Scale of Standards Dynamics:

Change in formal, international IT standards

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Standards might be presumed to be stable. But how stable are they in reality? This paper presents the findings of a quantitative analysis of standards dynamics in ISO/IEC JTC1, the formal international standards body for IT standardization.
It shows the volume of different types of change and developments over time. Certain themes are elaborated upon, such as whether there is a relationship between standards' age and area of technology. The paper closes by drawing attention to a few maintenance policy issues, and raises a number of questions for follow-up research.

Introduction

One might assume that committee standards are stable and are not changed easily. Indeed, on the face of it 'stability' would seem to be an intrinsic, defining characteristic of standards. It is in most cases a precondition for interoperability between IT products and services, the area of technology addressed in this paper. Standards are signposts (Mansell & Hawkins, 1992). They are a point of reference for producers, suppliers and consumers, and reduce transaction costs (Kindleberger, 1983). They coordinate technology and market development (Farrell & Saloner, 1988). To effectively work as such, they need to be stable.
However, as we intuitively know, standards are not static entities. In practice they are revised, split and merged, withdrawn, succeeded, reinstated, etc. The changes which a standard undergoes after it has been developed and published, including its withdrawal, replacement and its possible after-life, we refer to by the term *standards dynamics*.
Although, exceptions aside[1], no systematic research has yet been done that takes standards dynamics as its core-focus, there is a fair amount of anecdotal evidence and evidence from specialist journals for IT practitioners. Moreover, there are also some case studies about post-hoc changes to standards. Usually these deal with more radical changes. Examples of such cases are,

- Telefax (Comité Consultatif International Télégraphique et Téléphonique, CCITT). The problem with Telefax standardization started when a Group 3 digital telefax standard was proposed. At the time, there already were two standards: the Group 3 for analogue networks and the Group 4 for digital networks. The main opposition against the new proposal came from the Group 4 supporters. To prevent the Group 3 digital telefax standard from being accepted, they came up with a compromise. In the ensuing stalemate, the CCITT decided to accept the compromise as well as the proposal for a Group 3 digital telefax, creating rival technologies that could well fragment the market. (Schmidt & Werle, 1998)

- Internet Protocol (Internet Engineering Task Force, IETF). To solve the lack of internet addresses in Internet Protocol version 4 (IPv4) the Internet standards body started working on a version 6 (IPv6) in 1990. It took a long time to develop (Request for Comments, RFC 2460, 1998). The resulting protocol was not compatible with IPv4. In order to prevent the development of separate networks and to ease the transition to IPv6 and recreate compatibility, a separate standard on "Transition Mechanisms for IPv6 Hosts and Routers" (RFC 2893, 2000) was developed. (Van Best, 2001)
- Standard Generalized Markup Language (SGML) (ISO/IEC JTC1). The SGML (1986) standard, a standard for structuring information, was already amended in 1988, but thereafter remained stable until 1996. In 1996 a Corrigendum was added (ISO 8879: 1986/ Cor 1:1996). In the same year work on Extensible Markup Language (XML) started in the World Wide Web Consortium (W3C). XML was to bring SGML functionality to the web. Although XML developers originally aimed for compatibility with SGML, this point was not prioritized. In the end, despite additional measures to re-create compatibility - by means of non-binding recommendations in XML 1.0 (1998) and a second corrigendum by ISO (ISO 8879: 1986/ Cor 2:1999) – a fragmented practice resulted. XML partly replaced SGML, fragmented the existing market and created new markets. (Egyedi & Loeffen, 2002)

Radical changes such as the above but also smaller changes can lead to problems for standards users (implementors) and consumers (end-users). Some of the main problems are

- the lack of transparency that may arise and increased transaction costs (e.g. consumer unawareness of differences between versions or of the consequences for interoperability of products complying to different versions).
- the costs of update and loss of investments for standard implementors and IT consumers;
- interoperability is not self-evident anymore; that is, uncertainty may arise about the interoperability of new standard-compliant IT with ones own installed base and with the installed base of others.

In sum, standards dynamics is a problem.[2]

In this paper we aim to complement case study-based insights with more quantitative research into standards dynamics. We explore the scale of standards dynamics. Our main research question is: *How stable are standards?* That is, which types of dynamics are at stake? How often do they occur? What is the average age of a standard? Etc.. We focus on international, formal IT standards, that is, on standards developed in JTC1, the Joint Technical Committee1 of ISO (International Standardization Organization) and IEC (International Electrotechnical Commission).

The paper is structured as follows. First, we summarize the terminology used and the procedures developed by JTC1 on standards maintenance, for standard maintenance defines its perspective on standards dynamics. Next, we describe characteristics of the dataset and the research methodology used. Two sets of analyses have been done. The first gives an overall impression of the changes that have occurred (level 1 analysis). The second group of analyses focuses on themes of change, e.g. differences in age between standard documents, and the relation between age and area of technology (level 2 analysis). The findings are presented

successively. The paper closes with a summary of the main findings, with a number of conclusions and with recommendations for follow-up research.
In respect to recommendations, the insight gained in the scale of standard dynamics is a stepping-stone towards investigating the causes thereof, an issue addressed in follow-up research. Therefore, one of the outcomes aimed for is identifying new questions, questions which this study raises. They will be listed as research recommendations in the concluding section.

Standard maintenance in JTC1

JTC1 was installed in 1987 to address the surge of work items in the field of information technology. JTC1 has a collaborative agreement with ITU-T, the part of the formal International Telecommunication Union that develops formal standards (i.e. recommendations) for telecommunications. Although JTC1 is officially one of ISO and IEC's technical committees (e.g. the ISO central secretariat administers JTC1 data), in certain respects it operates as an autonomous body. For example, it has its own website, its own directives, and currently 16 subcommittees. These produce International Standards (ISs) and standard-type documents, namely Technical Reports (TRs) and international standardized profiles (ISPs)[3]. Apart from developing and ratifying standards, they do maintenance work on standards. Standards maintenance starts with a periodical review. No more than five years after publication of the most recent edition of a standard, it is reviewed to decide whether it should be confirmed, revised, declared as stabilized, or withdrawn (JTC1, 2004, 15.3.1). To start with the first option, a standard is confirmed if it has been implemented at the national level and applied in practice[4].
A revision may involve supplementing a standard with a separate document called

- a *Technical Corrigendum* (Cor)[5] to correct a *technical defect* (i.e. a technical error or ambiguity in a standard that could lead to its incorrect or unsafe application; JTC1, 2004, 15.4.1);
- a *Technical Amendment* (Amd), which is a *technical addition or change*[6]*;*

or it may consist of

- a next *Edition* (Ed.) (e.g. to correct editorial defects[7] or integrate supplements in the main body),
- a *Replacement* (e.g. standards A,B, and C may merge into standard D; or D may be split into A,B, and C), and acquire a new project number, or
- a *Change of document type,* e.g. from an IS into a TR.

For example, the set of standards and standard-type documents on Local and metropolitan area networks ISO/IEC 8802 consists of different parts (1- 12 parts, part 8 and 10 missing). All of them are ISs except for part 1, which is a TR. For most parts new editions have replaced old ones (e.g. part 3 four times). Some parts also have Corrigenda and/or Amendments. These are sometimes replaced by a new Corrigendum and/or Amendment (e.g. part 2), or are integrated into a new edition.
A standard might be withdrawn because a new edition replaces it, because it gets a new project number, or because it has become obsolete (no replacement).
Lastly, a standard may be declared to be stabilized. *Stabilized standards* are not subject to periodic review (JTC1, 2004, 15.3.1). "A stabilised standard (...) will be retained to provide for the continued viability of existing products or servicing of equipment that is expected to have a long working life." (JTC1, 2004, 15.6)[8] That is, other standards and/or in-use implementations depend on them. An ISO document (ISO/TMB, 2004)

gives us two examples:

- The rationale to reinstate and stabilize the programming language Algol 60 (ISO 1538:1984), which was withdrawn in 1990, was that the standard and algorithms therein are still referenced to e.g. in textbooks and national standards.
- The rationale to reinstate and stabilize a standard for Basic mode control procedures (ISO 2628:1973; ISO 2629:1973), which was withdrawn in 1997, was that "there are many terminals in existence operating TPAD and other similar protocols (...) that are based on ISO 2628 and ISO 2629", and which are character-oriented.

Since their market is not expected to evolve anymore, no standards maintenance is needed (e.g. it is not necessary to keep a committee secretariat in place).

In all, JTC1 has 193 such stabilized standard documents (i.e. ISs, TRs, Amendments and Technical Corrigenda (dd. 27th of April 2004).

The notion of 'stabilized standard' already suggests that other standards may not be stable. It already indicates that JTC1 also grapples with problems of legacy and standards dynamics. A second sign thereof is the notion of 'provisionally retained edition' (ISO, 2004, p.3). *A provisionally retained edition* is an edition, which has been updated but is still valid – instead of being withdrawn, as is common procedure[9]. For example, one of the standards for quality management and quality assurance, ISO 9000-1 (1994) was revised in 2003. However, because the certification market still works with it, the 1994 edition has been retained. The 'provisionally retained edition' procedure is a double-edged sword. It allows parties who value compliance to international standards but cannot or do not wish to update their implementations, to preserve their investment. But the validity of successive editions may cause confusion and reduce the transparency of the standards market for newcomers.

If we take a closer look into what the procedures for *stabilized standards* and *provisionally retained editions* are used for, they are to a large extent used to re-confirm the current relevance of earlier Open Systems Interconnection (OSI) standards. For all 27 provisionally retained editions (ISO, August 15, 2004), and a majority of the stabilized standards (i.e. 101 out of 193) are OSI- related. This does not fit well with the widely shared feeling that OSI, because of a lack of market, is passé.

Methodology

The empirical results presented in the next section are based on quantitative analyses of the JTC1 database. The database was accessed in the period 12-15 July 2004[10], at the ISO secretariat in Geneva, Switzerland. Two types of queries were done. Firstly, because not all JTC1 data is public, some straightforward queries (lists and frequencies) were done for us by the central secretariat (i.e. not hands-on). For example, a list of revised standards was provided. Such data is in most cases not suitable for statistical analysis.

Secondly, permission was granted to directly query data that is also publicly available via ISO's website (www.iso.ch). At stake is a predefined subset of the database. This subset contains all JTC1 standards and standard-type documents (i.e. the whole population), but not all variables (data fields). It includes basic document features such as standard reference, date of publication, document number, document type, committee number, technical area addressed, and the most relevant fields in respect to standards dynamics such as the review stage of the document, the date, type and number of editions, and the number of amendments and corrigenda. According to the International Classification for Standards (ICS) level 1, the documents address the technical areas of *Telecommunications, Audio and Video Engineering* (category 33) and in particular *Information Technology / Office Machines* (category 35).

The JTC1 database covers data from 1969 onwards. That is, it includes data from ISO TC97, the predecessor of JTC1. Data has been systematically and rigorously gathered since 1998. Earlier data can be conflicting or missing[11]. For example, during our research the edition number of a standard sometimes turned out to be incorrect (e.g. 8482 and 11801), was not included (e.g. 1155, 2593, 1860), or the same standards document was included twice because it was assigned to different ICS areas (e.g. 948, 962,1092-1). However, as far as we are aware, this is exception rather than rule. Moreover, due to the large number of documents the statistical significance of our results is not affected.

We mainly used SPSS 11.5 software as our statistical tool, sometimes next to and in combination with a spreadsheet program. To acquire overall insight in the scale and characteristics of standards dynamics, primarily descriptive statistics (e.g. frequencies and cross tabulations), variance analysis (e.g. ANOVA and Kruskal-Wallis test), and post-hoc tests (e.g. Tamhane test) were used. The reason for choosing specific analyses will be discussed on a case-by-case basis.

Lastly, some choices had to be made. As the reader will see, in all graphs the year 2004 is excluded because of the moment the data was gathered (mid-August). Furthermore, sometimes the area which a standard covers is addressed by a set of document parts. In the following these parts are treated as original, separate standards departing from the idea that for the purpose of examining standards dynamics it is irrelevant whether an area is addressed by different standards (different reference numbers) or by different standards parts (which share the same reference number).

Results

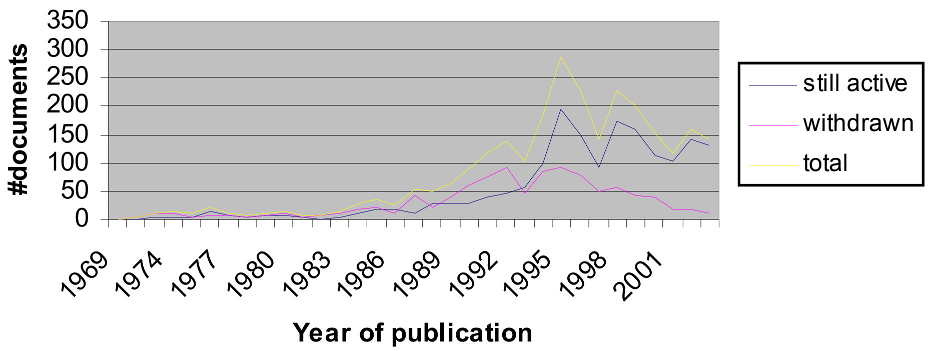
The JTC1 database contains 2752 documents. 2318 of them are international standards (ISs), 264 are international standardized profiles (ISPs) and 170 are technical reports (TRs). These are in the following referred to as standards unless explicitly stated. The 2752 documents consist of active and withdrawn documents, different types of revisions and replacements, original documents and supplements, and old and new editions.

Below, to begin with, we examine these features of standards dynamics in a straightforward manner; i.e. by treating all documents on a par (level 1 analysis). This serves, in particular, to gain insight in developments over time. Some of the level 1 findings are later studied in more detail by aggregating the data on main documents (level 2 analysis).

Dynamics overall

The total amount of documents published per year increased considerably from 1990 onwards, peaks slightly in the year 1992 and more pronounced in 1995, and decreases after that. See Figure 1.

Figure 1: Standards published per year:
Number of active and withdrawn documents



This can largely be explained by the following factors:

1) a phase of Eurocentrism (1985-1992) in formal international standards bodies in the period leading up to 1992;
2) support for the OSI standards trajectory by the formal SDOs and the market uptake of competing Internet protocols from the early 1990s onwards;
3) a radical increase and competition from standards consortia in the field of ICT from 1995 onwards; and the possible emergence of a new equilibrium.

More specifically, the peak in 1992 coincides with the prior deadline of the European Commission to remove technical barriers to trade and achieve a harmonized Common Market. In the period leading up to December 1992, the Commission acquired the support of the European formal standards bodies for delivering the necessary standards in the given time frame (e.g. by means of mandates). European standardization gathered momentum. Ties with the international standards level were tightened. Formal international standardization passed through a phase of Eurocentrism (Egyedi, 1996). See box 1. That is, European developments could well explain the increase in international activity in and around 1992.

Box 1: Eurocentrism and the Cooperation Agreements between formal European and International standards bodies.

In the period leading up to 1992 European Common Market deadline three cooperation agreements between European and International standards bodies were developed: the IEC-CENELEC *Agreement on exchange of technical information between both organisations* (1989), the IEC-CENELEC *Agreement on common planning of new work and parallel voting* (1991) and the *Agreement on technical cooperation between ISO and CEN* (Vienna Agreement, 1991). Two features in these agreements are of interest. Firstly, if a European body contemplates new standards work, it first ascertains that the work cannot be accomplished within an international standards body. Secondly, international draft standards (DIS) automatically become European drafts (prEN). The drafts are voted upon in parallel internationally and on the European level. Likewise a European prEN is put to a parallel vote at the international level.

The agreements offer the European partners the possibility to intervene in international standardization where work items of European origin show slow progress. In the IEC/CENELEC agreement (1991, p.6) a failure of planning is cited as grounds for withdrawing an item and proceeding its standardization at the European level. Between ISO and CEN, apart from timing reasons of technical and procedural nature are also noted as grounds for intervention. ("CEN reaffirms the primacy of international standardization work, (...) and use of international results wherever possible, (...). However, it is to be acknowledged that CEN (...) chooses, according to the advice of its interested parties, amongst (..) possibilities (...)."[12]. At stake is a conditional commitment of the European partners, a conditionality based on reference to European mandates and standards for European regulatory purposes.

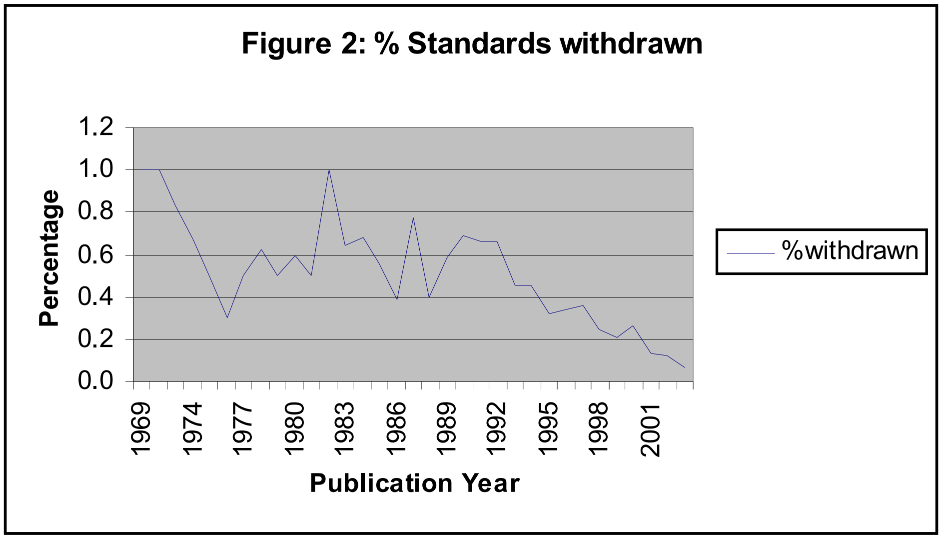
Taking a closer look at the peak in 1995 (N=286), 60% (N=172) of the documents published in that year are OSI-related (ICS 35.100). Many of them are ISPs (N=104).[13] We assume that this flurry of OSI activity is at least partly caused by the rising popularity of a competing network solution: Internet (e.g. Abbate, 1994). From 1993 onwards implementations of Internet protocols (TCP/IP, SMTP, etc.) are fast gaining ground. Lastly, we hypothesize that the decline in number of JTC1 standards published after 1995 is related to the exponential growth of the number of standards consortia in the second half of the 1990s (Hawkins, 1999). Where previously many newly founded fora and consortia adapted to or were assimilated in the overall formal structure (Genschel, 1993), they played a more competitive role from the mid-1990s onward. That is, they were pinned as competitors in the discourse about timely and effective standardization. Although perhaps too early to say, it seems as if the decline in the number of JTC1 standards published per year seems to have come to a halt. This suggests that an equilibrium has been reached between JTC1 and the IT consortia in respect to standards work. (NB: Possibly the argument can be extended beyond the number of consortium standards, relative to formal standards, to the number of consortia, relative to formal bodies. Indirect support is provided by Blind & Gauch (2005), who note that the number of consortia most relevant for European IT standardization (i.e. CEN/ISSS) is declining.)

Withdrawals

Currently, 1762 of the 2752 standards that have been published in the past are still active, while 990 have been withdrawn (see Table 1). Figure 1 shows the absolute number of standards published per year, part of which are still active and part of which have later been withdrawn. The withdrawal line follows the overall pattern of standards published and shows a 'bump' in the period 1992-1995. We have to keep in mind that, in general, older standards are more likely to have been withdrawn than standards just published – in absolute numbers. How many standards have been withdrawn per year proportionate to the total number of standards published? Figure 2 shows an irregular pattern in the period before 1989. Very few standards were published then (e.g. only one was published in 1969 and ultimately withdrawn). If we disregard this period, a clear trend emerges. This, too, is interesting. For one could expect that due to the extra time pressure and workload in 1992 and 1995 JTC1 might have developed less robust standards, that is, standards which would sooner require a new edition – and, thus, also a withdrawal of the old one. Moreover, a shortening of standards development time (see Table 5) also seems not to have impacted the withdrawal rate.

Table 1: Standard documents active and withdrawn

	Stage in life-cycle		Total
Type of standard document	still active	withdrawn	
International Standard	1418	900	2318
Int. Stand. Profile	223	41	264
Technical Report	121	49	170
Total	1762	990	2752



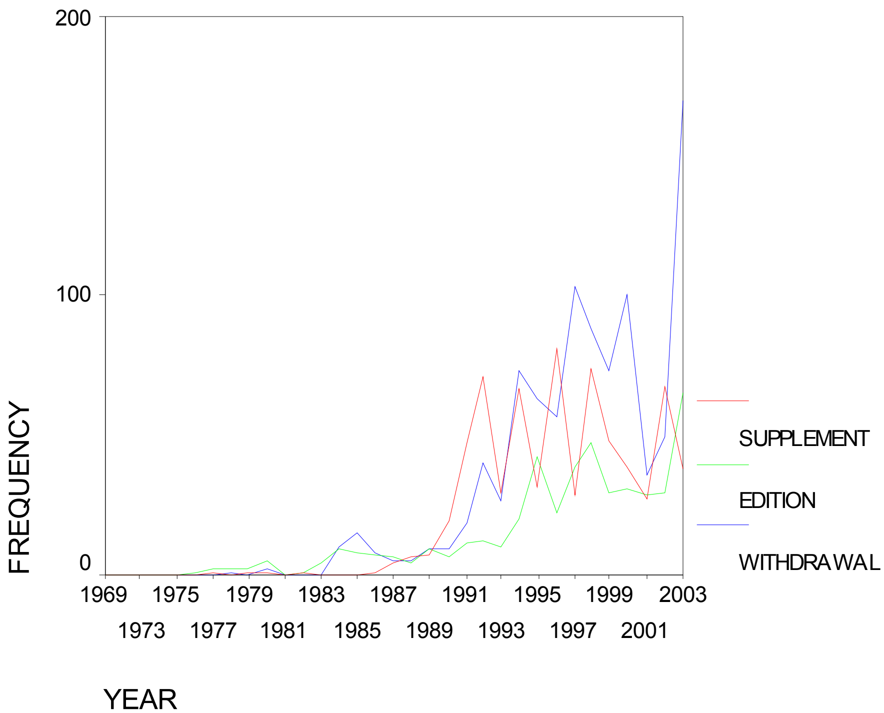


Figure 3: Changes over time: Supplements (by publication date), Editions (by publication date) and Withdrawals (by withdrawal date).

In the above, we focused on year of publication. If we look at the withdrawal line in figure 3, the number of withdrawn documents increases with periodic spurts, roughly proportionate to the overall number of publications, shows a sharp decline in 2001-2002, and a sudden increase again in 2003. Of interest is that two other features of standards dynamics share the dip in 2001, which is something to be examined further.
In respect to standards dynamics, the year of withdrawal is in most respects more informative than the publication year. It is e.g. a partial indicator of maintenance activity over time. In the following we will therefore focus on year of withdrawal unless explicitly stated otherwise.

Revisions

Revisions may concern new editions of single documents, changes of document type, integration of or a split into several documents, etc. Some documents *revise* previous documents and are later themselves *revised by* new documents. For example, part 4 of IS 7816 (7816-4), active since 1995, is in 2004 revised by a new part 4, a part 5, a part 8 and a part 9 (Table 2). Table 2 shows that the new part 9 of standard 7816, which is active since 2004-06-11, revises and integrates several other parts as well as part 4, including the amendments and corrigenda belonging to these parts.

Reference	Stage Started	Revised by	Stage/Started	
ISO/IEC 7816-4:1995	9092	ISO/IEC 7816-5	6000	2004-10-21
(id 14738)	2001-02-23	ISO/IEC 7816-4	6000	2004-11-19
JTC 1/SC 17/WG 4		ISO/IEC 7816-8:2004	6060	2004-06-11
		ISO/IEC 7816-9:2004	6060	2004-06-11

Table 2: Example of a forward document revision ("revised by"). (Source: ISO Secretariat, 26-11-2004.)

Reference	Stage Started	Revises	Stage/Started	
ISO/IEC 7816-9:2004	6060	ISO/IEC 7816-9:2000	9599	2004-06-11
(id 37990)	2004-06-11	ISO/IEC 7816-4:1995	9092	2001-02-23
JTC 1/SC 17/WG 4		ISO/IEC 7816-5:1994	9092	2000-02-10
		ISO/IEC 7816-6:1996	9599	2004-05-21
		ISO/IEC 7816-8:1999	9599	2004-06-11
		ISO/IEC 7816-4:1995/Amd 1:1997	6060	1997-12-18
		ISO/IEC 7816-5:1994/Amd 1:1996	6060	1996-12-19
		ISO/IEC 7816-6:1996/Cor 1:1998	9599	2004-05-21
		ISO/IEC 7816-6:1996/Amd 1:2000	9599	2004-05-21

Table 3: Example of a backward document revision ("revises"). (Source: ISO Secretariat, 26-11-2004.)

In all, 999 documents have been "revised by" another. 559 documents have revised one or more others. The difference between the two numbers indicates that integration and merging occurs more often than splitting up documents.

Replacements

From the administrative angle, there are two types of replacements[14]. Firstly, those standards which have been given a new document number but which are still of the same document type. There are 109 such cases, all published between 1980 and 2004. Salient is that 70 of them were published all in one year (i.e. 1994). Secondly, some replacements keep their number but change document type: there are 23 of those, all published between 1988-2004.

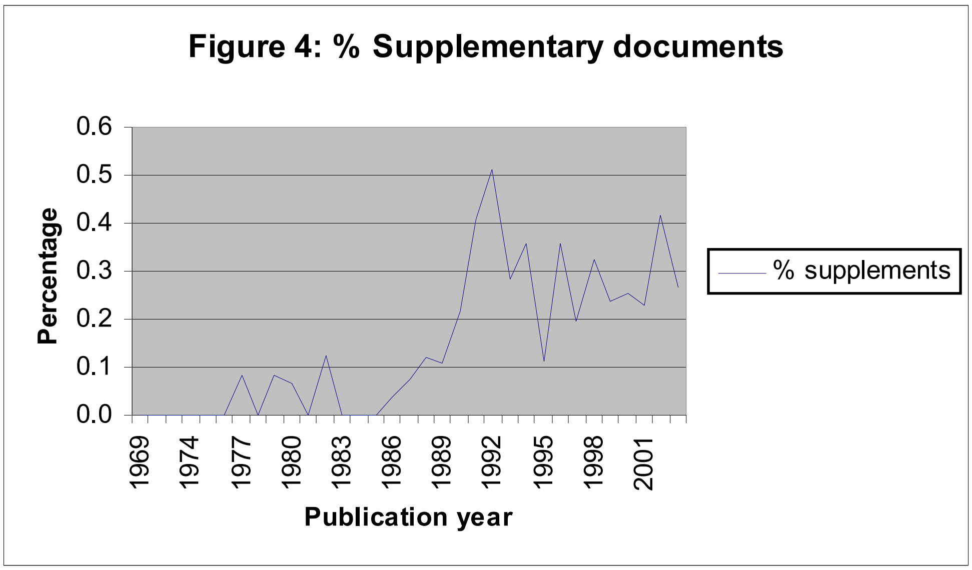
Supplements

Of all documents one quarter (25.7%, N=708) is a supplementary document: Corrigendum (N=413), Amendment (N=278), or Addendum (N=17). See Table 4. (NB: Addenda were only published between 1977 and 1991. See figure 5.)

Table 4: Supplements

Supplement	Frequency	Percent
0	2044	74.3
Corrigendum	413	15.0
Amendment	278	10.1
Addendum	17	.6
Total	2752	100.0

The use of supplementary documents really starts in 1990. From then on the amount of supplements remains rather stable over the years - although it can vary strongly per year. See Figure 3. Also in proportion to the total number of standards the number of supplements remains rather stable, the years 1992 (50%) and 1995 (10%) excepted. See Figure 4.



There are different explanations possible for the steep incline in 1991, explanations which have very different implications (see conclusion). Firstly, the steep incline partly coincides with the overall response to the challenge posed by the European 1992-Common Market requirements. That is, it roughly fits in with the general pattern.

Secondly, between 1989 and 1992 ISO/IEC procedures were adapted to hasten up the process from 7 to 3 years for a draft IS. See Table 5. Possibly the use of supplements has become a structural post hoc measure to compensate for 'too hasty' or, more positively formulated, 'efficient' standards development.

Figure 5: Supplementary documents specified

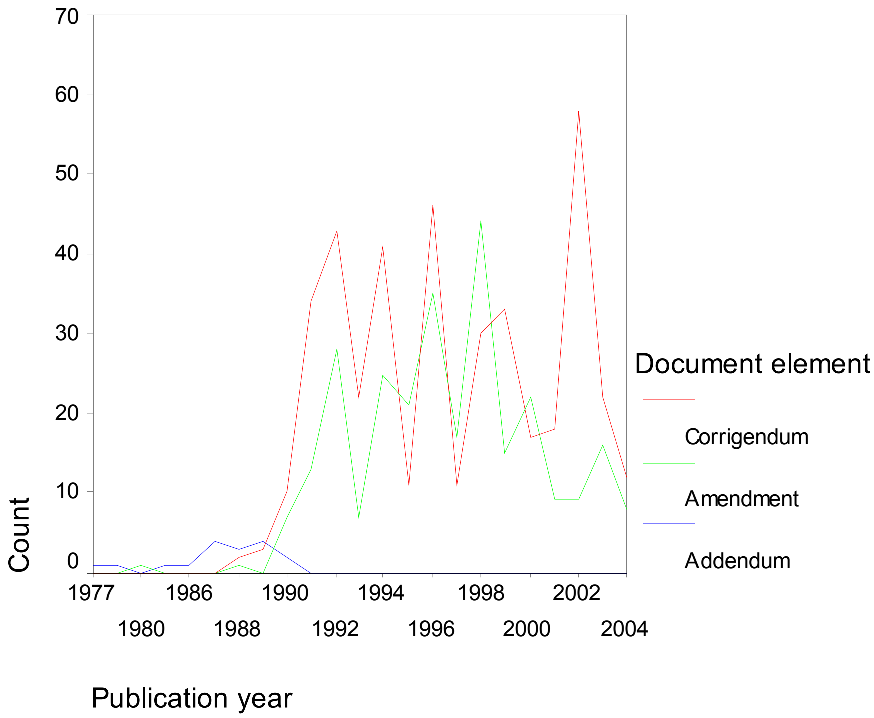


Table 5: Designated time for standards development (ISO/IEC, 1989, 1992).

From date of inclusion project in program of work to	**1989**	**1992**
Working Draft stage	2 years	1.5 years
Committee Draft stage	5 years	2 years
Draft International Standard stage	7 years	3 years

Thirdly, parallel to devising procedures that shortened the standards process, standards review and maintenance procedures may have been professionalized. This assumption needs to be checked. However, if so, where errors were dealt with in an implicit manner before (e.g., perhaps they were hidden in new editions, informally passed on by mouth, etc.), a more professional approach to maintenance would then suddenly uncover more problems, part of which may then have been addressed by supplementary documents.
Lastly, supplements are hardly re-issued as new editions. However, they do undergo change. Roughly an equal amount is active (46.8%) as is withdrawn (53.2%). This differs significantly from other documents, of which only 30.0% is withdrawn.

Editions

Of the 2752 documents most documents are first editions (N=2292). See Table 6 below. Only 16.7% are higher editions (edition 2-6).

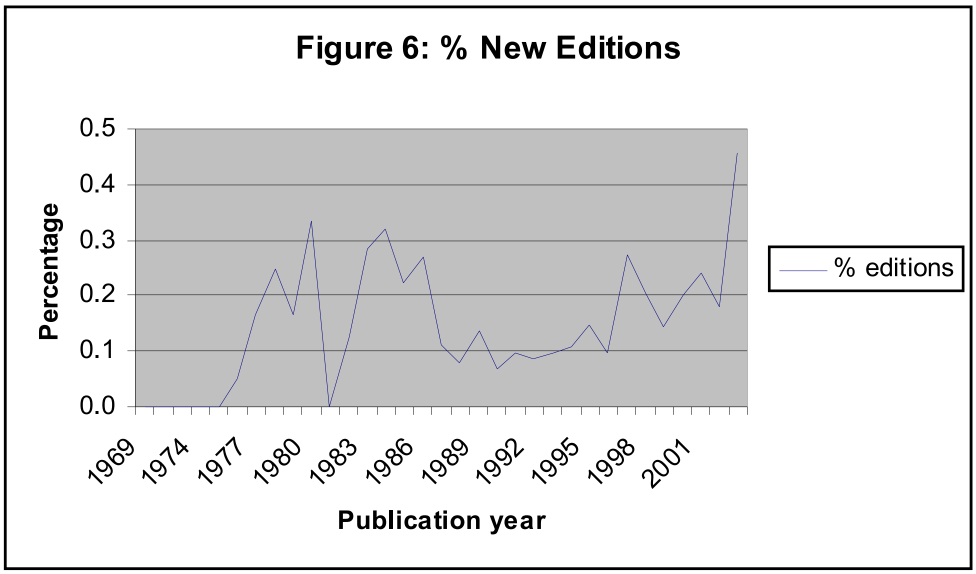
Table 6: Edition

Edition no.	Frequency	Percent
1	2292	83.3
2	344	12.5
3	86	3.1

4	24	.9
5	5	.2
6	1	.0
Total	2752	100.0

The number of new Editions rises gradually over the years in absolute numbers (see Figure 3) and proportionally from 1990 onwards, in parallel with the overall rise in number of standards (see Figure 6). This might be expected with an increasing number of standards documents overall and the time lag which usually exists between successive editions.

If this trend persists, it could indicate that JTC1 is shifting emphasis from using supplements (stable use over the years) to using new editions (rising use) as a means to revise standards. See Figure 3.



First editions are, as might be expected, more often withdrawn (N=861) (37.6%) than higher editions (N=129). About a quarter of all higher editions is withdrawn (28%).

Sum of changes over time

Table 7 summarizes the amount of change in absolute numbers per feature of standards dynamics.

Features of standards dynamics	Sub-category	N	Ref. date of data source
Withdrawals		990	14-07-2004
Revisions	Is revised by	999	26-11-2004
	Revises	559	26-11-2004
Replacements	New number/ same document type	109	20-07-2004
	Same number / new document type	23	20-07-2004
Supplements		708	14-07-2004
Editions 2-6		460	14-07-2004

Table 7: Summary of amount of change at stake.

The figure below shows the sum of (the absolute number of) changes per year, including replacements but excluding revisions (see earlier explanation).

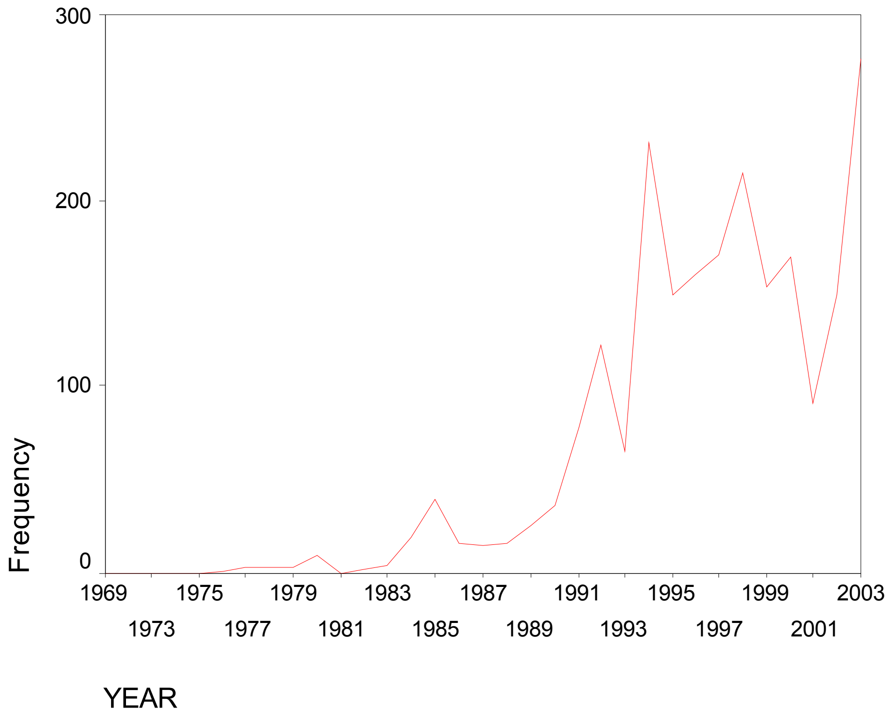


Figure 7: Sum of changes per year: withdrawals, new editions, supplements and replacements.

If we contrast the number of changes (figure 7 above) to the number of documents that have remained stable (see figure 8 below), we can conclude that the proportion of maintenance work done in JTC1 outruns pure standards development work in respect to the number of actions taken [15].

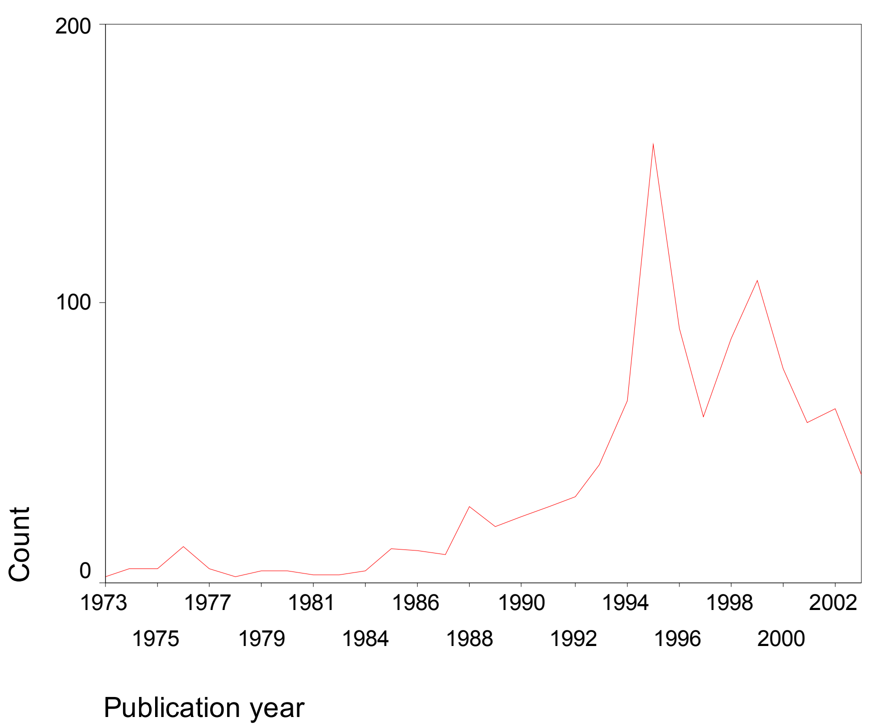


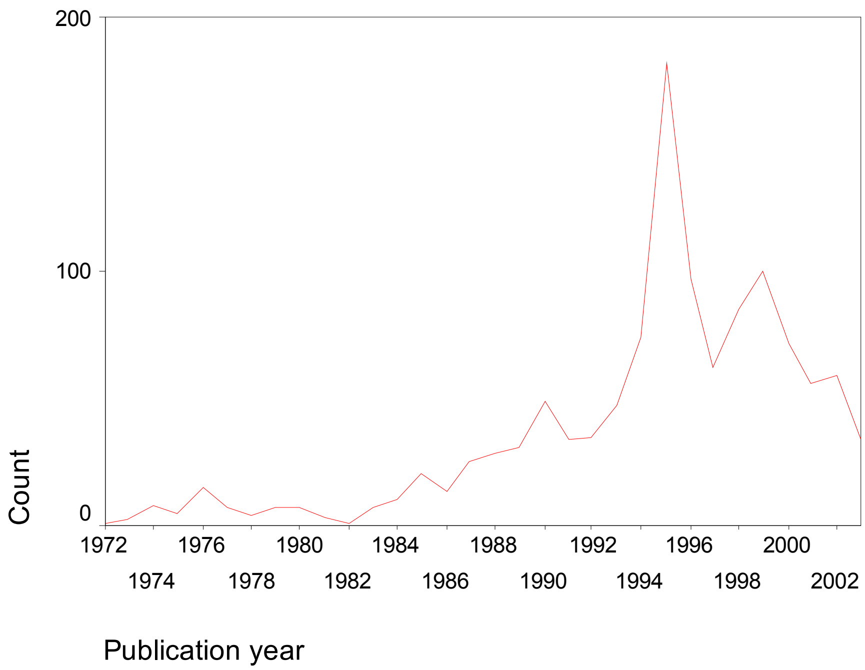
Figure 8: Still active first editions of main documents (no supplements)

Dynamics of Main Documents

While in the previous the main document was treated on a par with its supplements and new editions, in this section our starting point is the main (original or "parent") document.[16]

There are 1527 such main or parent documents. The overall pattern of number of parent documents published per year is very similar to that of all documents, except that the peak of publications in 1995 is more pronounced. See figure 9. (NB: This coincides with the relatively few supplements (10%) published in 1995.)

Figure 9: Parent documents published (still active)



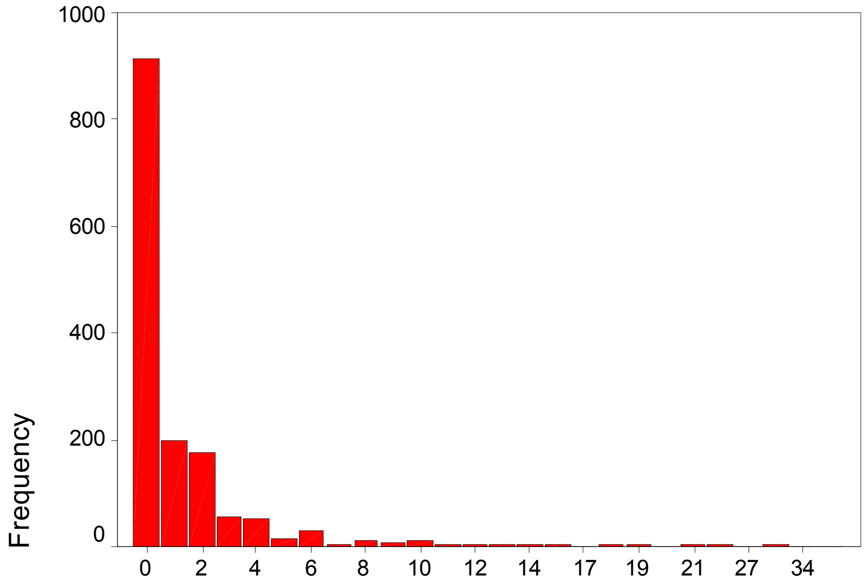
In our dataset, 60.1 % (N=917) of the main documents undergoes no change (no new edition, supplement or withdrawal). They are stable standards in the period researched. The others have undergone 2158 changes in all (i.e. on average 3.54 changes per parent, and 1.41 changes for all documents). See Table 8. 66 % of the 'parents' have no 'children' (i.e. supplements and/or new editions). Those who do can have up to 24 children. Some have undergone up to 49 changes.

Table 8: Parent Documents

	% Parents without	% Parents with	Minimum	Maximum	Sum	Mean	Std. Deviation
Withdrawals	68.4	31.6	0	25	990	.65	1.623
New Editions	78.1	21.9	0	5	460	.30	.653
Corrigenda	87.4	12.6	0	12	413	.27	.987
Amendments	89.8	10.2	0	21	278	.18	.814
Addenda	99.3	0.7	0	3	17	.01	.142
# changes	60.1	39.9	0	49	2158	1.41	3.336

# children docs	66.1	33.9	0	24	122 5	.80	1.827

Figure10: Changes to parent documents



changes

The above graph shows the distribution of changes over parents. In 200 cases only 1 change is at stake of the total of 2158 changes. In other words, 410 parents (26.8%) are responsible for 1958 (90.7%) of the changes, which is most of the dynamics by far. See Table 9.

Table 9: Number of changes to main document * Type of standard document (% of Total)

		Type of standard document			Total
		International Standard	Int. Stand. Profile	Technical Report	
# changes	0	41.9%	12.1%	6.0%	60.1%
	1	11.3%	.5%	1.2%	13.1%
	2-49	24.3%	1.5%	1.2%	26.8%
Total		77.5%	14.1%	8.4%	100.0%

Furthermore, the changes primarily occur within ISs. That is, the percentage of parents with changes is considerably higher for ISs (45.9%) than for ISPs (14%) and TRs (28.1%). Are these differences also statistically significant? *That is, in respect to standards dynamics, does it matter which document type is at stake?*

To evaluate the differences between the three groups, a one way Analysis-of-Variance (ANOVA) can be used. However, to use ANOVA, firstly, the condition of normally distributed averages must be met. Due to the sufficient number of cases per category (N>80) this can be assumed by the Central Limit Theorem. Secondly, also the variances of the number of changes should be equal for all three categories. The homogeneity of variances test shows that this is not likely to be the case at a confidence level of 95%. (NB:

Unless stated otherwise, we take a 5% level of significance as default.)
Therefore, instead of a one way ANOVA, we use the *non-parametric* Kruskal Wallis Test. This test indicates that there is a significant difference between the three means. But whether they all differ significantly from each other or only two of them needs to be examined with a post-hoc test. Because, as said, the number of cases for each category is sufficient to assume a normal distribution, we can use the parametric Tamhane test, a test which assumes no equal variances. See Table 10 (Tamhane/ Dependent Variable: number of changes)..

Table 10: Multiple Comparisons Type of standard document x number of changes

(I) Type of standard document	(J) Type of standard document	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
International Standard	Int. Stand. Profile	1.18(*)	.145	.000	.84	1.53
	Technical Report	1.03(*)	.168	.000	.63	1.44
	Technical Report	-.15	.163	.738	-.54	.24
	Int. Stand. Profile	.15	.163	.738	-.24	.54
Int. Stand. Profile	International Standard	-1.18(*)	.145	.000	-1.53	-.84
Technical Report	International Standard	-1.03(*)	.168	.000	-1.44	-.63

* The mean difference is significant at the .05 level.

The test shows that ISs and ISPs differ significantly from each other in respect to the mean number of changes per parent document. Also the difference between ISs and TRs is significant. ISPs and TRs do not differ significantly from each other. That is, the mean number of changes which IS parents undergo differs significantly from the means of ISPs and TRs.
Is this difference significant with regard to all three specific features of dynamics: supplements, withdrawals, and new editions? Following the same procedure as above for all three features, the homogeneity of variances tests show that the variances are not the same. The Kruskal Wallis tests indicate that for all three features some or all of the means differ significantly. Below, per feature an overview of the means and the results of the Tamhane post-hoc tests are successively presented.

Table 11: Supplements

Type of standard document	Mean	N	Std. Deviation
International Standard	.57	1184	1.672
Int. Stand. Profile	.12	215	.336
Technical Report	.02	128	.197
Total	.46	1527	1.493

Table 11 summarizes the mean number of supplements for each document type. The Tamhane test shows that all the differences between the mean number of supplements per parent IS, ISP and TR are significant.

Table 12: Withdrawals

Type of standard document	Mean	N	Std. Deviation
International Standard	.75	118 4	1.786
Int. Stand. Profile	.22	215	.715
Technical Report	.38	128	.775
Total	.65	152 7	1.623

Table 12 summarizes the mean number of withdrawals for each document type. The Tamhane test shows that the differences between the mean number of withdrawals of ISs on the one hand and both ISPs and TRs on the other are significant. But the difference between the means of TRs and ISPs is not.

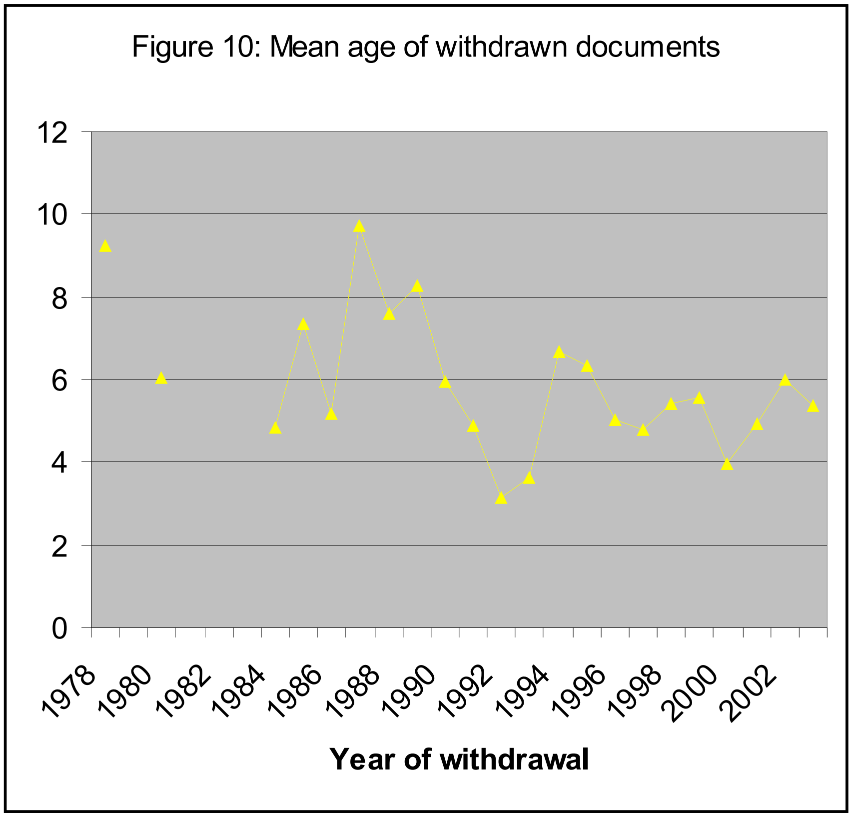
Table 13: New Editions

Type of standard document	Mean	N	Std. Deviation
International Standard	.34	118 4	.670
Int. Stand. Profile	.14	215	.456
Technical Report	.23	128	.734
Total	.30	152 7	.653

Lastly, Table 13 summarizes the mean number of new editions for each document type. The Tamhane test shows that the difference between ISs and ISPs is significant, but not the other differences.
Recapitulating, in particular in the case of supplements and withdrawals the difference in means between ISs and the other two types of documents is both fairly large and significant. That is, International Standards show more dynamics in this respect than the other two document types.

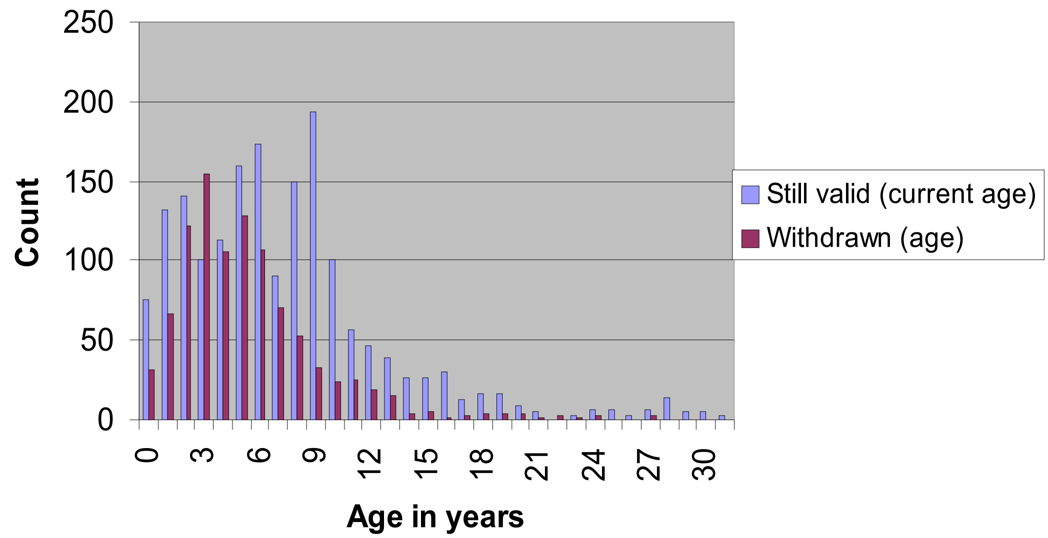
Age of Standards

How stable are standard documents in number of years? The final age of parent- and other documents can only be determined for those that have been withdrawn (i.e. year of withdrawal – year of publication). The average age of standards in this group is 5 years (M = 5.33 years; maximum age 27 years). However, most of them are already withdrawn after three years (mode = 3 years, N= 155).



Over the years the mean age of (withdrawn) standards seems to remain rather stable – that is, if one disregards the more erratic pattern in the early years caused by the low number of standards. See Figure 10. Moreover, the 5-year review procedure would seem to perfectly explain the 5-year average age. However, if we compare the average age of withdrawn standards with the average age of 'still active' standards, the latter is already much higher (M=7.35). Indeed, the graph below shows that the largest group of standard documents still active is currently already 9 years of age (i.e. mode = 9 years). See figure 11. The average age of the withdrawn documents is therefore not a good indicator for the expected age of still active standards.

Figure 11: Age of standard documents



Does the mean age of documents differ in respect to type of document (IS, ISP, TR)? To answer this question we take 'withdrawn documents' as a starting point in order to avoid the problem of having an open-ended age category, as would be the case with still active documents.

Table 14 suggests that the mean age of the three document types (IS, ISP, TR) do indeed differ. But do they differ significantly? This can be determined by means of a variance analysis.

Table 14: Age withdrawn documents

Type of standard document	Mean	N	Std. Deviation
International Standard	5.45	900	4.042
Int. Stand. Profile	3.27	41	1.858
Technical Report	4.73	49	2.928
Total	5.33	990	3.951

The Homogeneity of Variances test shows that the variances of age are not the same. Therefore, instead of ANOVA we use the *non-parametric* Kruskal Wallis Test. This test shows that there is a significant difference between the mean ages of the three document categories. In order to examine wherein the difference between means lies, we want to perform a post-hoc test. However, the amount of ISPs and TRs are somewhat low, which means that we cannot assume a normal distribution of the mean age. Indeed, the histogram of the ISPs shows that this one, at least, is not. Therefore we must choose a non-parametric post-hoc test.

The Mann-Whitney test can be used to compare groups in pairs. NB: Because there are three groups involved and three comparisons, a lower level of significance will be needed (α = 1.7% for each test if we want to keep the overall chance of making a type I error smaller than 5%)

The outcome of the pair-wise comparison is that the difference between the mean ages of IS and ISP is significant; IS en TR is *not* significant; and ISP and TR is significant at a significance level of 1,7%. That is, it matters which type of document is at stake. The ISP mean differs significantly from the mean ages of the TRs and ISs. However, is this difference best explained by the different characteristics of standards setting for these document types (e.g. less or more strict conditions; see footnote 4); or does the fact that all ISPs except one are OSI-related better explain the difference? Additional research is needed, research that falls outside the time frame of the current paper.

Does the mean age of documents differ in respect to supplementary documents? The data in Table 15 already indicate that the mean age of supplements differs considerably from that of main documents. This finding is to be expected since main documents always precede their possible supplements, and possibly outlive them – never the other way around. But is the difference statistically significant? And is there no significant difference between the mean ages of supplements, as the Table suggests?

Table 15: Mean age of withdrawn supplements

Document element (Corr./Amd)	Mean	N	Std. Deviation
0	6.58	613	4.256
Corrigendum	3.32	211	2.436
Amendment	3.11	149	1.827
Addendum	4.59	17	2.002
Total	5.33	990	3.951

The number of Addenda is very low (N=17). It will be difficult to draw any significant conclusions in connection to this category. Therefore we leave it out of the following analysis.
To compare the average age of the other categories, we cannot do an ANOVA, as we would like, because the test of homogeneity of variances shows that the variances differ. Instead we turn again to the non-parametric Kruskal Wallis Test. This test shows that there is a significant difference between the mean ages of the remaining three categories. To explore which differences are at stake, we turn to the Tamhane post-hoc test again, a test which assumes no equal variances, only normally distributed averages, as is the case here.
As expected, the post-hoc test shows that the mean age of both types of supplements differs significantly from that of the main document. But there are no significant differences in mean age between the two types of supplementary documents.

Change per Technology Area

Is the number of changes, which a standard undergoes, related to the technology area it addresses? We focus on the main documents, and adopt the ICS code used in standardization for distinguishing areas of technology. See Table 16.

Table 16: ICS code and area of technology

ICS code	Area of Technology	Action
33040	Telecom systems; including network (system) aspects	-
33050	Telecom terminal equipment	de-select
35020	IT in general; incl. general aspects of IT equipment	(if problems, de-select)

35040	Character sets and Information coding; incl. coding of audio, picture, multimedia and hypermedia information, IT security techniques, encryption, bar coding, etc.	-
35060	Languages used in IT	-
35080	Software development and system documentation	-
35100	Open Systems Interconnection (OSI)	-
35110	Networking (LAN, MAN, WAN)	merge with 33040
35140	Computer graphics	merge with 35240
35160	Microprocessor systems; incl. PCs, calculators, etc.	recode 35999
35180	IT terminal and other peripheral equipment; incl. modems	recode 35999
35200	Interface and interconnection equipment	recode 35999
35220	Data storage	-
35240	Applications of IT	-
35260	Office machines	de-select
35999	Hardware / Equipment	new

Because statistically some areas are not sufficiently represented (N> 80), which makes drawing statistically significant conclusions difficult, we merge, where arguable, smaller ICS categories into new ones, and delete others. Our arguments for de-selecting and recoding, as indicated in last column of Table 16, are that

- the N for 33050 is statistically negligible (N=1) [de-select]
- there is no other category closely related to 35260 (N=18) [de-select]
- there is no obvious category closely related to 35020 (N=28)[de-select if necessary]
- both 33040 and 35110 (N=27) address networks [merge]
- 35140 (N=36)can be seen as an IT application area (35240) [merge]
- 35160 (N=26), 35180 (N=24) and 35200 (N=63) can be captured in a new category Hardware/ Equipment [merge, recode 35999]

The new, recoded ICS categories are listed in Table 17.

Table 17: Recoded ICS levels: number of changes

Recoded ICS Levels	Mean	N	Std. Deviation	Sum	Minimum	Maximum
33040	1.31	114	2.104	149	0	10
35020	1.32	28	1.335	37	0	4
35040	1.29	224	4.131	288	0	49
35060	1.73	113	2.709	196	0	11
35080	.21	84	.493	18	0	2
35100	1.82	496	3.497	904	0	27
35220	.50	155	1.047	77	0	6
35240	2.33	181	5.102	422	0	34
35999	.52	113	1.512	59	0	13
Total	1.43	150 8	3.354	215 0	0	49

The Test of Homogeneity of Variances shows that the variances of the recoded ICS areas differ for the

number of changes to documents. All categories are large enough to assume a normal distribution of the average number of changes – except for ICS 35020. The histogram shows a mixed picture for this category. We therefore also leave this one out of the comparison.
The non-parametric Kruskal-Wallis test can now be used. This test indicates that there is a significant difference between the means. We use the Tamhane post-hoc test to determine which ones differ significantly. Table 18 summarizes which mean differences are significant.

Table 18: Summary of sign. differences between means Recoded ICS levels (Tamhane post-hoc test)

ICS codes	33040	35040	35060	35080	35100	35220	35240	35999
33040	-			x		x		x
35040		-		x				
35060			-	x		x		x
35080	x	x	x	-	x		x	
35100				x	-	x		x
35220	x		x		x	-	x	
35240				x		x	-	x
35999	x		x		x		x	-

The mean difference is significant at the .005 level.

Table 18 shows a pattern. There are significant differences between two clusters of technology areas. On the one hand there is the cluster consisting of 35080 (Software development and system documentation) 35220 (Data storage), and 35999 (recoded: Hardware / Equipment), of which the average number of changes is low; and on the other 33040 (recoded: Networks), 35060 (Languages used in IT), 35100 (OSI) and 35240 (recoded: Applications of IT). The hardware-software dichotomy only partly explains the difference between the clusters (the low mean of ICS category 'Software development and system documentation' and the high mean of 'Networks' then still remains to be explained). A better but related explanation could be that the material feature of hardware leaves much less room for 'on the fly' improvements than software does.[17] Therefore, where hardware is concerned standardization is more likely to occur ex post, that is, after the technology has been developed and tested. In the case of software standardization, ex ante standardization and parallel standards and technology development are more likely to occur. OSI (35100) being a case in point. More revisions can then be expected since experience with the standard comes after the fact. That is, ex ante (or parallel) standardization versus ex post standardization next to the hardware-software dichotomy explain cluster-specific standards dynamics.

Conclusion

In this paper we explored the scale of standards dynamics, or, worded differently, the degree of stability of standards. Standards bodies address such issues under the headings of 'standards maintenance'. For example, apart from the normal review procedures, JTC1
has procedures that specifically address the need for stable standards (*provisionally retained editions*) and

implicitly refer to the lack thereof (i.e. *stabilized standards*). The latter procedure is largely used for securing the continuous availability of Open Systems Interconnection (OSI) standards.
Throughout the years JTC1 has published 2752 standard documents. Since 1995 there has been a steady decrease, a decrease which coincides with an increase of standards from standards consortia. This decline seems to have come to a halt, which suggests that a new equilibrium between the two standard setting environments is emerging.
If the number of changes to in JTC1 standards is anything to go by, maintenance work outruns initial standards development work. Most changes are due to withdrawals, revisions and supplements. There are relatively few replacements and new editions.
To highlight the main results of the analyses of dynamic features:

- **Supplements.** Since the sharp increase in the relative use of supplements towards 1992, a development which corresponds to the 1992 deadline of the European Common Market, their use has been consolidated. Supplements are systematically used as a post hoc measure for correcting errors. For a certain category of work items standardization is becoming a two-step process: a rough main document developed in consensus followed later on by a supplement that clarifies ambiguities, etc. This is a point for follow-up research.
- **Withdrawals.** One could expect that the time pressure of the 1992 deadline, changes in standards procedures and the radical cut-down of standards development time which this has led to, and the extra workload in 1995, together, this would have negatively affected the quality and appropriateness of the standards published in that period –and would have led to early withdrawals. However, the standards published in this period are not more prone to withdrawal than in other periods.
- **Editions.** As noted, the (proportional) use of supplements has remained rather stable over the years. In 2003 it equals the proportional use of new editions, which has been rising steadily these last years. If both trends persist, it means that JTC1 is changing maintenance strategy and is shifting from using supplements to using new editions as a means to revise standards. Could this be the case? If so, it becomes of interest to determine whether new editions or supplements are the lesser problem of standards dynamics.

We also explored certain themes in more detail. Summarizing the outcomes of these analyses:

- **Main documents.** Fourty percent of the main documents undergoes one or more changes and is in this sense not stable. A quarter of these documents undergo roughly 90% of all changes, most of which are International Standards (ISs). The latter have significantly more chance of being supplemented or withdrawn than other document types.
- **Age.** The average age of a withdrawn standard (M = 5.33 years) is not a good indicator for the expected age of still active standards (M=7.35 years). In respect to age, it matters which type of document is at stake. The mean age of ISPs is significantly less than those of TRs and ISs, a factor which also explains the fewer changes in ISPs. But if this is foremost related to document type or to technology area (OSI) requires additional research.

- **Technology Area.** The number of changes, which a standard undergoes, is related to the technology area which it addresses. We identified two technology-related clusters. The hardware-software dichotomy, namely that the material feature of hardware leaves much less room for 'on the fly' improvements than software does, partly explains their difference. Moreover, where hardware is concerned standardization is more likely to occur ex post, while in the case of software standardization more likely occurs ex ante or in parallel to technology development. That is, ex ante (or parallel) standardization versus ex post standardization next to the hardware-software dichotomy largely explain cluster-specific standards dynamics.

Questions for follow-up research

The paper provided some answers regarding the scale of standards dynamics. But at the same time it raises several new questions, questions about the causes of dynamics. For example,

- What explains the dip in dynamics overall in 2001?
- What characterizes the 410 parent documents that are responsible for ninety percent of the dynamics?
- Why is the mean age of ISPs (OSI standards) significantly lower than that of TRs and ISs?
- Why is the mean number of changes of the ICS category 'Software development and system documentation' significantly lower than most other averages?

We hope to address these and other issues that shed light on the cause of standards dynamics in a forthcoming paper.

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Abbreviations

Amd	Technical Amendment
CCITT	Comité Consultatif International Télégraphique et Téléphonique (predecessor of ITU-T)
CEN	Comité Européen de Normalisation
CEN/ISSS	CEN/Information Society Standardization System
CENELEC	Comité Européen de Normalisation Electrotechnique
Cor	Technical Corrigendum
DIS	Draft International Standard
Ed.	Edition
ETSI	European Telecommunications Standards Institute
ICS	International Classification for Standards
ICT	Information and Communication Technology
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IP	Internet Protocol
IS	International Standard
ISO	International Organization for Standardization
ISP	International Standardized Profile
IT	Information Technology
ITU-T	International Telecommunication Union – Telecom Standardization sector
JTC1	ISO/IEC Joint Technical Committee 1
OSI	Open Systems Interconnection
RFC	Request for Comments ("Internet standard" are also RFCs)
SDO	Standards Development Organization
SGML	Standard Generalized Markup Language
TCP/IP	Transmission Control Protocol/Internet Protocol
TR	Technical Report
W3C	World Wide Web Consortium
XML	Extensible Markup Language

Biography

Tineke M. Egyedi (PhD, 1996) is Senior Researcher Standardization at the Delft University of Technology, the Netherlands. Her present research and coordination tasks address issues of Interoperability (Sun Microsystems), Standards Dynamics (EU project, NO-REST) and Flexible Infrastructures (NGI/TU Delft). She is associate editor and member of the editorial board of two international journals on standardization (CSI and JITSR), and vice-president of the European Academy for Standardization. She has published widely (e.g. books, reports, book chapters and articles).
She has worked as a consultant and researcher in several companies and organizations. In these capacities she e.g. did studies for Dutch ministries (Infrastructure) and participated in several European projects (ELECTRA, SLIM, consortium standardization, SDOs & users).. She was e.g. organizer of EURAS2001 and the IEEE SIIT2003 conference.

Petra Heijnen is assistant professor at the Delft University of Technology. She studied Applied Mathematics at the same university, followed by four year PhD-research in coding theory at the faculty of Applied Mathematics at the Eindhoven University of Technology. She worked as a research member of the National Institute of Statistics in the Netherlands in 1998.
Since 1999 she works at the faculty Technology, Policy and Management at Delft University of Technology, first as a project member of a large Economy, Ecology and Technology project called *Batch Processes: Cleaner and more efficient*, and currently as an assistant professor for the Energy & Industry group. Her research and educational activities focus on the use of statistics and multi-level optimization.

[1] Apart from Egyedi & Loeffen (2002), we are not aware of other work in this area. NB: At the time of writing (December 2004) a European project is underway (NO-REST) of which one of its work packages, the one led by the first author of this paper, explicitly focuses on Standard Dynamics. See e.g. Gauch (forthcoming) on DVD standards and Jakobs (forthcoming) on IEEE 802.11.

[2] Standards operate in a changing environment, and may need to be adapted or replaced in response to evolving market and societal demands. That is, sometimes change is necessary. More will be said about this dilemma in an upcoming paper.

[3] An IS is "a normative document, developed according to consensus procedure, which has been submitted for vote by all national bodies and approved by 2/3 of the P-members of the responsible technical committee with not more than ¼ of all votes cast being negative." (...) A TR is "an informative document containing information of a different kind from that normally published in a normative document (e.g. collection of data), approved by a simple majority of the P-members of a technical committee or subcommittee." An ISP is "an internationally agreed, harmonized document which identifies a standard or a group of standards together with options and parameters, necessary to perform a function or a set of functions." (ISO, 2004, p.2)

[4] See the Letter of Keith Brannon, ISO/IEC Information Technology Task Force, 2004-02-12, on Systematic review of International Standards. We have no information on whether this is decided based on hard data, on the impression of subcommittee members, or otherwise.

[5] Technical corrigenda are normally published as separate documents, the edition of the IS affected remaining in print. However, the ITTF shall decide (...) whether to publish a technical corrigendum or a corrected reprint of the existing edition of the IS. (op. cit. JTC1, 2004, ch.15.4)

[6] A technical addition or change is an alteration or addition to previously agreed technical provisions in an existing IS. (JTC1, 2004, 15.4.1)

[7] An editorial defect is "An error which can be assumed to have no consequences in the application of the IS, for example a minor printing error." (JTC1, 2004, 15.4.1)

[8] "(...) [H]owever, each Sub Committee shall periodically review a current list of its own stabilised standards to ensure that they still belong in stabilized status." (JTC1, 2004, 15.3.1)

[9] "Previous editions of standards (including their amendments and technical corrigenda) may be included in the ISO and IEC Catalogues on an exception basis as determined by the SC, noting that these documents should be used for reference purposes only." (JTC1, 2004, ch.15.1.5.)

[10] Some data was provided outside this period. Where this is the case, it is indicated. See Table 7.

[11] Private communication ISO Secretariat.

[12] Revised "Guidelines for TC/SC Chairmen and Secretariats for implementation of the Agreement on technical cooperation between ISO and CEN", 1992, p.2.

[13] E.g. the ISP 10609 on Connection-mode Transport Service over connection-mode Network Service (N=27).

[14] Source: Printout provided by the ISO Secretariat (26-11-2004).

[15] This is the case even given the overlap between the number of new editions and the number of withdrawals which this mostly accompanies (the provisionally retained editions excepted). Whether the conclusion also applies for the volume of work done in JTC1 is a different matter, requires different data,

but would seem less likely.

[16] This requires that we aggregate the data on main documents, a process by which some information is lost. For example, in respect to document type, the aggregated database only contains the document type first mentioned (i.e. also information about change in document type, of which there are N=16 in all, gets lost. However, Because of this small number, the results will hardly be influenced.). We identify main documents by document number and part number combined, as argued in the methodology section.

[17] The same reasoning would seem to apply to artifacts where network externalities play an important role. This needs to be examined further.