Societal and technology trend report

Smart Standards – From a market and industry perspective

Executive summary

This Societal and Technology Trends Working Group report, released by the IEC Market Strategy Board (MSB), discusses the development of "standards machine applicable, readable and transferable (Smart)" Standards from a business perspective. Smart Standards constitute the key, critical enabler through which the digital transformation of industries and society can be realized.

Whereas Strategic Group (SG) 12 of the IEC Standardization Management Board (SMB) focuses on the technical development of Smart Standards, this report centres on business views regarding such standards and how these views influence both the IEC as a producer of standards and end users as consumers of standards. In addition to providing an economic analysis of the value Smart Standards represents for the IEC and for end users, several stakeholders were interviewed to capture a broader business view.

The core finding of this report is that Smart Standards offer a sensible way forward which stakeholders welcome. Even if many stakeholders are not entirely clear as to what exactly constitutes a Smart Standard and how such standards will benefit business precisely, they trust the IEC to pave the way toward a digital future for standards. Most stakeholders sense that the IEC needs to operate in a manner more characteristic of business and want it to publish a roadmap for the development of Smart Standards, one that provides a plan for potential investments associated with these standards. Overall, the IEC is trusted to do the right thing, but re-enforcing this sense via clear communication will be helpful, as end users are easily tempted by competing standardization organizations, if the latter appear to offer better value.

This report describes Smart Standards from three perspectives, namely technical, market and economic perspectives, in the process describing various industrial pilot projects. The technical perspective (Section 1) uses the lock-and-key metaphor to explain the technical changes introduced by Smart Standards from a business perspective: IEC is changing the key, so businesses must change the lock.

The market perspective (Section 2) addresses viewpoints on Smart Standards of industry, standards organizations and regulators. The results of interviews conducted are formulated into different viewpoints reflecting both a forward-looking perspective (i.e. the viewpoints of a time-traveller, an optimist, a pessimist and a historian) as well as from a call-for-change point of view (i.e. the viewpoints of a critic, an activist, and a business strategist) (Section 3).

Three types of business value are associated with Smart Standards: performance value (increasing efficiency), risk value (eliminating errors) and future value (increasing revenue). These are applied in a business model canvas that provides insights into the business structure of the IEC in the near future (Section 4).

Industry-driven pilot projects demonstrate the added value of working with Smart Standards. Examples are drawn from the energy industry and the aviation industry and are complemented with a quality infrastructure pilot project that includes accreditation and conformity assessment activities (Section 5).

The report concludes with a set of considerations for the IEC Community (Section 6).

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List of abbreviations

Technical and scientific terms

ADSPT	advanced standards processing tool
AI	artificial intelligence
CATIA	computer-aided three-dimensional interactive application
CE	European conformity[1]
DPD	digital product definition
FAIR	findable, accessible, interoperable and reusable
GUS	generic user story
ISV	independent software vendor
IT	information technology
NSB	national standardization body
O&M	operations and maintenance
pdf	portable document format
PDM	product data management
QI	quality infrastructure
SDO	standards developing organization
SLA	service level agreement
Smart	standards machine-applicable, readable and transferrable
SME	small and medium-sized enterprise
TC	technical committee (IEC)
XML	Extensible Markup Language

1 CE is a European Union (EU) marking certifying that given goods or products meet the applicable EU regulatory requirements.

Organizations, institutions and organizational strutures

BIPM	International Bureau of Weights and Measures
CAPE	China Aero-Polytechnology Establishment
CEN/CENELEC	European Committee for Standardization/European Committee for Electrotechnical Standardization
CSG	China Southern Power Grid
DIN	The German Institute for Standardization
DKE	German Commission for Electrical, Electronic & Information Technologies
IAF	International Accreditation Forum
IDiS	Initiative Digitale Standards[2]
IEC	International Electrotechnical Commission
IEC SMB/SG 12	Strategic Group 12: Digital transformation and systems approach, of the IEC Standardization Management Board (SMB)
IEEE	Institute of Electrical and Electronics Engineers
ILAC	International Laboratory Accreditation Cooperation
IMO	International Maritime Organization
ISO	International Organization for Standardization
ITU-T	Telecommunication Standardization Sector of the International Telecommunication Union
MSB	IEC Market Strategy Board
OIML	International Organization of Legal Metrology
PTB	Physikalisch-Technische Bundesanstalt (German National Metrology Institute)
SMB	IEC Standardization Management Board

2 IDiS designates the joint Digital Standards Initiative (Initiative Digitale Standards) network group of the German Institute for Standardization (DIN) and the German Commission for Electrical, Electronic and Information Technologies (DKE).

Glossary

artificial intelligence

AI

advanced computational capabilities that can be designed to enhance and/or replace cognitive functions and modelling traditionally associated with standards production and consumption

NOTE AI is mostly relevant for machine interpretation in level 4.

copyright

exclusive and assignable legal right, given to the originator for a fixed number of years, to print, publish, perform, film or record literary, artistic, or musical material

copyrighted standards

IEC documents (Standards) that are legally protected by copyright and which form a pillar in the economic foundation of the IEC

end user

consumer of machine-applicable, readable and transferrable (Smart) standards who may use standards from a variety of standards developing organizations (SDO)

future value

in terms of revenue value, the income that products or services generate, now and in the future

national standardization body

NSB

a national affiliate of ISO/IEC and/or CEN/CENELEC that becomes a re-seller of Smart Standards

other SDOs

standards developing organizations (producers) other than IEC, ISO and CEN/CENELEC

paper standard

standard printed on paper, associated with utility level 0 for standards

pdf

portable document format

portable document format used when a file needs to be saved that cannot be modified but nevertheless needs to be easily shared and printed

NOTE Most standards today are issued in this format.

performance value

the reduction of errors in the design and operation of a product or service

risk value

comprehensive identification of all relevant clauses to ensure that they are not omitted at any stage of the product lifecycle, thereby minimizing litigations

semantic enrichment

enhancement of content with information about its meaning

NOTE 1 An example of semantic enrichment might be: ('{this is a} a semiconductor base material').

NOTE 2 Semantic enrichment is relevant from level 3 and upward.

service level agreement

an agreement defining the level of service expected from a vendor and laying out the metrics by which the service is measured

Smart Standard

a digital standard that is machine-applicable, readable and transferable (Smart)

Smart classifications

levels of digitalization and utility to machines (levels 0-4)

software license

a license that modifies copyright of software code for end users, granting them only the rights needed for the intended use of the code

standard

a codification of technical and non-technical business agreements

Extensible Markup Language

XML

machine-readable data format that supports information exchange between computer systems such as websites, databases, and third-party applications

NOTE XML is relevant from machine-readable level 2 and upward.

Section 1

Introduction

Businesses add value by delivering products and services according to market expectations. The IEC provides a trusted international platform through which to negotiate and specify requirements in support of delivering the necessary quality. IEC Standards are codifications of technical and non-technical business agreements. Any business that uses IEC Standards, or more precisely the articles in them, assures market compliance and gains the trust of their partners and customers in the value chain.

The incessant increase in the complexity of products forces manufacturers to use a greater number of standards, which themselves become increasingly complex as well. For example, the recently updated IEC 62061:2021, *Safety of machinery – Functional safety of safety-related control systems* contains a broad spectrum of requirements, ranging from process design and management of functional safety to safety functions, sub-system design and development, software, validation, and documentation. Businesses need solutions for dealing with that degree of complexity and believe the answer lies in digitalization.

Sectors that make an extensive use of standards recognize that integrating standards into their own processes improves efficiency and renders their products safer and more secure. This experience establishes the rationale and generates demand for digitally enabled standards from the IEC and other standards developing organizations (SDO). Moreover, as many organizations are becoming accustomed to information technology (IT) systems that help them navigate the complexities of modern business, they see no reason why standards should be exempt from this process.

The IEC and its partners are impelled to develop standards that are machine-applicable, readable and transferable (Smart). Smart signifies the transformation from document-centric content towards machine-executable data. Standards are becoming machine-readable and thereby support digital systems (which could employ artificial intelligence as an accelerator). This report uses the lock-and-key metaphor to explain how Smart Standards fundamentally change the interactions between the IEC and its end users: when the IEC starts offering standards in the form of software (the key), everyone will need to change their standards processes (the lock), a development with huge ramifications for the industry.

The Smart Standards project will introduce new market-driven, innovative services that nudge standardization organizations toward changing into service organizations. It is not yet clear just how the IEC should or could change. The present report offers various insights concerning this challenge by identifying business models for the IEC, the value proposition for the market and industry, and providing direct feedback from industry. This results in a number of suggestions for the IEC as a whole and for the Market Strategy Board (MSB) in particular.

This MSB Smart Standards report has been created within the framework of the IEC MSB, whose primary task is to identify and investigate technology trends and market needs in IEC's field of activity. This includes investigation of market needs and industry opinion concerning

IEC strategic activities on Smart Standards. This MSB Smart Standards project also acknowledges ongoing activities within IEC SMB SG 12, IEC CAB WG 19 as well as the Joint IEC/ISO Task Force on Smart Standards. These activities are addressing not only the technical perspective of Smart Standards, but also business perspectives from the viewpoint of Smart Standards creators. Thus, the present report complements the activities being conducted within IEC SG 12 and the Joint IEC/ISO task force.

1.1 Technical perspectives on Smart Standards

The IEC Smart Standards project offers a route to modernizing standards and providing standards as a service. It considers how current and future IT technologies will change the capabilities and internal structure of businesses and other organizations. It is recognized that digitization can:

a) make it easier for users to find, select and use the right articles in standards,

b) reduce human errors of learning, understanding and transferring standards content,

c) transfer technical requirements from a standard into software systems to apply the standard more accurately and efficiently,

d) offer tailored standardization solutions where businesses only pay for what they use,

e) facilitate digital conformity assessment mechanisms down to individual products, and

f) drive more efficient standards development and higher quality requirements.

The IEC is a business-oriented service provider that assists companies to succeed in their business ecosystems. The IEC focusses on the conceptualization, design and development of technical solutions for Smart Standards in collaboration with industry partners. Subsection 1.2 explains the levels of digitalization currently being discussed, how they alter a business and why businesses should care.

1.2 Proposed levels of digitalization for Smart Standards

The “standards machine-applicable, readable and transferable” (Smart) format represents a drive to create a new class of standards that can be consumed by machines without (or at least with less) human intervention. Smart Standards would represent a new ISO/IEC product provided in the form of software rather than as documents. This should enable machines to query, extract and assess information, make decisions, and execute tasks based on information embedded in Smart Standards. The level of digitalization that Smart Standards may offer is grouped into five classes.

The resulting classification scheme for Smart Standards is based on “utility to machines” (or “machine readiness”). The scheme focuses on characteristics displayed or enabled by content at different levels. The higher the classification, the more use cases can be applied to that content – literally “the more useful it becomes”. The model distinguishes between five levels (see Figure 1):

0) Paper format

1) Open digital format

2) Machine readable document

3) Machine readable and executable content

4) Machine interpretable content

Level 0, the paper format, represents the traditional approach: it uses articles from printed standards to ensure that products and production processes adhere to industry standards of good practice. Level 1 does not add much to this format, save that it can be read (and used to enable searches) from a pdf file. Level 2 introduces metadata to the standard: data about the data. In level 2 the metadata includes indexes for the structure of

the document (title, article, table, etc.) and may contain links to other articles or standards or the time that the article was created. That information is captured in a machine-readable format (viz. Extensible Markup Language (XML)) that retains the basic structure of a traditional standard but makes it more flexible with regard to rearranging the structure of the document. Level 3 introduces metadata for semantic enrichment. Essentially this signifies that specific forms of meaning supplement individual articles and standards. This could include explaining (or linking to) definitions, highlighting a standard's importance for a specific industry, listing synonyms or adding process information such as: "this is the last step in the process", etc. Semantic metadata makes standards, and the articles contained in them, findable, accessible, interoperable and reusable (FAIR), which allows for content matching via software. Level 4 enters the realm of "semantic interoperability" of Smart Standards, a concept that was explored in the MSB's 2018 white paper *Artificial intelligence across industries* [1][3]. Level 4 replaces the rigid structure and compartmentalization of standards to move to a content repository. Adding metadata about the linkage between articles (whether they are in the same standard or not) makes it possible to create a network of clauses that may be queried from different viewpoints or used in different standards. Automated knowledge brokers can query the database and tailor and match design requirements and standards and articles for individual and specific usage scenarios.

1.3 A metaphor to explain Smart Standards

The utility model in Figure 1 does not clarify just how fundamental the involved change is. Smart Standards are not simply standards in a digital format, they constitute a fundamental change in the way standards are utilized. This subsection

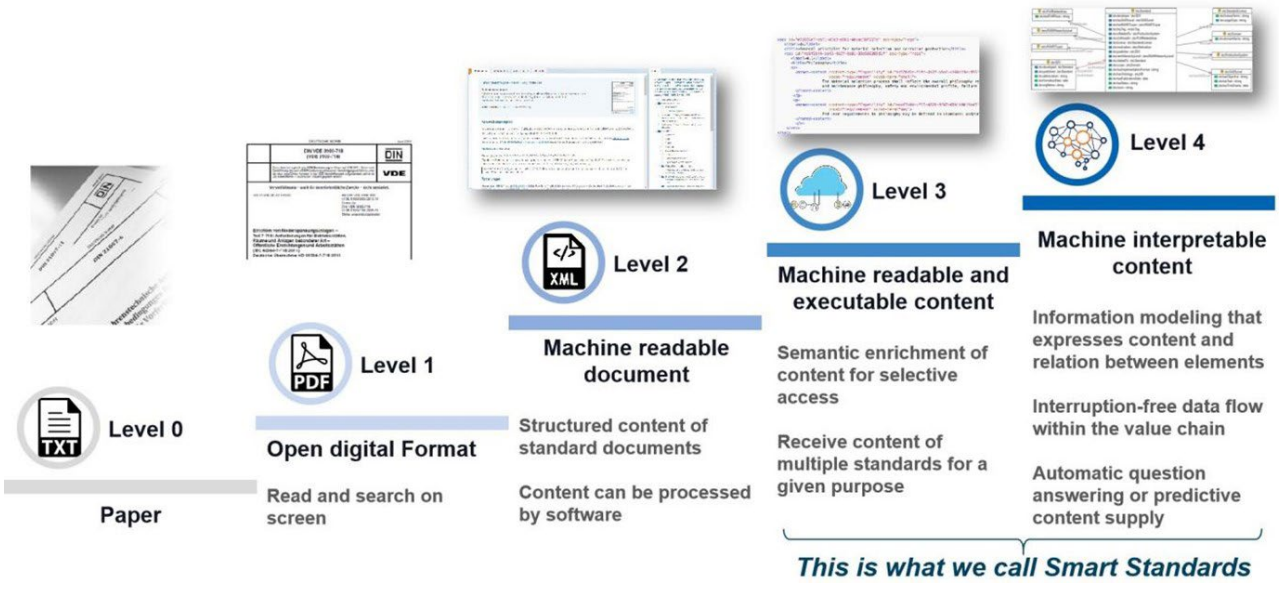

Figure 1 | ISO/IEC utility model

3 Numbers in square brackets refer to the Bibliography at the end of this document.

introduces the lock-and-key metaphor to explain what differentiates the change to Smart Standards so fundamentally from previous changes that standards have undergone.

Take, for example, a designer of high-voltage electrical relays or a manufacturer of switches for railroads. These actors will work with specific sets of standards, each containing a unique set of articles that codify (part of the) requirements arising from market expectations. If it is accepted that each set of standards that businesses require represents a kind of code, standards may be thought of as constituting a key that grants access to the markets involved. Following that metaphor, the IEC facilitates the *forging* of keys in collaboration with stakeholders and supplies them to the market, either directly or through affiliated national standardization bodies (NSBs).

Businesses can contribute to an industry value chain by *using* the key, if they have the right business processes in place to create products or services conforming to market expectations laid down in industry standards. Continuing with the above metaphor, it helps to think of these business processes as a lock consisting of two parts: a) a key-matching mechanism to match products with requirements, and b) a product-creation mechanism that creates the desired products or services. Key matching is to be understood as the mechanism used to compare the content of the standards with the desired products or services intended for market consumption. This is traditionally carried out by human experts reading standards and adjusting the design of products. But product creation is the manufacturing process or the given mechanism that a business uses to deliver products or services to the market. Designing machines to manufacture products or the mechanisms used to deliver services is, again, traditionally a task performed by humans.

Smart Standards change the key-matching process in that they facilitate automated matching and interpretation and, perhaps, even encrypt it directly into products. In many ways this is a logical step, because product creation processes already tend to be highly digitized (consider, for example, high-tech manufacturing facilities or digital services). Equipped with a digital key-reading mechanism, they could interact much better with machine-readable standards.

The lock-and-key metaphor helps explain why businesses should care about Smart Standards: we are changing the key, so you need to change the lock. In other words, when the codification of standards becomes digital, users of standards need digital systems to read, match, interpret or embed them into their business processes. The interface between the IEC as a supplier of standards and businesses as consumers of standards is fundamentally transformed.

Section 2

Market perspectives on Smart Standards

This report incorporates views from various stakeholders of the IEC, with an emphasis on the end users of standards. The procedure employed is based on an interview method suggested in the Futures Toolkit [2], a resource for futures thinking developed by the Government Office for Science of the United Kingdom. In this report the so-called "seven questions method" involves an interview technique in which seven questions are posed focussing on the interviewed person's perspectives on the future of Smart Standards. Interviews were performed with individuals representing different IEC stakeholders from various geographical areas. The interviews resulted in different perspectives on the future that call the IEC to action in different ways.

2.1 Seven questions method

The aim of this method is to make strategic topics visible and discussable. The method is suitable for identifying disparities and can be performed in groups as well as with individuals. The seven questions method, as the name indicates, employs a total of seven questions, which were adapted to fit this investigation whilst retaining the gist of their original formulation:

1. If you could speak to someone from the future who could tell you anything about Smart Standards, what would you like to ask?
2. What is your vision for success?
3. What are the dangers of not achieving your vision?
4. What needs to change (systems, relationships, decision-making processes, culture for example) if your vision is to be realized?
5. Looking back, what are the successes we can build on? What are the failures we can learn from?
6. What needs to be done now to ensure that your vision becomes a reality?
7. If you had absolute authority and could do anything, is there anything else you would like IEC to do?

For this exploration, 11 organizations from around the globe were able to participate. They are categorized into the following three groups: end users, SDOs and regulators (see Table 1).

Each of the interviews was summarized in a report and inspected by interviewees. The relevant information was extracted by abstraction and reworded into viewpoints. These viewpoints are represented in the form of personae, which respects the privacy of the interviewees and makes the viewpoints more relatable. The seven viewpoints represented include: the time traveller, the optimist, the pessimist, the historian, the critic, the activist and the business strategist.

2.2 Perspectives of the future

The **time traveller** from 2033 is cautious about explaining how Smart Standards developed, because it was a complex process, but she can provide insight on the measure of success that was achieved. She says that some industries have adopted Smart Standards, and in those industries

Table 1 | Participants in the seven questions interviews

End users	IDEC (Asia), WAGO (Europe), Aviation Industry Corporation of China (Asia), China Southern Power Grid (Asia), Ford (Americas), Port of Rotterdam (Europe)
NSB/SDO	Canadian Standardization Bureau (Americas), Chilean NSB (Americas), European Committee for Standardization/European Electrotechnical Committee for Standardization (CEN/CENELEC) (Europe)
Regulators	Australian government (Australia), European Railway Agency (Europe)

Smart Standards have penetrated the majority of businesses. The latter are mostly technological companies in sectors in which the IEC is active, but to name individual companies she will have to investigate deeper. From a business perspective she reports that the envisaged future has helped bring the industry forward. Even if level 3 Smart Standards are the more obvious (and relatively successful) products, some sectors bypassed them straight to level 4 and some have surpassed that level altogether. She also indicates that some sectors were left behind, most of which are less engaged with the IEC today. She also mentions that novel (third party) consultancies have sprung up to support industries to work with Smart Standards. In some jurisdictions, the legal status of standards has changed. She says that the transition wasn't cheap and that the IEC is still working on reaching out beyond its traditional markets. She has some trouble remembering what the roadmap looked like in 2023 and which pivotal use cases altered the course of the development. From an innovation and progress point of view she reports that human errors were minimized in the standardization ecosystem and that industry has become more efficient in designing and operating smart connected systems either with or without the help of digital twins.

Back in our own time, the **optimist** sees a world ten years from now in which the IEC is the global leading custodian for Smart Standards that provide excellent business support to up to 80% of affiliated businesses. She sees highly automated error-free standard consumption systems that are user friendly and that support business objectives, the systems being seamlessly integrated into local enterprise business processes and facilitating plug-and-play design and engineering that automatically deals with standards in the background. IEC enjoys global trust because it has just finished an excellent management-of-change process for the transition to Smart Standards and has collaborated with all relevant stakeholders to ensure integration with alternative standardization institutions and various forms of digital legislation systems in relevant jurisdictions.

The **pessimist** fears that global innovation and trade suffer when Smart Standards cannot be delivered on time. The complexity of future systems surpasses human comprehension which makes Smart Standards indispensable. She worries that the technical delivery of Smart Standards may be too complicated or may require coding skills from domain experts that may turn such persons off. But if the IEC cannot deliver, it renders itself irrelevant. It will be hard to find a position between global domination or utter irrelevance. A specific concern of the pessimist is that she is not convinced that customer support receives sufficient attention from the IEC and this may make it hard for the IEC to remain a trusted partner. She is also worried that lack of alignment between IEC and other

standardization bureaus damages the IEC, and business may start looking elsewhere for solutions. Similarly, on a slight tangent, she wonders how all of this helps the IEC fill the gap that is widening between government and industry.

The **historian** sees lessons learned in the past as a way to project the future. She notes that the IEC has become better at embracing global diversity (e.g. by using hybrid meetings) and engaging with end users and has learned to incorporate conformity assessment. She recommends that all of these approaches be taken on board from the start of any project, including the development of Smart Standards. At the same it is her assessment that the IEC operates from a position of relative comfort but could do with a stronger sense of urgency to modernize its procedures, perhaps learning from technological successes reported by IEC members. She also suggests that the IEC learn from and repeat successful stepwise introduction processes based on a clear management-of-change process based in turn on a clear roadmap. On the more practical side, she thinks that the IEC should try to communicate more clearly and consistently about Smart Standards and should learn from virtual experiments such as those conducted in SG 12. It should also assess the usefulness of the open standards development process used in the UK. At the same time she cautions that megalomaniac IT projects in the past have been very expensive indeed.

2.3 Options for change

The **critic** thinks that the IEC has to operate more like a corporation, focusing on lifecycle management of its product and professionalizing business functions such as policies, advertising, process flows, impact assessment and third-party sales. This should make the IEC more agile and more rapid in its response to market demands, but it could also require a significant financial injection. The critic also believes that the IEC should attempt to understand its end users better, especially those experiencing difficulty in keeping up with developments, and should endeavour to provide such users with the right level of customer support. She feels a culture change be may required for the organization to become more business-like and that it may help in this regard to take on young dreamers and entrepreneurial SMEs that are willing to fulfil their vision of a better future. The critic also would like IEC to stop talking so much about Smart Standards and get moving on their implementation by working on innovation, experimentation and prototyping, because she sees an enormous market in this regard for validation and conformity assessment.

The **activist** tells the IEC to create the blueprint for a roadmap NOW! That roadmap should set the ecosystem for a Smart system in motion with achievable goals. The plan should be based on a management-of-change process that is designed as if it were a large-scale engineering project. It should focus on the needs of end users (for standards consumption), consider different types of markets (to ensure diversity), different kinds of experts (for content creation), and involve the professionalization of various business functions within IEC. The activist believes that the extreme credibility of the IEC will inspire others to follow in the IEC's footsteps. She also urges initiation of a few bold projects such as experiments with document processing, hiring and motivating young people and bringing added energy and enthusiasm into Smart Standards development. She also wants the IEC to develop a clear dissemination plan for Smart Standards immediately and to reach out to users and inform them why the IEC considers Smart Standards to be so important. Finally, the activist wants IEC to ensure internal harmonization of definitions used in standards!

The **business strategist** thinks that the IEC possesses all the qualities that are relevant to the digital future. It must remain dedicated to delivering business value as a trusted brand and

should endeavour to hold fast to the fundamentally human principles of contribution, collaboration and consensus. But delivering Smart Standards requires the IEC to adjust its core process of convening, coordinating and communicating good practices. To prepare its affiliates and its client base, it has to work on expectation management by developing a clear narrative and an actionable, transparent roadmap with which to follow suit. The core purpose of the roadmap is the delivery of digital Smart Standards, which requires adjustments in the financial and operational business functions of the IEC. Important elements on the roadmap include: globally harmonized standards formats; harmonization of definitions used in the standards; quality-checks for proposed standards; engagement with (or development of) (an) internal technical research branch(es) and attracting funding for or stimulating experimentation; further professionalizing of business functions perhaps together with trusted consultancies; initiating horizon scanning and setting up a customer service department. The transformation to Smart systems constitutes a fundamental shift in the IEC business process that may require a significant financial injection, and in this connection it may be opportune to consider merging with the ISO.

2.4 Top six lessons

- It is still very unclear to outsiders what exactly Smart Standards are and what they will achieve. The IEC should create clarity about this with a comprehensive communication plan, because businesses need clear objectives and a time to plan for investments.
- The IEC should design a roadmap with achievable, industry-relevant goals to develop the ecosystem for Smart Standards. Perhaps the management-of-change process could be modelled on a large-scale engineering project, to develop the ecosystem for Smart Standards.
- It would be good if the IEC continues leading the transformation toward a more dynamic organization through active participation with others in developments and experiments aimed at promoting Smart Standards by participating, initiating, collaborating, perhaps even supporting research around the globe.
- The IEC needs to hold fast to its traditional values of contribution, collaboration and consensus but at the same time modernize operational business processes for convening, coordinating, and communicating best practices. This includes collaborating with other relevant global partners besides ISO.
- The cost of failure may be that the IEC loses its international leadership position as a standards developing organization.
- The IEC needs to maintain its relevance in the face of competition by increasing its engagement in consortia, in order to a) be recognized as being at the forefront of developments and b) increase its visibility beyond its traditional collaborators.

Section 3

Economic perspectives on Smart Standards

This section investigates the economic perspectives of end users and that of the IEC. With regard to value creation for end users, three economic perspectives connected with Smart Standards are explored: performance value, risk value and future value. Following a brief explanation of each of these different values, these economic perspectives are blended with the lock-and-key metaphor to provide additional detail about their benefits for businesses. Concerning the business model of the IEC itself, a first draft is provided for a business canvas.

3.1 The value chain for Smart Standards

The question facing businesses is why would they want to go through the trouble of changing standards at all? The simple answer is that the new Smart format accelerates business at lower costs. The German Institute for Standardization (DIN) and the German Commission for Electrical, Electronic and Information Technologies (DKE) have worked on financial modelling of Smart Standards in their programme entitled “Initiative Digital Standards” or IdiS [3] [4], which proposes three areas of value creation for working with Smart Standards: performance value, risk value and future value.

Performance value of Smart Standards covers the reduction of errors in the design and operation of a product or service, the improvement of the production process and the subsequent impact that those benefits have on the organization as a whole. Designers can work with comprehensive lists of items under consideration, and with the help of efficient digital systems, some of the considerations can be made by the machines themselves, particularly if they are equipped with artificial intelligence (AI). This should eliminate errors of omission and, on the basis of itemized and clear action points, should ensure that all points receive the attention they require. Once semantic information is added to Smart systems, errors of interpretation should also decrease, as the designer will have precise information available about the topic being addressed. Similarly, errors during operation will be reduced in the sense that action points are less easily overlooked, and easier to understand. This is true for the development of the product, as well as for development of the machines or processes that manufacture the product, and thereby also has an impact on the organization itself, perhaps simplifying business processes for product support or maintenance. Performance value translates into better product quality, better production quality and healthier businesses when adopting Smart Standards. Suggestions for performance value measurements include time spent on standards processing, reductions in the number of customer complaints, and higher return on investment.

Risk value is tied to litigations. With Smart Standards it is easier to comprehensively identify relevant clauses and to ensure they are not omitted at any stage of the product’s lifecycle. It may be easier to perform legal assessments when legislative rules are also coded in a Smart format but this is not strictly necessary. Again, a comprehensive points list can be drawn up about the litigations, and these can be monitored through time in relation to changing legislation, changing end user behaviour and, perhaps, specific aspects

of litigations in relation to recycling. Suggestions for measuring risk value include cost monitoring for legal acceptance procedures (e.g. CE marking) and the number of cases brought to court in the industry and/or the product involved.

Future value, or revenue value covers the income that the products or services generate, now and in the future. With the use of Smart Standards the product creation cycle becomes more cost-effective which leads to better profit margins. Cost benefits can be found in the fact that less time is spent on studying standards (thereby finding better things to do for experienced engineers) or perhaps through delegating such tasks to junior engineers. Concerning existing product ranges or services, it also becomes easier to widen the product range, enter new markets, adapt to changing standards or change the ways in which products are used, because Smart Standards help bring new challenges to light. Together with rapid product development (performance value) and market acceptance (risk value) it is also easier to re-develop the product or simply launch a new product that improves upon the current one, thus guarding profit margins. Suggestions for monitoring future value include profit margin monitoring and the time to develop for changing products or services.

3.2 A new business model for industry

With the introduction of Smart Standards, the IEC is changing the way in which standards are constructed, disseminated and consumed. But as Subsection 3.1 indicates, for many end users it is not yet clear how exactly they will benefit. Table 2 below illustrates how businesses benefit at different levels in the utility model by describing typical business processes end users may expect to use in their business as well as the value they may expect to obtain from them. Table 2 is structured using the different levels of Smart Standards in the utility model of the IEC, and the lock-and-key metaphor is used to explain the way the business changes as a result. The farmost column on the right also structures the business benefits using the three values proposed in Section 3.

The table shows that Smart Standards infuse various business processes with digital accelerators that offer specific business values. As the utility level increases, the benefits increase, but it should be kept in mind that the level of digitalization required will also increase. It should likewise be noted that some businesses may already have developed processes and software to deal with higher Smart Standard utility levels.

Level 4 assumes that the end user is proficient in working with digital twins, machine interpretable source files and possibly with various forms of AI in their business processes. This is where Smart Standards interact most frequently with technical developments that are relevant in business today. Smart Standards are an important facilitator for working with such modern technologies, and more and more businesses are developing competence in this regard. But even if level 4 constitutes a driver for change, levels 2 and 3 probably remain relevant for many businesses around the globe.

Table 2 | Business value of Smart Standards for industry

	Standards codes (**key**)	Key-matching (**lock-selector**)	Digital accelerator	Product-creation (**lock-action**)	Digital accelerator	Business benefit
Level 0	Articles in paper document	Humans select, read and apply relevant articles in relevant standards and match and use them for their business processes		Humans interpret and transfer standards contents to machines and design and install equipment and processes to produce products and services according to market expectations		**[baseline value]** ▪ Products and services according to market expectations
Level 1	Articles in digital format (e.g. pdf)	Humans select, read and apply relevant articles in relevant standards and match and use them for their business processes	Word searchers on screen speed up the searching/ reading process	Machines can display the document and design and install equipment and processes to produce products and services according to market expectations	Customer support through links to relevant standards can be provided with the product software	**[baseline value]** ▪ Reduce workload for standards matching ▪ Digital (quality) references for customers

	Standards codes (**key**)	Key-matching (**lock-selector**)	Digital accelerator	Product-creation (**lock-action**)	Digital accelerator	Business benefit
Level 2	Indexed articles in machine-readable document (e.g. XML)	Humans use editor systems to navigate through relevant articles in multiple standards and order them in their preferred way. They then read and apply them for their business processes	Decoding process by using document navigation systems to facilitate amalgamation of relevant articles from multiple standards in any desired format and tailored to various business processes in the organization	Machines can identify structure and perform basic actions on the document, and candesign and install equipment and processes to produce products and services according to market expectations	Content can be processed by software. Automation of process, quality, management and control: systems may be linked directly to all relevant articles and processes, regardless of the standard they originate from	**[performance value]** ▪ Reduce workload by automating standards topics matching ▪ Blueprint for quality control systems ▪ Local standards content database ▪ Facilitate technical indicators and methods comparison ▪ Better standards coverage **[future value]** ▪ Production cost savings through automation of business process ▪ Fewer qualifications required for the application of standards leading to cost reduction ▪ Less time spent on standards, freeing staff for more complex design tasks

	Standards codes (**key**)	Key-matching (**lock-selector**)	Digital accelerator	Product-creation (**lock-action**)	Digital accelerator	Business benefit
Level 3	Semantically annotated articles with metadata in machine-readable and -executable content	Humans use requirement management software to oversee the semantic matching of business processes with articles in standards	Product requirements and articles from (many) standards are semantically matched in a (semi-) automated manner, taking much less time to create the amalgamate of articles (use case – testing different project options without cost)	Machines can perform more complex actions based on the semantic enrichment (and/ or tagging) in standards. Requirement management software accelerates design and installation of equipment and processes to produce market-ready products; the outline of management & control systems may be generated (semi-) automatically	Concurrent design of product and production procedures and machinery	**[performance value]** ▪ Local standards content database with additional (local) semantic declarations ▪ Reduce workload by automating standards content matching ▪ Integration with pre-existing requirement models **[risk value]** ▪ Automated design of digital quality control system **[future value]** ▪ Concurrent design of product, standards and production mechanisms

	Standards codes (**key**)	Key-matching (**lock-selector**)	Digital accelerator	Product-creation (**lock-action**)	Digital accelerator	Business benefit
Level 4	Information model containing information units and their relationships, metadata and semantics	Humans supply metadata from engineering models and digital twins that is semantically enriched; they are automatically matched to the metadata of articles-based standards, including engineering principles, declared engineering concepts and their relationships. Machines can automatically find the articles needed in given context, even predictively supply the content	Product design & manufacturing design collapse into a single automated business process	Machines can automatically execute according to standard content. The customer's (indeed any) metamodels for product lifetime and/or asset management are incorporated in the design of production process	Adaptable production processes and automated compliance data & management assure conformity to standards down to individual products. Standards that can be interpretable by machine without human intervention. Standards code transferrable to products	**[performance value]** ▪ Local standards content database with additional (local) semantic declarations ▪ Fully automated standards matching with engineering models and digital twins **[risk value]** ▪ Digital twin prototype assessment ▪ Conformity assessment down to individual products **[future value]** ▪ Quick response to changes in the market ▪ Enclosing standards-code directly in individual products or production machinery

3.3 A new business model canvas for IEC

The business model canvas presented here offers insight into the business model of IEC once it starts working with Smart Standards. In terms of the lock-and-key metaphor, this means that IEC is changing keys to unlock market value. The canvas focusses on the value propositions, infrastructures, customers, and financial aspects of the business model in the near future, assuming that the current business structure of the IEC does not change significantly. The business model canvas addresses the services and products that Smart Standards will enable IEC to offer to end users (see Table 3). The different areas of the canvas are described in more detail below.

Value proposition

Smart Standards are used in different phases of the business offering lifecycle, i.e. concept phase, design phase, deployment phase and decommissioning. For each phase within the solution/product lifecycle, Smart Standards provide a different set of services to manage the complexity of the lifecycle.

Smart Standards within the concept phase will offer the marketing department an exhaustive overview of the requisite standard compliance and its specific requirements. This will assist the business developer/marketers to retrieve quickly all requisite standard requirements applicable to their business proposal and will substantially reduce the time that business developers/marketers spend on analyzing these requirements. At the same time, AI can facilitate the mapping of the business developer's/marketer's ideas towards the required list of standards.

Smart Standards will reduce the human error factor by automatically retrieving all technical and conformity requirements autonomously via the Smart Standards platform during the design phase, thereby increasing the quality of the solution/product design. They will also accelerate the design process itself and thus positively influence the solution/product time to market.

Smart Standards, provided they are machine-executable, will reduce the complexity of solution/product interoperability to other products and/or components and will ease the conformity requirements of solutions/products during the deployment phase, perhaps performing a specific set of conformity assessment activities automatically. This will again reduce the conformity assessment process time, thereby reducing the time to market of the solutions/products.

Smart Standards will automatically retrieve the regulatory requirements for the decommissioning phase of the solutions and products, such as those related to waste management, circular economy, etc.

Key activities

Smart Standards require the development of customer segment-specific services, which need to be offered by the NSBs to end users and integrated with the development tools used during the industrial product management and design process. In terms of the lock-and-key metaphor, they sell new keys to customers and must help such customers learn how to use the keys. Furthermore, innovative business models are needed to complement the Smart Standards copyright license, effectively turning it into a software (SW)-based right-to-use license.

Key resources

Smart Standards will require standardization experts who have the competence to develop information models, semantics and ontology as content for the Smart Standards. Today, these experts are technical engineers who are capturing the requirements in English. However, Smart Standards are machine-readable and -executable, which will force the requirements contained in these Smart Standards to become a set of information models, capturing the meaning of the information data elements (as well as the meaning of values of the information data elements) in machine-readable language, in order to make the

Smart Standards machine-readable and machine-executable.

The Smart Standards will require IEC/ISO service staff to design and deploy Smart Standards services in support of the efforts of NSBs to provide such services to their end users. The IEC/ISO and the NSBs shall provide customer service staff to deliver the required customer services to the end users. Tools need to be developed by the international software vendor (ISV) and open source communities to integrate Smart Standards within the industrial business development, product management, and design processes.

Key partners

IEC, the International Organization for Standardization (ISO) and the European Committee for Standardization/European Committee for Electrotechnical Standardization (CEN/CENELEC) are providing the content for Smart Standards to NSBs and/or end users. Furthermore, IEC, ISO and CEN/CENELEC are furnishing Smart Standards services to the NSBs in order for these bodies to offer localized, customized Smart Standards services to end users. Software suppliers (i.e. ISVs, open source) will integrate Smart Standards into industrial design software, and other standardization organizations who embrace Smart Standards will be supported by IEC, ISO and CEN/CENELEC. In terms of the lock-and-key metaphor, IEC helps other standardization bodies to make keys according to a Smart Standards protocol.

Customer relationships

The IEC, ISO and CEN/CENELEC will maintain a supplier relationship and will serve as the point of contact with the NSBs for Smart Standards as a service. In addition they will supply Smart Standard services directly to large international companies. Customer relationships need to be tailored to the needs of end users, such as marketing, purchasing, designers and testers.

Channels

IEC and ISO direct service channels will support the offering of Smart Standard services to international end users and NSBs. IEC, ISO and CEN/CENELEC business-to-business service channels will offer Smart Standard services to the NSBs.

Customer segments

End users are the consumers of Smart Standards and services. Following the lock-and-key metaphor, they have to put new locks in place. Marketers will benefit from automated evaluation of the complexity, impacts and costs of standards usage for their solutions/products. Purchasers will benefit from the quality and conformity requirements for the purchased services/goods. Designers will require less time to integrate standards in products/solutions and avoid human-introduced errors. Testers will shorten the validation time through the automated technical compliance requirements implementation within the solutions/products. Conformity assessors will validate the conformity of products/solutions to ensure mandatory regulatory compliance. National standardization bodies may take Smart Standards content from IEC, ISO and/or CEN/CENELEC.

Cost structure

The cost structure of Smart Standards relates to the creation of these standards and their services. Costs that will be incurred concern content, provisioning of Smart Standard services, necessary customer services and the Smart Standards software upgrades and maintenance.

Future streams

Smart Standards will generate additional revenue streams in the areas of software right-to-use licenses (provided the Smart Standards are machine-executable), Smart Standards-related customer service level agreements (SLAs), specific customer segment Smart Standards services, customized Smart Standard services, and Smart Standard upgrade services.

Table 3 | Smart Standards business model canvas for the IEC

<table>
<tr>
<td rowspan="2">Key partners

IEC, ISO and CEN/CENELEC are partners in developing and offering machine-readable and -executable standards to the market (i.e. Smart Standards).

IEC, ISO and CEN/CENELEC jointly provide supporting services to the national standardization bodies (NSB).

NSBs are resellers of Smart Standards and will provide the necessary local services to support the deployment of Smart Standards in the end users.

As yet undetermined software suppliers (e.g. ISVs, open source) provide technical software services to provide an interface between IEC, ISO and CEN/CENELEC and their clients.

Other standardization development/ specification organizations (e.g. the International Maritime Organization (IMO)) who embrace Smart Standards become a novel group of resellers of Smart Standards or standards using the Smart Standards template. They require guidance and become advocates for Smart Standards.</td>
<td>Key activities

Content for Smart Standards needs to be developed and/or rewritten from traditional standards.

Guidance and support needs to be created to help technical committees (TC) and other SDOs to develop standards in the Smart format. This may require a specialized Smart Standards expertise committee that performs reviews and/or delivers arbitration.

IEC, ISO, CEN/CENELEC Smart Standards services need to be developed to support the NSBs.

Industrial design softwares require add-ons to integrate the Smart Standards within the industrial product management and design processes.

Localized customer services need to be developed to support Smart Standards as a service offering.

An acceptable business model for the standardization organizations and the industry needs to be developed to change the copy right licensing into a software right-to-use licensing model.</td>
<td rowspan="2">Value propositions

Smart Standards provide performance value, risk value and future value for businesses. These materialize in different forms in the lifecycle of products and services as follows.

Concept phase:

Smart Standards will offer performance value and risk value through an exhaustive overview of standards requirements for the products and solutions. This also enables thorough assessments of alternative products or production mechanisms post-production.

Design phase:

Smart Standards will offer future value by decreasing the time to market of products and solutions.

Smart Standards offer performance value by diminishing human errors for requirements and conformity assessment.

Smart Standards will offer risk value by improving the interoperability between different products and/or components which decreases the integration complexity of products.

Deployment phase:

Smart Standards offer risk value by compliance to regulatory requirements, such as safety regulations.

Smart Standards will deliver future value by allowing automatic upgrades to comply to new versions of standards.

Decommissioning:

Smart Standards will support future value and risk value by compliance to decommissioning products, such as waste management and circular economy.</td>
<td rowspan="2">Customer relationships

IEC, ISO and CEN/CENELEC will be the global custodians and govern the methods and protocols for the development and deployment of Smart Standards.

The IEC, ISO and CEN/CENELEC will channel Smart Standards content to the market through NSBs that increase their business and impact. NSBs will become the first point of support for end users of Smart Standards as a service.

Standardization experts receive training and access to Smart Standards tools so they become more efficient standards developers and increase the value of the companies they work for.

Large international companies may take the service support directly from IEC, ISO and/or CEN/CENELEC.

The customer relationships may be customized to the type of end users (marketing, purchasing, designers, testers).

The IEC, ISO and CEN/CENELEC assist other standardization organizations in developing standards in the Smart format.</td>
<td rowspan="2">Customer segments

End users, businesses and other consumers of Smart Standards benefit from instantaneous access and benefit by improving a) performance value, b) risk value and c) future value.

End users may have different professions that benefit in different ways.

Marketing users benefit from rapid evaluation of complexity, impacts and costs in post-product assessments, which enables them to assess product viability and post-product assessments for performance, risk and future value.

Purchasing users benefit from clear structuring of quality and conformity associated with purchased goods, offering performance and risk value.

Designers require less time to integrate standards in products/solutions and avoid human errors, offering performance value.

Testers will shorten the validation time for applying technical compliance requirements to their products/solutions, offering performance and future value.

Conformity assessors require less time to set up and execute assessments and report outcomes with less effort to higher quality standards as well as link through to legislative requirements, which offers performance, risk and future value.

National standardization bodies will become creators and resellers of Smart Standards using methods developed by IEC, ISO and CEN/CENELEC which offers them future value .

Legislators require less time to consider Smart Standards for referral or endorsement and may be able to integrate parts of Smart Standards into Smart legislation, perhaps even extrapolating Smart legislation from Smart Standards formats, which offers performance value.</td>
</tr>
<tr>
<td>Key resources

Standardization experts are key resources. When trained in Smart Standards information models, semantics and ontology they will draft the Smart Standards and become advocates within the companies that participate in TCs.

IEC, ISO, CEN/CENELEC staff need to develop the Smart Standard services to support the NSBs.

IEC, ISO and NSB staff need to develop the required end user services to deploy Smart Standards in their business processes.

ISVs and open source developers are required to develop the necessary tools to integrate Smart Standards within the business development, product management and design software tools.</td>
<td>Channels

Smart Standards as a service can be offered directly by IEC and ISO to international end users.

Smart Standards as a service offer support by IEC, ISO and CEN/CENELEC to the NSBs.

Smart Standards as a service will be offered by the NSBs to the end user.

IEC engages in consortia to advertize, promote and develop Smart Standards in industry, education and legislation.</td>
</tr>
</table>

Cost structure	Future streams
▪ Provisioning of Smart Standards governance and content ▪ Provisioning of customer support services ▪ Provisioning of advanced digital customer services ▪ Provisioning of upgrades and maintenance services	▪ Smart Standards software licensing and right-to-use for end users ▪ Increased numbers of TC members when Smart Standards impact their business ▪ Industrial design software require licencing for integration with Smart Standards ▪ Service level agreement for large international customers and national standardization bodies ▪ Advanced services for dedicated customer segments

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Section 4

Examples of the application of Smart Standards

4.1 Energy industry

Taking transformers and circuit breakers as pilot projects, China Southern Power Grid (CSG) has constructed the standard knowledge base and knowledge domains map for main grid equipment, established a standard digital platform, and implemented advanced applications such as digital reading, intelligent retrieval, knowledge recommendation, knowledge Q&A, differential comparison of standards, and digital standard compilation. With deeply embedded business scenarios such as power grid project planning & design, bidding & procurement, and operations and maintenance (O&M), CSG can fully mine and unlock the value of standard data, paving the way for digital power grid construction and equipment standardization.

Scenario of power grid project planning & design: By utilizing the indicator extraction and verification capabilities of the standard digital platform, coupled with the advanced feasibility study review software designed specifically for power grid infrastructure projects, it is possible to automatically identify and address common issues such as non-compliance with standards or implementation documents and delayed updates of reference standards within feasibility study documents. This sophisticated system provides intelligent reminders and alerts to improve the efficiency of standards reviews, ultimately reducing project construction risks associated with design flaws and delays.

Scenario of bidding & procurement of power grid equipment: Through structured processing of technical specifications and leveraging the advanced functionalities of the standard digital platform, including standard query, indicator query and indicator verification & comparison, the scenario can be invoked by the bidding business system to realize a streamlined, digital and intelligent process of bid invitation, submission and evaluation.

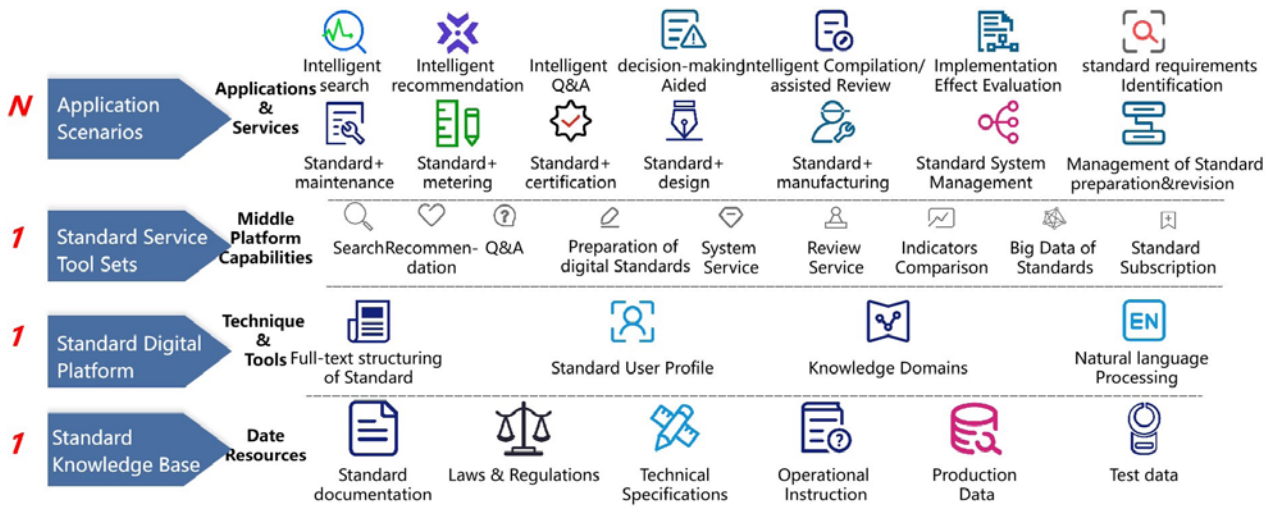

Figure 2 | Example of Smart Standards system structure (China Southern Power Grid/CSG)

4.2 Aviation industry

Standards span the entire lifecycle of product design, production and operation and are the primary source of technical data for the aviation industry. The traditional application mode of standards is that people try to learn and understand standards first, and then integrate related data and content into product development or the supply chain process. It is obvious that the level of digitization in standards no longer matches the level of digitization in product development and production.

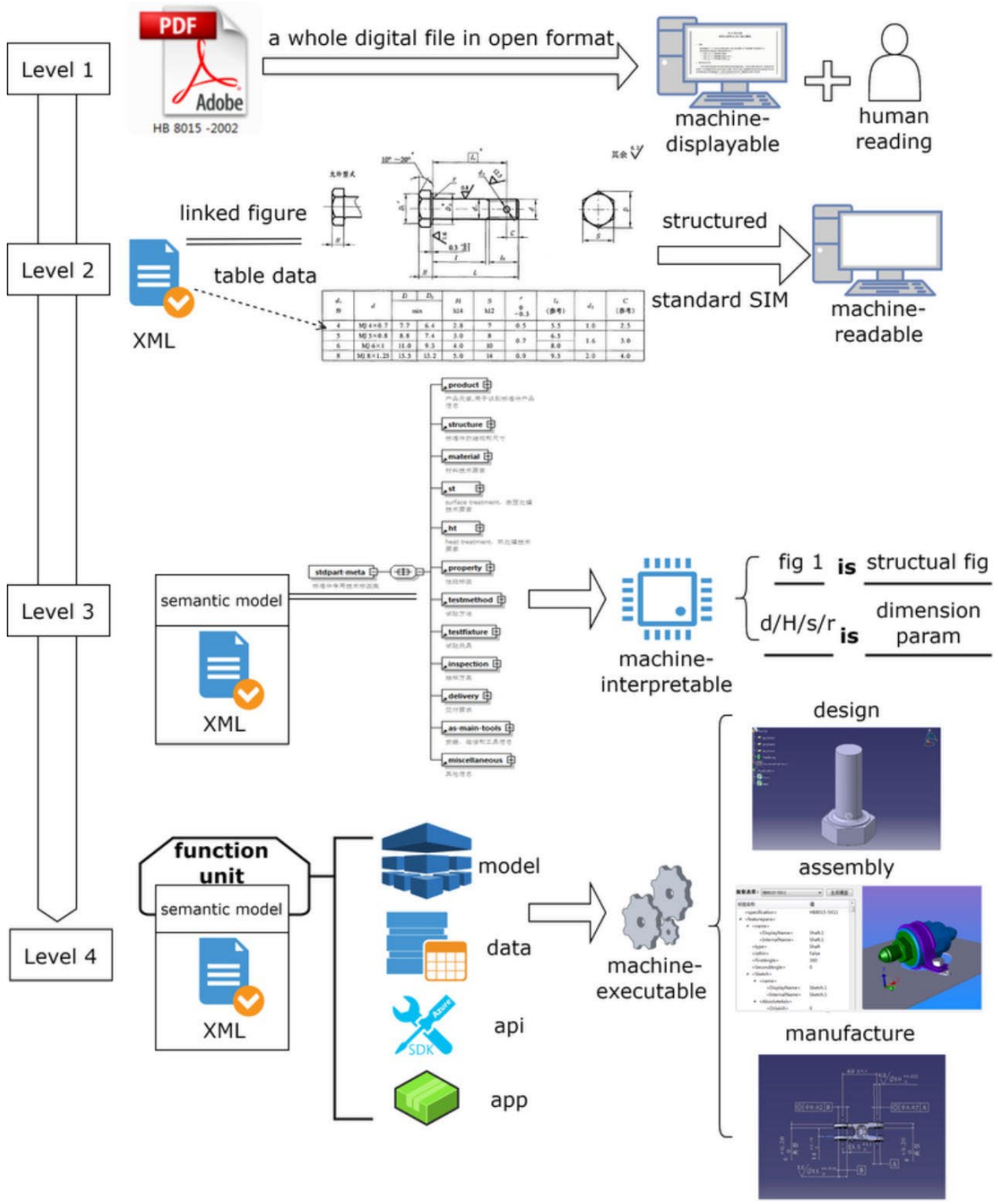

Figure 3 | Smart Standards pilot in aviation industry (China Aero-Polytechnology Establishment/CAPE)

The digital transformation of aviation standardization is driven by the evolving needs of digitalization in aerospace engineering, such as digital product definition (DPD), product data management (PDM), digital manufacturing, and integrated logistics support. The ultimate goal is to improve design and manufacturing efficiency and quality and to integrate the product development process with standards tightly. It requires that: a) the standard content should be machine-readable and -interpretable without the need for human interpretation, and b) the standard content can serve as the foundational corpus for AI and other intelligence technology applications. ▶

In practice, advanced standards processing tools (ADSPTs) can integrate Smart Standards into computer-aided three-dimensional interactive application (CATIA) software[4], to achieve higher degree of automation in design, reduce low-value work, such as filtering specifications and modelling, and help technicians focus on product innovation. In product assembly design scenarios, ADSPT will read Smart Standards, match available specifications based on features of an assembled object, create the 3D model of the standard part, and complete the positioning and assembly tasks automatically.

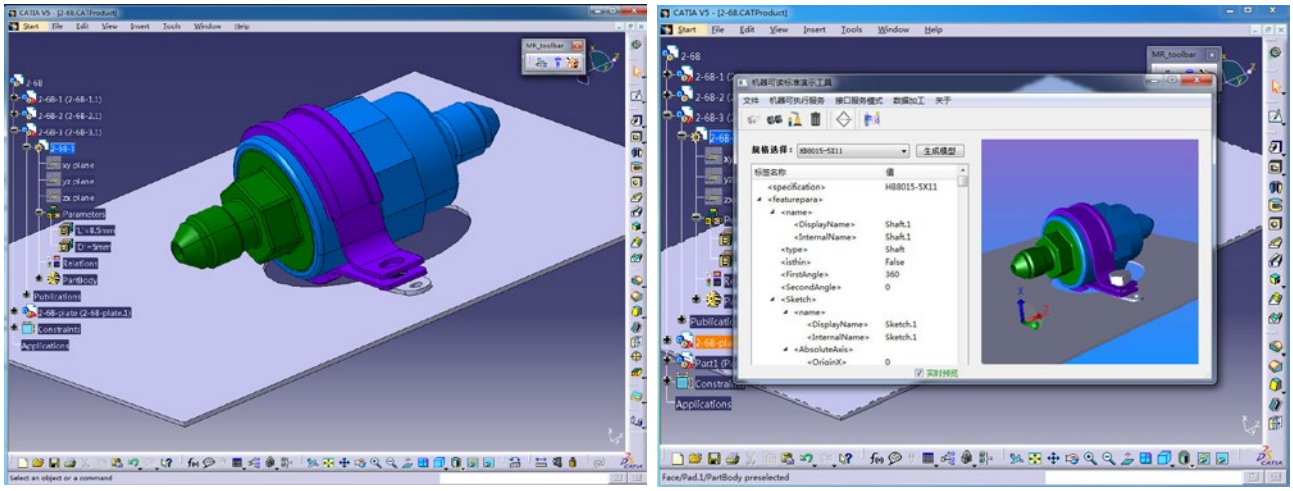

Figure 4 | An insight into IT solutions for assembly (China-Aero Polytechnology Establishment/CAPE)

4.3 Quality infrastructure (QI)

As the digital transformation of standardization and implementation of Smart Standards progresses, there may be many impacts on the quality infrastructure value chain that can in turn impact industry, especially as standards development moves into the level 3 and level 4 phases. Quality infrastructure is comprised of five key components: ▶

- Metrology
- Standardization
- Accreditation
- Conformity assessment (including testing, certification and inspection)
- Market surveillance

Adding to the five key components that can impact industry is the regulatory component. This could be at

4 CATIA software has been developed by Dassault Systèmes.

the national or regional level as well as at local levels where product acceptance requirements may be mandated in regulation. Standards incorporated by legislation at the regulatory level will need to address how they will treat Smart Standards that may be updated and changed on a more frequent basis, and how the regulatory process will adapt to recognize the Smart Standards. Accreditation bodies will also need to address this ever-changing standards environment and how they will accredit testing, certification and inspection bodies based on their identified scopes of accreditation. Conformity assessment bodies will need to work more closely with manufacturers and customers to address product compliance and effective dates for compliance to ensure timely recognition. Standards development bodies, who will be adopting Smart Standards and issuing national differences, if necessary, will also be key contributors to the success of Smart Standards integration.

Initially, this complexity may add increased costs for manufacturers as these value chain entities further define their activities to address Smart Standards. Consumers may not be impacted as much as manufacturers, however end users who specify and purchase complex or innovative products for use in industry may also realize economic impacts due to time and complexity of the new standards realm.

Eventually, governments and businesses should realize less business costs due to automated processes that will see greater efficiencies as well as a decrease in paper and administrative costs.

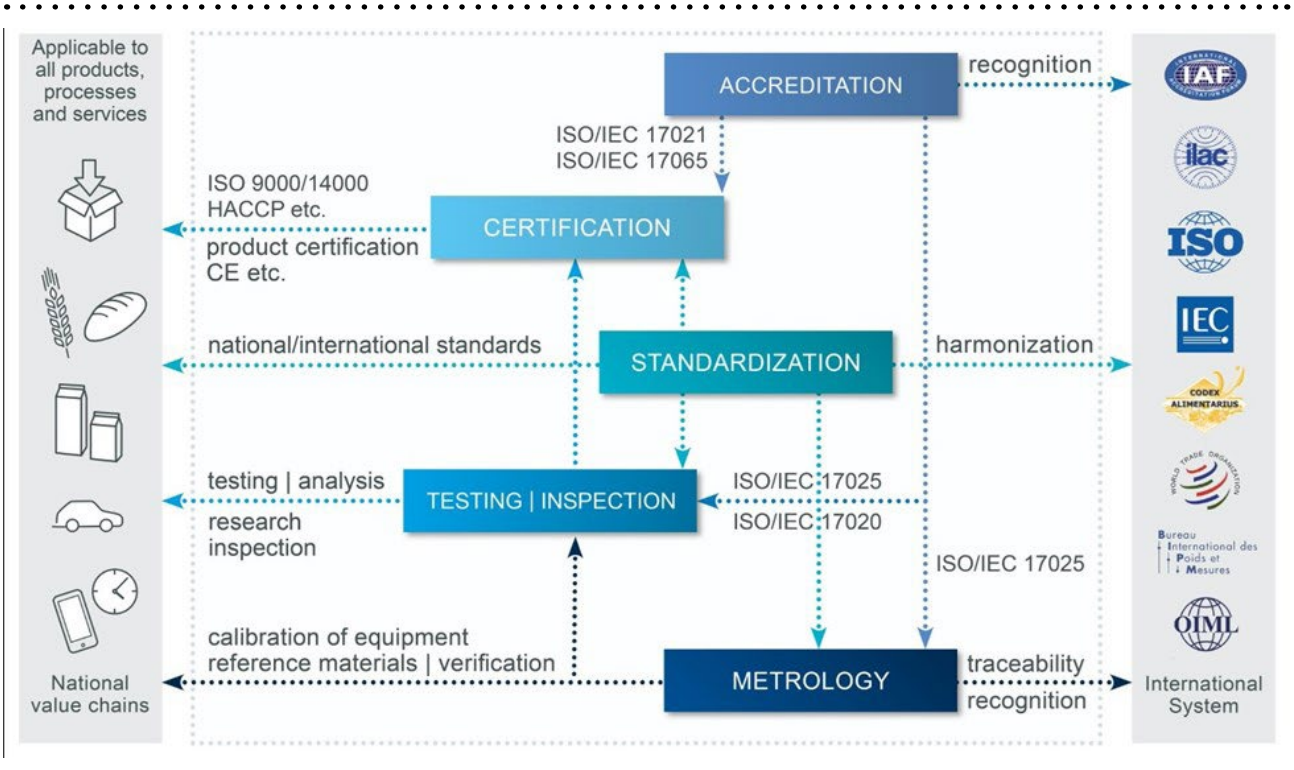

Figure 5 | Quality infrastructure value chain

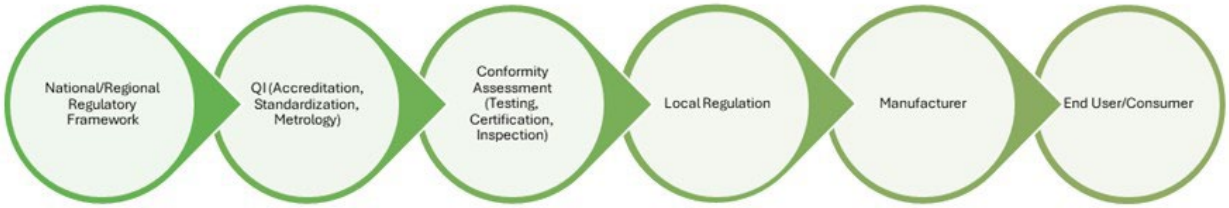

Figure 6 | Quality infrastructure (Source: Physikalisch-Technische Bundesanstalt/PTB)

As different countries progress the implementation of Smart Standards according to different time frames, standards harmonization, or lack thereof, may have an impact on mutual recognition agreements and economical trade between nations due once again to the increased complexity of integrating the processes into their quality infrastructures.

Section 5

Conclusions

Whereas the work of IEC SMB SG 12 is focussed on the technologies involved in Smart Standards, this report investigates the business side. The first task in this work was to understand exactly what Smart Standards entail and how to explain them in relatively simple business terms. This was solved using the lock-and-key metaphor, which helps explain what makes the shift from traditional standards to Smart Standards so relevant, and how it changes the way in which the IEC interacts with the market. The lock-and-key metaphor also elucidates what businesses need to do to follow suit. Table 2 in Section 4 illustrates these explanations in greater detail.

The lock-and-key metaphor explains that the IEC is changing the keys it utilizes in order to unlock better market potential for businesses. So the question end users should ask themselves is why they should change their lock. Businesses will have to alter their processes to match the new format of Smart Standards and may have to invest funds to implement this change. So what is in it for them? Before addressing that question, it might help to remember that some front-runners have progressed significantly in their digital transformation and have begun demanding Smart Standards to match their internal business processes. The examples provided in Section 5 illustrate this need. But Smart Standards offer significant added values. These values boil down to three main aspects: performance value, risk value and future value. Performance value translates to faster adaptation of standards and with less errors, i.e. end users can fabricate better products more rapidly. Risk value translates to better alignment with legislation and industry partners and improved conformity, which diminishes the risk of litigations. Future value translates to assuring future income for the business by operating better and more quickly in dynamic markets. Table 2 in Section 4 elaborates on these different forms of added value. It is expected that small and medium-sized enterprises (SMEs) will potentially benefit the most from Smart Standards, because the new format represents a form of outsourcing of industry alignment. Large international corporations may have dedicated departments for standards processes, but SMEs do not. Thus, the more value the IEC provides, the more SMEs may benefit.

But the introduction of Smart Standards will change the IEC as well, and it will have to adapt its own business processes accordingly. The prime driver for this adaptation will be a changing sales model moving from paying for copyrighted materials to paying for access to digital systems and/or right-to-use licensing. It remains unclear how this change would be achieved technically, which more properly constitutes a task for SG 12 to investigate. At the same time, the IEC MSB should consider options from a business perspective, which will need to include considerations concerning the embedding or outsourcing of digital services, generation of new revenue streams, the IEC's relationship with national standardization bodies and end users, and maintaining IEC core values during and after the digital transformation. Table 4 presents aspects concerning cost versus revenue in this regard.

Table 4 | Cost versus revenue

Cost structure	Revenue streams
The IEC and its members need to purchase specific tools to support the creation of Smart Standards. One can think about specific tools to create information models and to specify the semantics and ontology. New staff members with different skills are needed as well to support the Smart Standards creation.	Smart Standards are machine-interpretable and can be considered as software packages. Therefore, the IEC needs to issue software right-to-use licensing, as many software companies are doing. Different licensing models can be applied here, such as one-time-purchase and cloud-based services, e.g. Smart Standards as a service.
The IEC and its members offer governance and provisioning of professional services that are complementary to the Smart Standards. These Smart Standard services have to be developed, staff has to be trained and Smart Standards have to be advertized.	Each Smart Standard user requires additional services to complement the Smart Standards. These Smart Standard services can be purchased via service level agreements by the end users.
The IEC and its members are professional service companies and make the necessary customer services available on a 24/7 basis to the end users. The customer services need to be developed and customer support staff recruited and trained.	Each customer segment requires specific support services which can be offered to end users as a package complementary to the Smart Standards.
The IEC and its members provide upgrade and maintenance services for Smart Standards to secure the business continuity of such standards. They support a complete software upgrade lifecycle to keep the software up-to-date regarding bugs and other errors.	Smart Standards require upgrades and maintenance just as any other software-based applications and solutions would. The upgrades and maintenance can be offered in the form of an automated delivery to end users.

This work incorporates business interviews with IEC stakeholders. So rather than asking knowledgeable technical experts who are actively involved with the IEC through their participation in technical committees or workgroups, interviews were conducted with stakeholders who do not benefit from active involvement. Interviews using the semi-structured interview protocol based on seven questions yielded that (generally speaking) businesses welcome future-thinking in the form of digital transformation of standards but have trouble understanding what exactly Smart Standards are, and how their business will benefit from this new format. Their advice to the IEC is to communicate more and to be clearer about what Smart Standards are exactly and what the IEC does to develop them. They also recommended that the IEC should start developing (and communicating) about a roadmap for Smart Standards, and that it should consider operating more like a business, with associated business functions (such as participation in consortia, aligning with Smart legislation, creating a service department, developing educational materials, and maintaining a marketing department to follow up on customer demands). At the same time, they trust the IEC to maintain its leading international position by exercising its traditional values of

convening, collaboration and consensus to deliver the standards that help them succeed in their industrial ecosystem. Failure to do so may render the IEC irrelevant, because competitors would take the lead. One way to assure global leadership is to assume the role of custodian for Smart Standards methods and deployment: prescribing the lexicon, knowledge models and procedures for development, perhaps even providing technical assurance and/or arbitration. Slightly off-topic is that end users see an opportunity for the IEC to engage a new generation of engineering experts. Not only are such persons attracted by the novelty of Smart Standards, but they are also more apt at dreaming of novel services the IEC could provide.

End users have great expectations for Smart Standards, not only to propel their industry forward but also to prevent stand-still with regard to super-complex products. At the same time end users indicate that it is not just a question of creating Smart Standards but also of developing Smarter standards in general, which means they foresee a future in which both Smart and improved traditional standards are used and need to be catered for. Highly digitized businesses could depend on Smart Standards delivery, but for low-tech companies Smart Standards may not be worth the investment because traditional standards suffice.

To summarize, the world is changing, and the IEC has to change with it. Smart Standards offer a sensible way forward that stakeholders welcome. Even if it not always clear to them what Smart Standards are exactly, and how such standards will benefit their business, the stakeholders trust the IEC to pave the way to the future. At the same time, they want the IEC to become more businesslike and to clarify what the roadmap for Smart Standards is, because they sense it requires investment decisions for which they need to plan. At present, they trust the IEC to do the right thing, but that trust needs to be re-enforced, as they are easily tempted by competing standardization organizations, if the latter offer better value.

Section 6

Suggestions for the path forward

For the IEC:

- Carefully design, develop and execute a global dissemination plan about what Smart Standards aim to achieve, how they work and the manner in which this will impact the IEC's stakeholders.
- Claim global custody for Smart Standards governance regarding development, quality control and arbitration. This will require custody of technicalities (lexicon/knowledge models), conformity assessment (for conformity with Smart), and management-of-change processes associated with Smart Standards. Consider sharing custody with key partners such as ISO and/or CEN/CENELEC.
- Consider options for a business model under which the IEC becomes one part of a chain of software suppliers, perhaps in association with a reputable advisor.
- Consider re-organizing the terms-of-reference of the entities working on Smart Standards within the IEC.
- Consider hosting a joint event with other global standardization organizations including, but not limited to, the Institute of Electrical and Electronics Engineers (IEEE), the International Telecommunication Union's Telecommunication Standardization Sector (ITU-T) and the International Maritime Organization (IMO).

For the Standardization Management Board:

- (Assist in) finalizing technicalities for Smart Standards on as many levels as possible: an unambiguous lexicon, succinct and transparent technical data formats, and clear rules for machine-readable content. Where technologies do not yet clearly exist, make a prognosis.
- Design or develop a technical model for digital payment systems and/or right-to-use licensing.
- Develop a technical roadmap for the introduction and release of Smart Standards in the market.

For the Market Strategy Board:

- Design a management-of-change process for the introduction of Smart Standards, as if it were a large-scale technical engineering project.
- Publish a business roadmap for the introduction of Smart Standards in close association with the SMB Strategic Group 12: Digital transformation and systems approach.
- Consider options for working in consortia to a) accelerate the development of Smart Standards, and b) disseminate knowledge about such standards.

Annex A

The IDiS Smart Standards value-added model

A.1 Introduction: changing the standards workflow process with Smart Standards

Workflow process with pdf documents

In most companies, standards have so far generally been issued in paper or, at best, pdf formats. The advantage of making documents digitally available (here: in pdf) can be well visualized, for example, in engineering processes that form part of wider product development processes (see Figure A.1).

However, according to the new orientation provided in level 1 (pdf) of the Smart Standards utility model compared to that of level 0 (paper), the advantage is marginal, because the standards provided in paper format were only made accessible to a certain group of people, usually within a department, while other groups of people could not access the information. This format also posed a challenge to transmitting a flow of information, for example when transmitting customer requirements via sales to the design/ development department. With pdf documents, this challenge has been minimized, as standards may have become accessible to multiple areas since they were made available in pdf format.

A number of requirements arise in the workflow process, namely to research the relevant, applicable documents or to check the customer specifications for the use of standards, to obtain the entire documents involved (with a surplus of information that should not be underestimated), to read the documents and extract the relevant information, and finally, to combine such information sensibly. Behind and between each of these named process steps is the risk of an "information transfer error", which can affect the entire process chain and thus a product in all its facets (safety, security, performance, costs and, therefore, market acceptance).

Workflow process Smart Standard

To uncover the weaknesses of an existing system, an analysis of the most common processes in practice is required. As the term "process" suggests, in most cases this involves a sequence of interlinked process steps that are mapped holistically via a process chain. For entire processes it is common to stagnate if one link in the chain does not function correctly (e.g. lack of competence, lack of resources, etc.) and produces errors or even gaps in the flow of information (e.g. due to overload). It is therefore easy to understand that the subsequent steps (sub-processes) themselves are no longer functional, which can then lead to considerable monetary or liability risks for a company.

Digitalization within the framework of Smart Standards can provide a remedy here by providing the impetus for changing a process landscape. As part of the rough outline of the application processes of standards, a comparison between the use of pdf and Smart Standards (from level 3 onwards) reveals that there exist both sequential and parallel processes (see Figures A.1 and A.2). This means that a decoupling between the individual sub-processes takes place, and this can be maintained in parallel up to a certain degree of fulfilment. The flow of information no longer takes place in a chain but is controlled promptly at the beginning of a sub-process or in its planning. Thus, various co-dependencies are partially or even wholly eliminated.

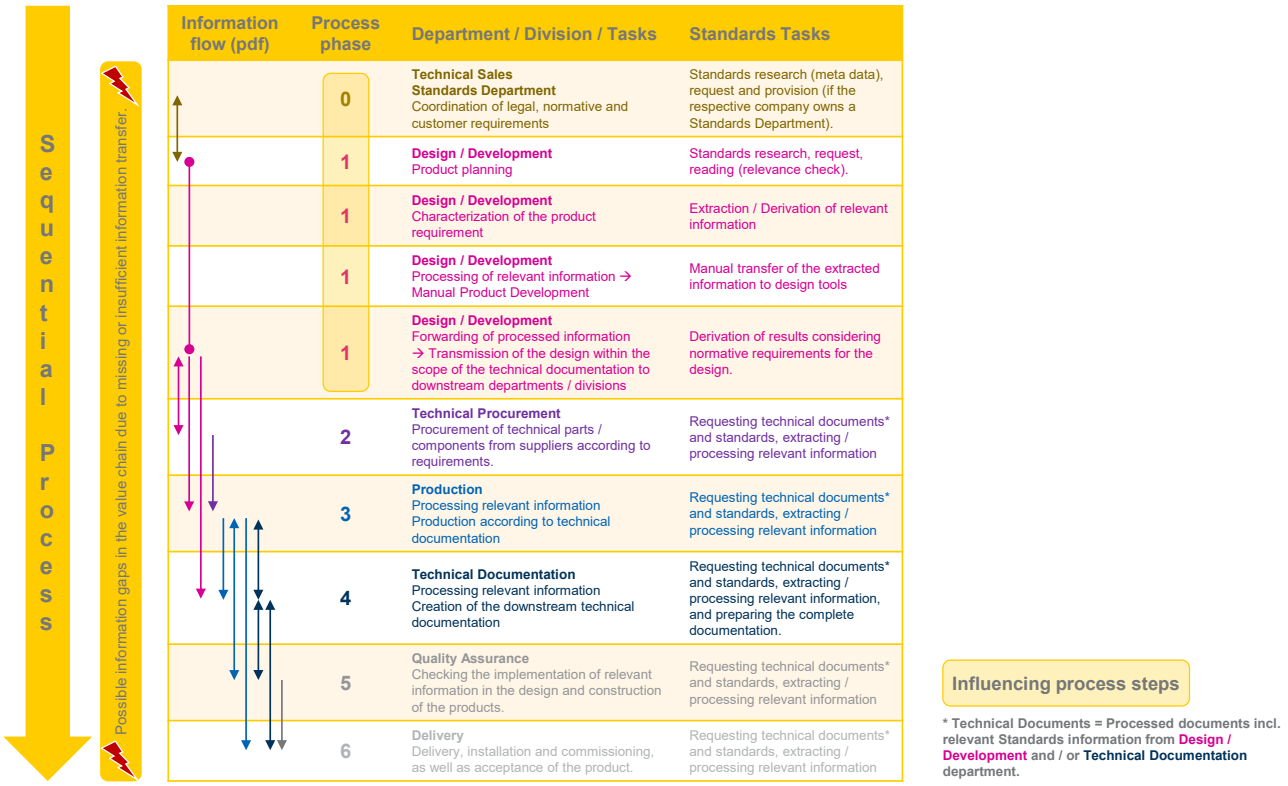

Figure A.1 | Information flow (pdf) within a product development and manufacturing process (Raymond Puppan – DKE)

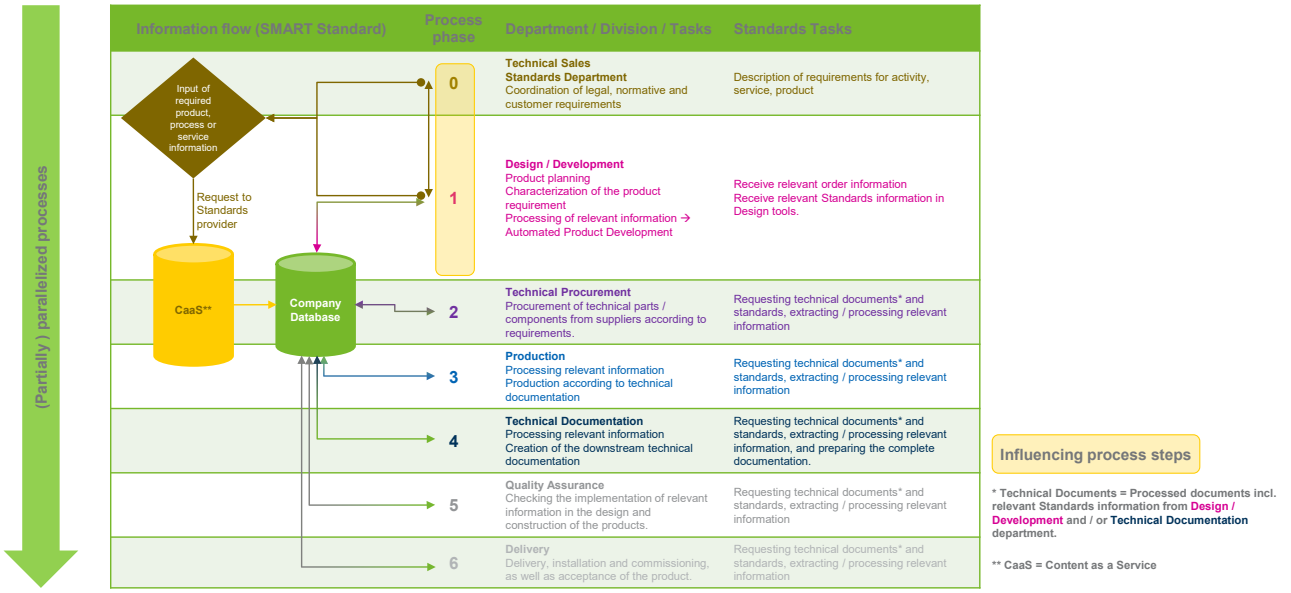

Figure A.2 | Information flow (Smart) within a product development and manufacturing process (Raymond Puppan – DKE)

A.2 Measuring the benefits of Smart Standards

For this purpose, a Smart Standards value-added model has been developed at IDiS (DIN/DKE), which will provide information about measurability, considering performance, risk and future value based on different aggregation levels. The benefits of Smart Standards must be visible, thus measurable. This approach forms the basis for the development of the Smart Standards value-added model.

From the point of view of the application of standards in business processes, the experience with the previous use of standards over decades (established processes) can be compared with that of the future, if answers to the following questions come from industry and the market. In undertaking such a comparison, support as well as core processes must be considered holistically:

1. What influence do Smart Standards have on my processes/process landscape?
2. What impact do Smart Standards have on my products over their entire lifecycle?
3. How does working with Smart Standards affect the key performance indicators of the company?
4. How do Smart Standards affect my (corporate) organization itself?

The questions were described in figurative language using a cube model to satisfy the multi-dimensional alternatives of examination. The basis for this was the idea that pdf standards contain information sorted into sections but are not available in sorted form for corporate workflow processes. Using Rubik's Cube as a template, it can be shown that Smart Standards have self-contained, assignable units of information that are tailored for the respective application step (see Figure A.3).

With the help of this consideration, three value categories were derived, which incorporate the different value examination alternatives of the total

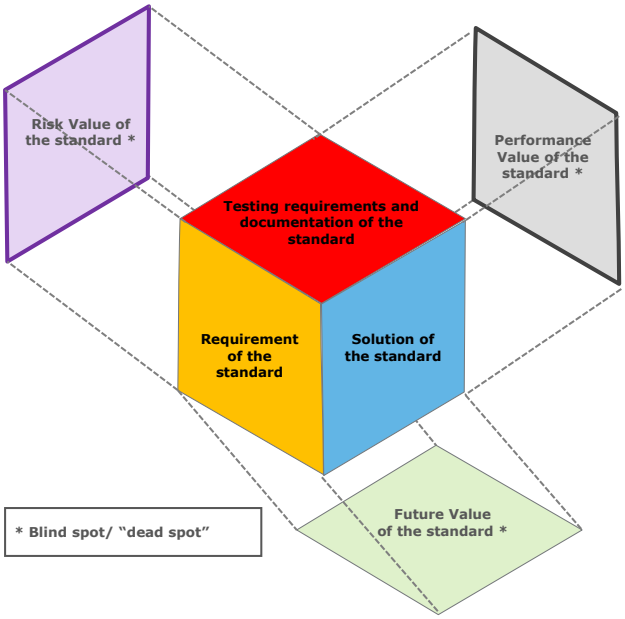

Figure A.3 | "Rubik's Cube" as the basis for the value-added model (Stefanie Voit – TS.advisory GbR, Raymond Puppan – DKE)

cube (Smart Standards) and the control criteria as partial cubes, and were described as aggregation level 1 of a Smart Standards value-added model as follows (see Figure A.4):

1. Performance value
2. Risk value
3. Future value

Approach in the value-added model (see Figure A.5):

- The partial cubes in the value-added model illustrate the control criteria (level 1).
- Every control criterion is split into control parameters depending on the value categories (level 2).
- Measurement indicators (level 3) are determined by control parameters.
- Quantitative indices (level 4) are determined by measurement indicator.

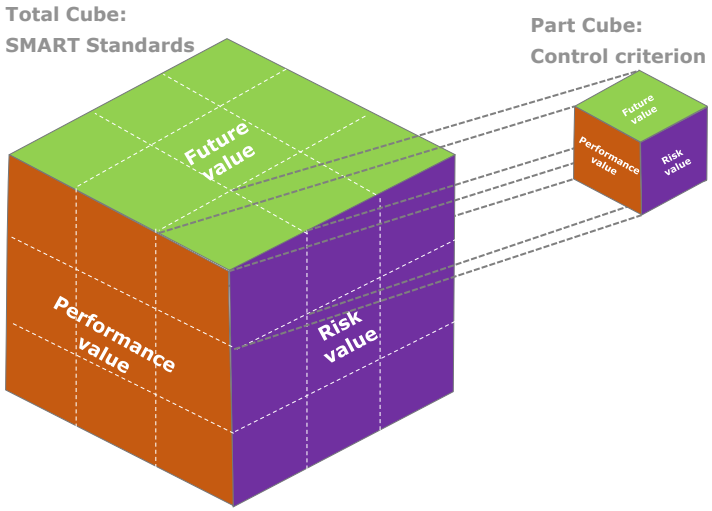

Figure A.4 | Total cube – Smart Standards value expression (Stefanie Voit – TS.advisory GbR, Raymond Puppan – DKE)

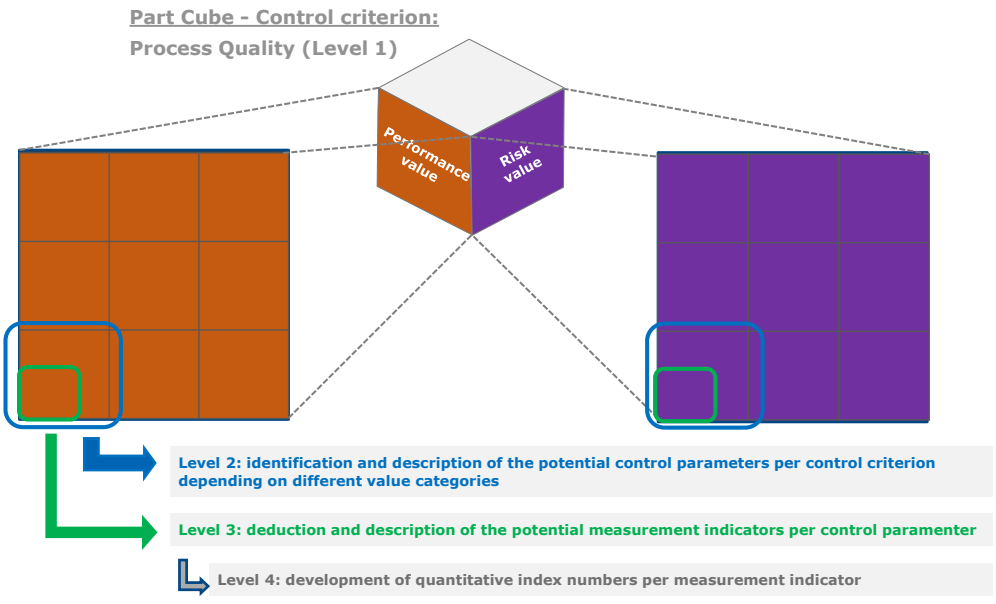

Figure A.5 | Partial cube – control criteria (Stefanie Voit – TS.advisory GbR)

With the structure of the value-added model, it became relevant to design matching future scenarios. This was then defined in coordination with the 11 ISO/IEC generic user stories (GUS) for specific use cases, and typical process flows in the companies were considered in their characteristics. In this way, the respective impact of the application of Smart Standards could be determined regarding process quality, product quality, revenue potential, and impact on personnel/the organization (control criteria, Step 1). To achieve the highest possible degree of accuracy, while at the same time ensuring a high degree of dispersion, various questionnaires were developed for companies to obtain the most precise information possible on current and future processes for using standards, so that adequate comparative values can be obtained. Tables A.1 to A.3 show how this worked out from the top-level model (Table A.1) through detailed parametrization (Table A.2) and part of the associated questionnaire to industry sectors and industry (Table A.3).

Table A.1 | Top level value model with direct and indirect influencing variables

Level 1 – Control criterion	Process quality	Product quality	Revenue potential	Personnel/ Organization
Value added effect	Direct	Direct	Indirect	Indirect
Level 2 – Control parameters				
Performance value	Standardization/increased efficiency in the development and manufacturing process	Product safety (Conformity to standards)	Increasing/securing the earnings potential per order	Capacity control/deployment of skilled workers
	Acceleration of the development and production process	Degree of fulfillment of customer requirements (customer satisfaction)	Increasing/securing the earnings potential of the business area/company	Know-how monopolies (“bottleneck issue”)
				Satisfaction/Acceptance/ Reponsibility
Risk value	Legal certainty in the identification of standards			
	Legal certainty in the implementation of standards			
Future value		Added value from a customer perspective	Future viability/ transformation	
		Feedback loop Standards development		

Table A.2 | Parameterization of measurable influencing variables for process quality

Level 1 – Control criterion	Level 2 – Control parameters	Level 3 – Measuring indicator	Level 4 – Key figure
Process quality			
Performance value	Standardization/efficiency increase in the development and manufacturing process	Time spent on standards application activities per job (TIME)	▪ Number of work/project days spent ▪ Costs = number of project days x calculatory personnel cost rate per day
Effect through Smart Standards	Reduction of time spent on standards application activities	Comparison of time required with and without the use of Smart Standards	
Stakeholder		▪ EB = Executive Board/Board of Directors (aggregation level: companies as a whole) ▪ BU-M = Management of Business units (aggregation level: Business unit) ▪ OM = Order/Contract Manager (aggregation level: individual order) ▪ OP = Employee/workplace (aggregation level: individual)	
Indicator evaluation		▪ P = Performance indicator (contribution to operational or short-term target achievement): - Guarantee of time specifications in the individual order ▪ B = Basic indicator (contribution to strategic or long-term target achievement) ▪ M = Motivation indicator (contribution to identity development): - No more justification for exceedeing time limits - Reduction of deadline pressure, overtime, etc.	

Table A.3 | (Part of) questionnaire for economic data gathering associated with process quality

Headline	Basic questions	Details	Calculation/indicator
Process quality	Time spent on activities for the application of standards without Smart Standards (actual figures) and with Smart Standards (estimates)	▪ Total number of work/project days spent on standards application ▪ Imputed personnel cost rate per day	Cost of standards application = number of project days for standards application x imputed cost rate per day
	Total costs for activities related to the aplication of standards in each case without Smart Standards (actual figures) and with Smart Standards (estimates)	▪ Personnel costs for activities related to the application of standards (direct costs) ▪ Material costs for the acquisition of the relevant standards in pdf compared to the license costs for tool-supported processing (direct costs) ▪ Follow-up personnel and material costs for complaints and rectifications (indirect costs) ▪ Total cost p.a., p.m., p.q. ▪ Renenue p.a., p.m., p.q.	Total cost of standard application in relation to turnover (p.a., p.m., p.q.)
	Production time from order receipt to delivery without Smart Standards (actual figures) and with Smart Standards (estimated values)	▪ Total number of work/project days spent	Cost of standard application = total number of project days x imputed cost rate per day

Note: p.a. = per anno (year), p.m. = per month, p.q. = per quarter

A.3 Findings and conclusions

With Smart Standards, sub-processes can be parallelized in some places, which will lead to time and resource savings potential by accelerating processes. This has relevant effects on process quality, product quality, revenue potential, and personnel/organization. The latter can be seen in the context of an example: by relieving the design/development departments in companies, annoying research and manual follow-up activities no longer arise, which in turn can create free space to expand the product range of a company and motivate employees to work closer to their core activities. To move beyond anecdotal benefits for Smart Standards, a rigorous economic measurement was designed to make the benefits tangible. The main report uses only the core measurement levels at aggregation level 1: performance value, risk value and future value. That suffices for the high-level approach in this report, but it is important to remember that it is part of a much larger economic model for Smart Standards developed in the IDiS project.

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