CPS standardisation) requires co-operation of different disciplines? If so, please state which ones and why. Otherwise, please explain why you don't see a need for inter-disciplinary co-operation in this field.
2. Are there any standards you refer to in your work on CPS development? If so, which Standards Setting Organisations (SSOs) developed them?
3. Are there any aspects in your work on CPS development for which you would like to have standards available that don't exist yet? If so, which aspects are these?
4. Do you see a need for dedicated CPS standardisation?
   If so, please explain
   – Why do you think that dedicated CPS standardisation would be beneficial for the field?
   – What should be standardised and why?
   – Roughly when should standardisation start / have started?
   – Which would, in your view, be the most promising approach to CPS standardisation?
     - A (new) SSO exclusively dedicated to CPS.
     - A (very) close co-operation of existing SSOs, each contributing its specific expertise.
     - A continuation of the current situation, i.e. a loosely-coupled web of SSOs developing potentially overlapping and sometimes competing technologies that support a pick-and-mix approach.

     Please explain why.

   Otherwise, please explain why you don't see a need for dedicated CPS standardisation.

Future Developments

1. Are there any new relevant (to CPSs) technologies or applications on the horizon? If so, please identify them.

2. If there are any such new developments, will any of them have ramifications for standardisation? Please state which ones and why.

Thank you very much indeed!

Dear Expert,

RWTH Aachen University has recently launched a small project that aims to get an idea how applications deploying a smart infrastructure (comprising Cyber-Physical Systems and the Internet of Things) will be standardised in the future.

The cyber world and the physical world will (have to) converge for the development of smart applications. And this will need to be reflected in the associated standardisation activities. In effect, this will imply the need for co-operation in standards setting between rather diverse disciplines. Depending on the application area these may include, for example, computer science, telecommunications, civil engineering, architecture, traffic engineering, electrical engineering (and probably several others). To the best my knowledge, such inter-disciplinary standardisation activities are in only their infancy today, but will need to become 'standard' in the future.

To get a better picture of the associated issues I'll need expert help. I would thus be most grateful if you completed the questionnaire below and returned it to Kai.Jakobs@cs.rwth-aachen.de, preferably by **13 October 2016**.

I appreciate that this may take some time (one could probably write whole essays in response to some of the questions) and I'll be happy with whatever (partial) information you are prepared to provide. In any case, all information will be treated as confidential and will only be used for the purposes of this project.

There is little I can offer in return for your efforts. Our work will hopefully help to improve standardisation of CPSs and make the eventually emerging standards more useful for everyone. Obviously, this would be a benefit in itself. Apart from that, I can offer to send you the final report of the project (if you are interested, that is). Just let me know.

If you liked to receive any further information about this project, please do ask. I will be more than happy to help.

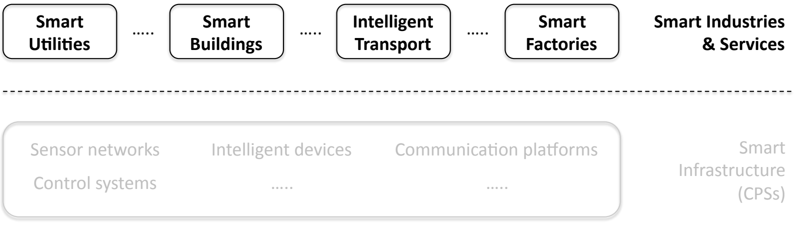
Many thanks in advance, and greetings from Aachen.

Kai Jakobs.

Future Standardisation of Smart Applications Deploying a Smart Infrastructure

(Comprising Cyber-Physical Systems, CPSs, and the IoT)

A Little Bit of Background



1. For how long have you been involved in standardisation activities on smart applications (those targeting the upper layer in the Figure) and with which Standards Setting Organisations / Technical Committees / Working Groups (SSOs/TCs/WGs)?

Current status

Standards organisations

1. Which SSOs/TCs/WGs are the major players in standardisation of smart applications (e.g. Smart Grid, Smart Cities, Intelligent Transport Systems, etc.) today? Please explain why.
2. Are you aware of any **competition** between these entities? If so, on which topics?
3. Are you aware of any **co-operation** between these entities? If so, on which topics?

Stakeholders

1. Is there a group of stakeholders that dominate the process (e.g. large manufactures, research institutes, government entities, service providers, users)? If so, which one(s) and from which sector(s) to they come (e.g. mechanical/electrical engineering, telecommunications, software engineering, etc.)?
2. Where does influence in the standards setting process in general come from (e.g. deep pockets, strong alliances between firms, good technical proposals, active/respected representatives, etc.)?
3. Are there, in practice, any barriers that (may) deter certain stakeholders (e.g. small companies, users, consumer advocates, etc.) from participating in the standardisation processes? If so, which ones?
4. How important are the capabilities (technical, rhetoric, diplomatic, etc.) of the individual participants?

Future developments

Standards organisations

1. Do you, from an application perspective, see a need for dedicated CPS (smart infrastructure) standardisation to establish an adequate infrastructure?

If so, please state

- When should such standardisation activities start?
- Should there be a dedicated standards setting entity for CPSs? If so, please explain why?
- Should that entity be a new SSO or be placed under the umbrella of an existing one? Please explain your preference.
- Would close co-operation between relevant existing SSOs also be a viable option? Please explain why / why not.

Otherwise, please explain why you don't see a need for dedicated CPS (smart infrastructure) standardisation.

2. Will any of the SSOs currently active in the standardisation of CPS-based applications become **more** important? Please state which ones and why.
3. Will any of the SSOs currently active in in the standardisation of CPS-based applications become **less** important? Please state which ones and why.
4. Are any additional SSOs likely to become active in in the standardisation of CPS-based applications? If so, which ones, will they be important and why (not)?
5. How would you rate the future importance of regional SSOs in in the standardisation of CPS-based applications. Please explain your views.

Stakeholders

1. From your point of view, which stakeholders should be actively involved in the standardisation of CPS-based applications (e.g. users, manufacturers, service providers, research organisations, consumer organisations, government entities, etc.)? Please explain why.
2. If you had to give the widest possible range of stakeholders a chance to influence the standardisation of CPS-based applications – which SSO would you consider to be the most suitable ones in terms of
    a. its overall importance in the standardisation of CPS-based applications,
    b. its process, regulations and by-laws?

Thank you very much!

Dear Expert,

RWTH Aachen University has recently launched a small project that aims to get an idea if and how the smart communication infrastructure (comprising e.g. M2M communication, the Internet of Things (IoT) and Cyber-Physical Systems (CPSs)) will be standardised in the future.

In any case, the cyber world and the physical world converge. My premise now is that this will need to be reflected in the associated standardisation activities. In effect, this will imply co-operation in standards setting between rather diverse disciplines, including e.g. various sub-fields of Computer Science, Mechanical/Electrical/Telecommunications Engineering and possibly also Biology and other Natural Sciences.

To get a better picture of the associated issues I'll need expert help. I would thus be most grateful if you completed the questionnaire below and returned it to Kai.Jakobs@cs.rwth-aachen.de, preferably by *****.

I appreciate that this may take some time (one could probably write whole essays in response to some of the questions) and I'll be happy with whatever (partial) information you are prepared to provide. In any case, all information will be treated as confidential and will only be used for the purposes of this project.

There is little I can offer in return for your efforts. Our work will hopefully help improve standardisation of a smart communication infrastructure and make the eventually emerging standards more useful for everyone. Obviously, this would be a benefit in itself. Apart from that, I can offer to send you the final report of the project (if you are interested, that is). Just let me know.

If you liked to receive any further information about this project, please do ask. I will be more than happy to help.

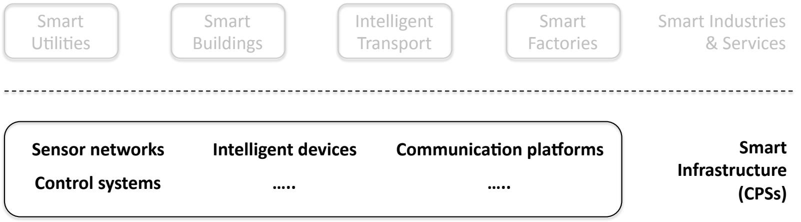
Many thanks in advance, and greetings from Aachen.

Kai Jakobs.

Future Standardisation of a Smart Infrastructure

– For Standards-Setters –

A Little Bit of Background



1. For how long have you been involved in smart-infrastructure related standardisation activities (those relating to the lower layer in the Figure) and with which Standards Setting Organisations / Technical Committees / Working Groups (SSOs/TCs/WGs)?

Current status

1. Which SSOs/TCs/WGs are the major players in smart-infrastructure related standardisation today? Please explain why.
2. Are you aware of any **competition** between any of these entities? If so, on which topics?
3. re you aware of any **co-operation** between any of these entities? If so, on which topics?

Future developments

1. Do you, in principle, see a need for dedicated smart-infrastructure standardisation (e.g. because of the need for co-operation between different disciplines)?

   If so, please state

   – For which smart-infrastructure related aspects would such dedicated standardisation be beneficial?

   – When should such standardisation activities start?

   – Should there be a dedicated standards setting entity for smart-infrastructure? If so, please explain why?

   – If you feel such an entity were necessary: Should it be a new SSO or be placed under the umbrella of an existing one? Please explain your preference.

   – Would close co-operation between relevant SSOs also be a viable option? Please explain why / why not.

   Otherwise, please explain why you don't see a need for dedicated smart-infrastructure standardisation.
2. Which additional co-ordination mechanisms between the different standards setting entities do you you envisage for the future (if any) and which ones would you consider helpful?
3. Will any of the SSOs currently active in smart-infrastructure related standardisation become **more** important? Please state which one(s) and why.
4. Will any of the SSOs currently active in smart-infrastructure related standardisation become **less** important? Please state which one(s) and why.

5. Are any additional SSOs likely to become active in smart-infrastructure related standardisation? If so, which ones, will they be important and why (not)?
6. How would you rate the future importance of regional SSOs in smart-infrastructure related standardisation. Please explain your views.

Thank you very much indeed!

Today, virtually all Information and Communication Technology (ICT) systems are based on international standards; they are the one major mechanism to ensure interoperability. That is, those who actively contribute to the development of these standards are in a position to shape future ICT systems to make them meet their respective technical and/or economic preferences. This may well be worth Billions od Euros.

Very generally, a company's standardisation management function is tasked with the 'translation' of the firm's strategy in a given sector into a supporting and enabling standardisation strategy and its implementation. Given the crucial importance of ICT systems for virtually every business (and beyond), this is of critical managerial relevance. However, so far only very little research has been done in this field.

This thesis aims to contribute to a better understanding of the different facets that, taken together, make up corporate ICT standardisation management. To this end, it develops a framework, which incorporates those external and internal (to the firm) factors that may exert an influence on it. Some of these factors are discussed in detail.

Kai-Uwe Jakobs has been with RWTH Aachen University's Computer Science Department since 1985. His activities and research interests focus on ICT standards and the underlying standardisation processes. Over time, he has (co)-authored/edited 30+ books and published 250+ papers. Kai is a member of the Board of the European Academy for Standardisation (EURAS); he's also the founder and former EiC of the 'International Journal on Standardization Research'. He holds a PhD in Computer Science from the University of Edinburgh and is a Certified Standards Professional.

This thesis has sprung from the Part-time PhD Programme at the Rotterdam School of Management, Erasmus University (RSM). Part-time PhD candidates conduct research against the highest academic standards on topics with real-world application value, thereby contributing to the positive impact of RSM research on business and other societal stakeholders.

RSM is one of Europe's top business schools with a strong reputation for academic research. It aims to develop business leaders immersed in international careers, who can become a force for positive change by carrying a critical, caring, and collaborative mindset into a sustainable future.

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