Standards in Disruptive Innovation

Assessment Method and Application to Cloud Computing

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Abstract

Standards define interoperability, portability, or security of products or services. They constitute the cornerstone of any distributed, open, and flexible system. The emergence of new technologies is typically followed by a high demand for standardization to counter lock-in effects or regulate markets. In the presence of disruptive innovations such as cloud computing existing technology, business, and legal frameworks only start to develop, turning the tasks of standards assessment into a challenge.

Outdated or wrong assessment are a logical consequence. Iterations of standards assessment are typically too costly as most of the work is carried out manually. Selecting the wrong standards can, however, increase cost, reduce market uptake and profitability, or lead to products or services being stuck in a niche. Selecting the right standards can result in as much as the exact opposite. Despite numerous efforts to create classifications of standards that should provide guidance for the selection of standards, there is a lack of approaches that provide a methodological foundation on how to assess standards in the context of disruptive innovation.

In this thesis, we propose a method for Assessing Standards of Emerging Technology (ASSET) that addresses the uncertainty of disruptive innovation, coordinates contributions of stakeholders and improves the efficiency of standards assessment through task automation. The method builds on a conceptual information model that defines the basic entities and their relationships that are required for standards assessment in any domain of disruptive innovation. ASSET defines a procedural model that guides standards assessment, including the instantiation of ASSET for a particular domain of disruptive innovation and stakeholder collaboration. The procedural model builds the foundation for the identification of automation support in standards assessment.

ASSET is grounded on experiences and learnings from designing and performing a comprehensive study to assess cloud standards in 2011. In this dissertation, we revisit the study's findings to validate ASSET's support for incorporating the uncertainty of disruptive innovation. We test ASSET's capabilities to improve the efficiency of standards assessment in disruptive innovation by discussing and analyzing our Proof-of-Concept (PoC) implementation of a service-based platform for standards assessment. We use the platform to create 20 digital standard profiles and perform case studies in automated cloud standards assessment to validate our approach. An outlook to the domain of Smart Grid provides first insights into validating ASSET's generalizability.

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I thank my families for loving me the way I am. You give me the strength and confidence to reach for the stars.

To Simone, for being my everything.

Karlsruhe, July 2015 *Robin Bühler*

Contents

Part I.

Foundations

1. Introduction

Standards define characteristics of products, processes or services and provide rules and guidelines for common and repeated use [56, 3.2]. They warrant product safety (e.g., CE marking), build the basis for interoperability (e.g., European Standard Gauge for railroads), or facilitate business interactions (e.g., IBAN, EDIFACT), for example. Moreover, standards allow for defining an unambiguous quality of products or services, using common characteristics, metrics, terminology, measurement units, or interfaces [29]. *Information and Communication Technology (ICT)* builds on the foundations of standards to provide connectivity (e.g., HTTP, TCP/IP or WSDL), facilitate data exchange (e.g., XML, SOAP, JSON), or ensure security (e.g., SSL or ISO 27001) of products or services [39]. In consequence, standards are a major factor in today's networked economies. Continuing macroeconomic studies estimate the contribution of standards to economic wealth at 0.3 to 1.0 percent of annual gross national products [67]. The economic benefits of standardization in Germany were valued to be approximately €19,23 billion in 2014 prices.[1] The values of standards for a given product or service, however, are driven by network effects (e.g., economies of scale) and depend on the field of application [51, 192].

Standards, thus, have to be used in products, services, laws, or regulations to come into effect. Private organizations may use standards strategically to set market rules or delimit barriers to market entry. They may inhibit competitors from entering a market by pushing for standards that require, for example, licensing of particular—potentially self-owned—patents as a strategic tool [176]. Also, they may seek to reduce competitive advantages of competitors by contributing to and pushing for the standardization of particular markets [182]. Therefore, they have to find standards that are relevant for their product or service in a given market. Likewise, policy makers such as the government or regulatory agencies are required to evaluate standards when setting legal and regulatory frameworks to ensure consumer safety or fair competition in open markets, for example [67]. Standards assessment, therefore, has to support decisions on different levels, addressing information needs of strategical an operational decisions.

1.1. Motivation

The goal of this work is to support standards assessment in *disruptive innovation*. While incremental innovations lead to step-wise performance improvements, *disruptive innovation* typically starts in new markets that value novel dimensions of product or service per-

[1] According to Töpfer et al., standards accounted for 31.5 billion Deutschmark of the gross national product in 1998 prices [182, p. 28]. The value was updated to €16.77 billion for the years 2002 to 2006 in [25]. 2014 prices have been calculated using historical data on inflation rates from `http://www.finanz-tools.de/inflationsrechner-preissteigerung.php`.

formance [30, 91]. Due to rapid technological improvements and steep performance trajectories, disruptive innovations may eventually replace existing markets [9, 41]. Emerging markets of disruptive innovations are, thus, characterized by a novel and instable interplay of technological, business, and legal aspects, presenting an open challenge to standards assessment.

In disruptive innovation *uncertainty* is ubiquitous [179], embracing unclear market structures, open battles for technology dominance, or vague consumer requirements [81]. Standards provide value in a defined context [56]. The uncertainty of disruptive innovation, thus, leads to situations where standards are effectively missing, due to the indeterminate applicability of standards. Absence of standards, in turn, leads to economic inefficiency, because of over verification of products or services [176], missing trust of consumers in the quality of goods and services [26], and lack of solution compatibility [157]. Low acceptance of disruptive technologies with potential users and slow uptake of the innovation by the market are immediate consequences [111]. Thus, providers and customers of emerging and incumbent technology, but also public authorities, demand for standards to counter the inefficiencies of managing disruptive innovation [68, 119, 157]. Creating trust, fastening market uptake, and guiding technology evolution with the help of standards, however, requires means to assess the needs and capabilities of standards in the presence of an evolving environment. Consequently, standards assessment methods and tools are required that interface with existing management approaches that incorporate the uncertainty of disruptive innovation [50].

The work presented in this thesis is based on research on standards assessment in the domain of *cloud computing*. The emergence of cloud computing and the shift towards providing and consuming services over the Web are an example of ICT-based disruptive innovation [125]. With cloud computing, new markets for on-demand network services at the infrastructure, platform, and application level have emerged. They fundamentally change the traditional model of self-hosted, self-owned IT solutions [16]. Alike, new value networks evolve, comprising new organizations such as Amazon Web Services (AWS), Google, or Salesforce.com, providing services at an unprecedented convenience. Picturing the uncertainty characteristic of disruptive innovation, customers of incumbent hosting providers argument for data consistency risks and security concerns [61]. Thus, they value performance in traditional attributes more than promises of increased availability and reduced costs that are provided by cloud-based systems [62]. While cloud computing quickly attained adopters, it is said to not leverage its full potential [68].

The lack of standards and its consequences for disruptive innovation (i.e., missing trust, quality, compatibility, security, and comparability) are main obstacles that hinder an even stronger adoption of cloud services [111, 27, 67]. Thus, significant efforts were conducted to assess standards and standardization activities for cloud computing: Regional and national governments (e.g., European Union [64], USA [97], Germany [20], and Japan [166]), standards development organizations (e.g., IETF [115], ITU [107]) and industry (e.g., NTT [154], CSA [45], EuroCloud [65]) conducted or sponsored respective studies. Whereas the results provide a broad picture of standards and standardization activities in general, results cannot be compared easily. Reasons are incompatible taxonomies and different methodologies that aim at fulfilling the respective needs of the varying sponsors. Moreover, the validity of results is challenged by the changing environment of disruptive innovation. Taxonomies that have been applied while conducting a study might, for example, already be outdated as technologies, use cases, market players, or legal and regulatory frameworks have evolved at the time of publishing results. Perpetuation of results is, however, too costly as standards assessment studies are typically done manually. Besides, procedures that are applied to perform studies are not designed for repeated standards assessment, as studies are typically tendered as one-time projects. Final reports summarize information according to the specific goals of respective studies. In doing so, they typically provide an overview of existing standards. However, little guidance on how to assess the suitability of standards for a given research project is given.

Research has long neglected the benefits of standards as a means to reduce uncertainty [108]. The majority of standardization research is, still, devoted to researching economic values of standards to understand their use and to realize maximum economic utility with standards [192, 176, 51]. Little research is, however, conducted that focuses on standards assessment methods to support the management of disruptive innovation. Methodologies, frameworks, and tools, which help standards developers, standards users, or policy makers with assessing standards are few. Existing works are too specific for a particular technology or domain of application or do not incorporate the uncertainty of disruptive innovation (e.g., [139, 93, 180]). Practical approaches for standards assessment describe informal procedures on how to select standards in engineering projects. In [53], for example, a generic procedural model is introduced. However, scientific and methodological foundations that provide replicable results are missing. Standards Development Organizations (SDOs) have also identified the need to assist standards users with evaluating standards. Existing tools to support the selection of standards, e.g., provided by International Organization for Standardization (ISO) or Deutsches Institut für Normung (DIN) are limited to search online collections of standards documents and supporting material.

In this thesis, we generalize a method for Assessing Standards of Emerging Technology (ASSET) that incorporates the uncertainty of disruptive innovation, coordinates contributions of stakeholders and improves the efficiency of standards assessment by task automation. The method is grounded on experiences and learnings from a comprehensive study to assess standards in cloud computing that enables a qualitative validation of ASSET's comprehensiveness. We will discuss extensions to the study's results, demonstrating ASSET's support for incorporating the uncertainty of disruptive innovation. Finally, we validate ASSET's capabilities to improve the efficiency of standards assessment in disruptive innovation, implementing a Proof-of-Concept (PoC) software prototype. We perform case studies in cloud standards assessment to validate our approach. Performing an additional case study of standards assessment in the domain of Smart Grid, we validate ASSET's generalizability.

1.2. Hypotheses & Contributions

In this work, we focus on supporting stakeholders of disruptive innovation in assessing standards. Assessment involves classification and evaluation. Classification comprises the (collaborative) definition of standards profiles. Standards evaluation comprises the selection of standards for a given product or service development project as well as the analysis of a portfolio of standards to support strategical decisions.

Our research aims to confirm two hypotheses that target enablement (see Hypothesis 1) and efficiency (see Hypothesis 2) of standards assessment:

Hypothesis 1
A conceptual information model for standards assessment in disruptive innovation enables information reuse and collaboration among stakeholders.

Hypothesis 2
A structured assessment process allows for coordinating iterative execution of assessment steps and for improving efficiency by task automation.

We will develop a *conceptual information model* to identify and structure the required information. Complementing the conceptual information model, we will design our method to orchestrate the necessary assessment steps. ASSET comprises a model of stakeholders and process models to coordinate assessment steps among the stakeholders. In doing so, ASSET provides the foundations to automate standards assessments in disruptive innovation and to reduce efforts of standards assessments based on information reuse and collaboration among stakeholders.

In detail, the following artifacts will be developed:

(a) *Conceptual information model for standards assessment:*

Reusing assessment information and collaboration among stakeholders are keys to reducing efforts in standards assessment. We develop a conceptual information model that represents required information at the level of entity types. The model defines modularity of information, supporting stakeholder-specific contributions and information filtering. Next to modularity of information, the conceptual information model provides support for aggregating varying stakeholder contributions. The model, thus, provides the foundations for standards profiles that are updated periodically as the technology progresses.

(b) *Model of stakeholders:*

The stakeholder model conceptualizes the needs and capabilities of stakeholders that assess standards of emerging technology in disruptive innovation. ASSET's stakeholder model, therefore, classifies stakeholders into five types. Also, the stakeholder may apply four standards-specific roles and an undefined set of domain-specific roles to model different perspectives of standards assessment. Each role, thereby, summarizes a stakeholder's needs and interests in standards assessment and its influences on standardization.

(c) *Procedural model for standards assessment:*

A domain-specific information model must be instantiated for a given domain of disruptive innovation. Instantiation requires the definition of the innovation's technology framework as well as the identification of domain-specific assessment attributes and stakeholder roles. ASSET's procedural model defines a process to support the creation of a domain-specific technology typology, i.e., an instantiation of the conceptual information model.

Moreover, ASSET's procedural model guides stakeholders in valuing a standard's attributes in a way that coordinates contributions from different stakeholders. It respects the type of the standard that is to be classified and the set of information that a particular stakeholder is capable of contributing. As motivated above, disruptive innovation and, thus, standards assessment in disruptive innovation is dynamic. ASSET's procedural model, therefore, defines events for coordinating iterative executions its sub-processes.

The classification of standards results in the generation of standards profiles. The final step of assessing standards, therefore, is to evaluate these profiles for a given purpose. ASSET provides processes that allow stakeholders to select standards or roadmap standardization activities. The processes build on the set of available standards profiles. Moreover, they define steps that are required to configure sub-typologies to find standards profiles that match the situation at hand.

The application of ASSET to cloud computing allows for examining its validity. Moreover, its conceptual application to Smart Grid enables the validation of ASSET's generalizability to another domain of disruptive innovation.

Performing a PoC, our implementation of ASSET into a software prototype for standards assessment allows for validating the realizability of task automation and, thus, improvements in the efficiency of standards assessment in disruptive innovation. Providing the basis for the validation of ASSET's automation support, we codify the information that is represented by the 20 *cloud standards profiles* of our cloud standards study into the database of the Cloud Standards Assessment Platform (CSAP). Therefore, we also codify a *cloud technology typology* that implements the technology framework, roles, and assessment attributes for assessing standards in cloud computing. In doing so, we provide further evidence on the suitability of our conceptual information model. The concept of the assessment platform and automation services are, however, not specific to cloud computing. CSAP could, thus, be used to assess standards in other domains of disruptive innovation.

In summary, this dissertation contributes to the body of knowledge in technology and innovation management and standardization research. It, moreover, contributes to the field of cloud computing research and provides practical solutions for building a community for cloud standards assessment.

1.3. Research Approach

The research method applied in this thesis is governed by *Design Science* [96, 95]. More precisely, the research applies principles of *Action Design Research (ADR)* [160].

ADR applies an iterative model to create research artifacts. Based on an initial *problem formulation*, research artifacts are *build* and, thereafter, undergo a set of *evaluations*. The goal of these evaluations is to *intervene* the artifacts with the problem to be addressed. Researchers, thereby, *learn* how well research artifacts solve the problem. Based on these findings, researchers *reflect* their proposed solution approach and, consequently, add additional or remove impractical solution features. Evaluations may also result in the reformulation of the initial problem, as the understanding of the research subject is steadily extended. The learnings are *formalized* as soon as the evaluations indicate an adequate solution to the formulated problem. ADR involves varying user involvements. Thus, different phases of the research process should engage different user groups. The degree and the moment of involving a particular user group are defined by the type of research artifact that is developed. Performing an early evaluation of research artifacts, we apply an IT-dominant design in this work (see [160]).

Figure 1.1 illustrates the applied sequence of research phases. The research process comprises six sequential steps, constituting two cyclic phases: In Phase 1 (Steps 1 to 3) we conducted a study of standards and standardization activities in cloud computing. We reflected learnings, built ASSET and evaluated ASSET, and formalized the results in Phase 2 (Steps 4 to 6). We will summarize activities and contributions of each step in the following:

- *Step 1 – Specify Problem:*

  We developed a first problem formulation for assessing standards in cloud computing in Step 1. Therefore, we designed a study for the assessment of cloud standards involving experts of cloud standards. Based on the creation of a view on the portfolio of available standards, the assessment was to provide support for selecting

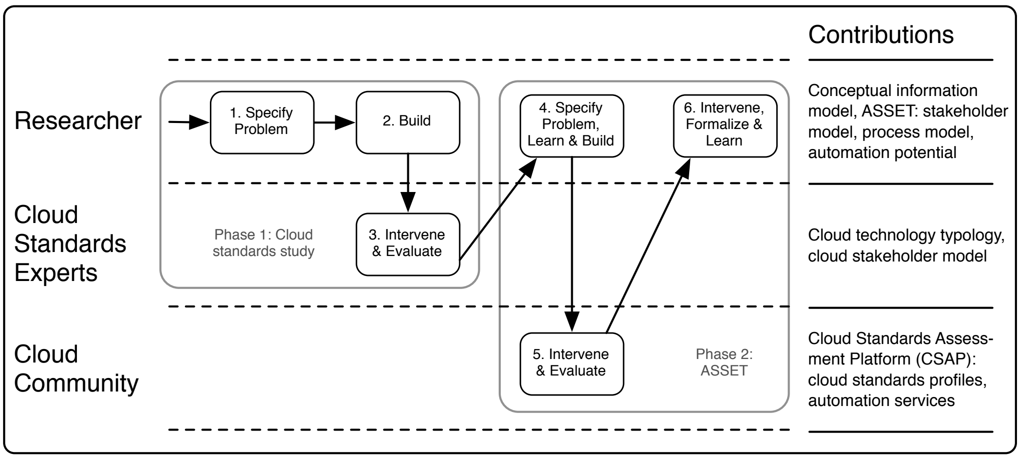


Figure 1.1.: Research Procedure

standards for cloud service development projects and for prioritizing next steps in cloud standardization.

- *Step 2 – Build:*

  The researcher designed the first version of the solution to assess standards in cloud computing in Step 2. Therefore, we designed a taxonomy for classifying cloud standards, comprising challenges and fields of standardization. The taxonomy has been identified by reviewing state-of-the-art publications on the state of cloud computing. Next to challenges and standards fields, a set of general aspects of cloud computing and standardization was used to refine the classification of cloud standards. Stakeholders of cloud standards were classified using a simple stakeholder model. We performed the initial classification of standards in an ad-hoc and unformalized process. Classification of standards involved screening documents (e.g., draft specifications) using keywords (e.g., protocol, interface, or data format). Likewise, we inferred classification of a standard according to challenges. The initial solution did not formalize the process to evaluate standards for a given cloud service engineering project.

- *Step 3 – Intervene & Evaluate:*

  We used questionnaires to evaluate the results of assessing standards of the initial approach with practitioners in this step. Experts of 14 pilot projects of the German Trusted Cloud technology research program were, therefore, asked to evaluate the relevance of identified challenges and standards fields for cloud computing. We, furthermore, evaluated the results of assessing standards in a series of face-to-face workshops with the named 14 projects. A final evaluation of our results was performed in a workshop with more than 50 cloud standards experts. The research method, its results, and respective evaluations have been published in [20] and [75].

- *Step 4 – Specify Problem, Learn & Build:*

  Based on the experiences of conducting the cloud standards study, we generalized learnings and reformulated the problem of assessing standards in disruptive innovation in Step 4. We identified currency as a particular issue for cloud standards assessment. Countering obsolescence with frequent updates of standards assessment, however, requires methodological support to coordinate assessment efforts. We designed a conceptual information model and ASSET to address this need.

- *Step 5 - Intervene & Evaluate:*

  Assessing the relevance and realizability, we applied ASSET to the field of cloud computing in Step 5. Therefore, we instantiated the conceptual information model and created a cloud standards typology. Moreover, we implemented CSAP, applying a PoC-approach. We used the software prototype to verify the identified potentials for automation of the assessment process. Results of ASSET's application to cloud computing have been published in [76, 74]. Moreover, results of our PoC are published in [35].

- *Step 6 - Intervene, Formalize & Learn:*

  Reflecting the final learnings, we formalized our method for standards assessment in disruptive innovation while preparing this thesis in Step 6. Thereby, we applied ASSET to the domain of Smart Grid, verifying the generalizability of ASSET to other domains of disruptive innovation.

Table 1.1 describes the evolution of research artifacts, comparing intermediate and final results side-by-side. As depicted, the research artifacts—i.e., constructs, models, and methods—matured through the cyclical research process until the completion of this dissertation thesis. The generalization of the method lead to adaptations and enhancements and resulted in redesigns, a common occurrence in design science research [184, 49].

Aspect	*Cloud Standards Study*	*ASSET*
Problem	Cloud standardization snapshot	Efficient standards assessment
Evaluation User Group	Standards experts	Communities*
Typology Concept	Challenges, standards fields (fixed)	Technologies, technology fields, and standards fields
Classification Attributes	Fixed†	Customizable domain- and standards-specific‡
Stakeholder Model	Simple	Modular
Assessment Process	Ad-hoc	Structured

* The evaluation was limited on validating ASSET in the domain of cloud computing and by testing transferability to other domains of disruptive innovation.

† Attributes are categorized into *basic*, *applicability*, and *assessment* attributes.

‡ Using attributes of the types *descriptive*, *applicability*, and *interpretative*.

Table 1.1.: Comparison of Research Artifacts

1.4. Structure of this Dissertation

Figure 1.2 illustrates the structure of this dissertation thesis, comprising ten chapters in four parts. We will briefly outline each part in the following.

Part I presents the foundations of this dissertation thesis. Chapter 1 introduces the problem of assessing standards in disruptive innovation, its decomposition into a research problem as well as the outline of the research process. Chapter 2 introduces relevant backgrounds. Section 2.1 summarizes the foundations of standards and standardization to set an understanding of economic and technical values, stakeholders of standards, different types of standards, and general approaches to standards assessment. Section 2.2

introduces the backgrounds on disruptive innovation, concepts of technology and innovation management and related assessment methods. Section 2.3 provides a characterization of cloud computing as a disruptive innovation, its basic principles, an approach to manage cloud services, and a summary of the value of standards in cloud computing. Section 2.4 summarizes the importance of assessing standards of emerging technology in disruptive innovation. The positioning of this dissertation thesis in the context of existing work is discussed in Chapter 3.

Part II presents the engineering of ASSET. We present core aspects of our cloud standards study in Chapter 4. Section 4.1 outlines the goals and the approach of the study. Selected

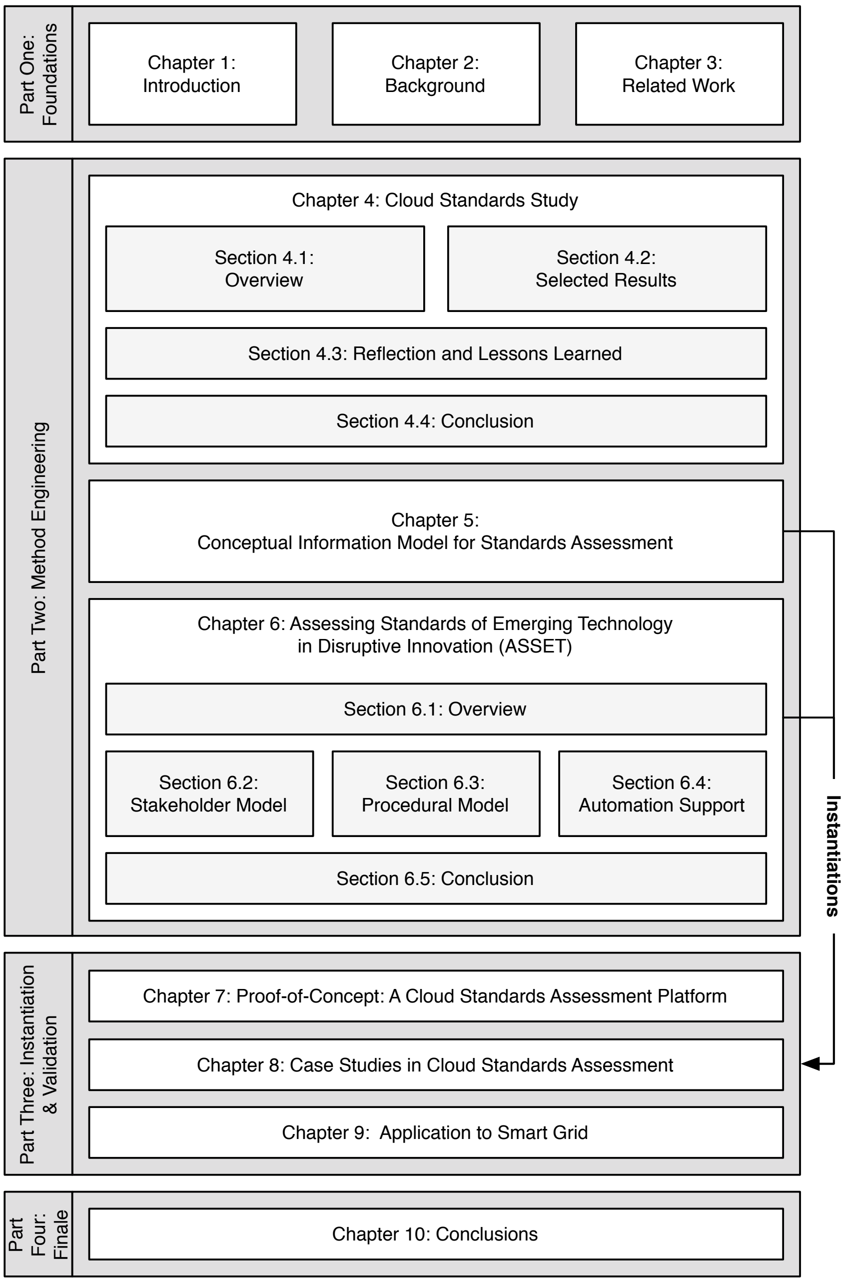


Figure 1.2.: Thesis Structure

results of the study are presented in Section 4.2. Based on the learnings from the study, we derive requirements for a method to support the assessment of standards in disruptive innovation in Section 4.3. Section 4.4 concludes the chapter's results. Chapter 5 presents our conceptual information model for standards assessment in disruptive innovation. Section 5.1 introduces our conceptualization of the problem. Sections 5.2 to 5.7 introduce the model's entities and their relationships. Section 5.8 discusses the contributions of the conceptual information model to provide the required method features. Chapter 6 introduces ASSET, beginning with an overview in Section 6.1. Section 6.2 presents ASSET's stakeholder model. Section 6.3 introduces the procedural model for assessing standards of emerging technology in disruptive innovation. Potentials for automation of assessment efforts are discussed in Section 6.4. Section 6.5 concludes ASSET's contributions.

Part III presents ASSET's instantiation and validation. Chapter 7 summarizes the efforts of implementing a proof-of-concept prototype to realize ASSET's automation support for cloud standards assessment. The validation of Hypothesis 2, thus, is the scope of this chapter. Section 7.1 presents the preliminaries, a software architecture, and technical details of CSAP. A discussion on the realizability of ASSET's basic assessment functionality is presented in Section 7.2. Section 7.3 provides details on the implementation of automation potentials. Finally, Section 7.4 concludes the results of validating ASSET's assessment functionalities and automation support. Chapter 8 presents case studies of standards assessment with ASSET. Section 8.1 presents the cloud-specific instantiation of ASSET's technology typology. Likewise, Section 8.2 and Section 8.3 presents case studies, validating the conceptual information model. The case study presented in Section 8.4 comprises a small experiment to assess cloud virtualization standards collaboratively. Section 8.5 completes this chapter by concluding ASSET's capability to reproduce the study's results. Chapter 8, thus, provides a validation of Hypothesis 1. Chapter 9 discusses the generalizabilty of ASSET. In Section 9.1, we introduce Smart Grid as another domain of disruptive innovation. In Section 9.2, we provide an outlook to validating the instantiation of a Smart Grid technology typology based on existing standards assessment works. We present additional aspects of classifying Smart Grid standards with ASSET in Section 9.3. Section 9.4 concludes the result of ASSET's application to Smart Grid.

Part IV presents final considerations of this thesis. Chapter 10 completes this dissertation thesis. Section 10.1 summarizes main contributions. Section 10.2 discusses the results in the context of our hypotheses. Section 10.3 suggests areas of future work.

2. Background

Standardization, technology management, disruptive innovation, and more specifically cloud computing constitute the fundamentals of this thesis. Figure 2.1 summarizes the corresponding fields of research. We apply theory, artifacts, and concepts from these fields to build our method for Assessing Standards of Emerging Technology (ASSET) and supporting tools. In this chapter, we will introduce the research context of this thesis. In doing so, the required background for transferring existing knowledge into new contexts is given.

Section 2.1 introduces *standardization* and general concepts of *standards*, introducing state-of-the art in standardization research. The values that standards provide will be discussed in Section 2.1.1. Values of standards, however, are subjective, i.e., depend on the type of a particular stakeholder. Section 2.1.2, consequently, presents different models to classify stakeholders of standards. Foundations on different types of standards will be introduced in Section 2.1.3. Based on the previous aspects, an introduction to assessment of standards is given in Section 2.1.4.

In Section 2.2, we will discuss technology and innovation management approaches in the context of disruptive innovation. We will introduce the concepts of *disruptive innovation* as a source for technology evolution in Section 2.2.1. Section 2.2.2, thereafter, discusses approaches for technology and innovation management. Section 2.2.3 will, finally, discuss related methods for technology assessment.

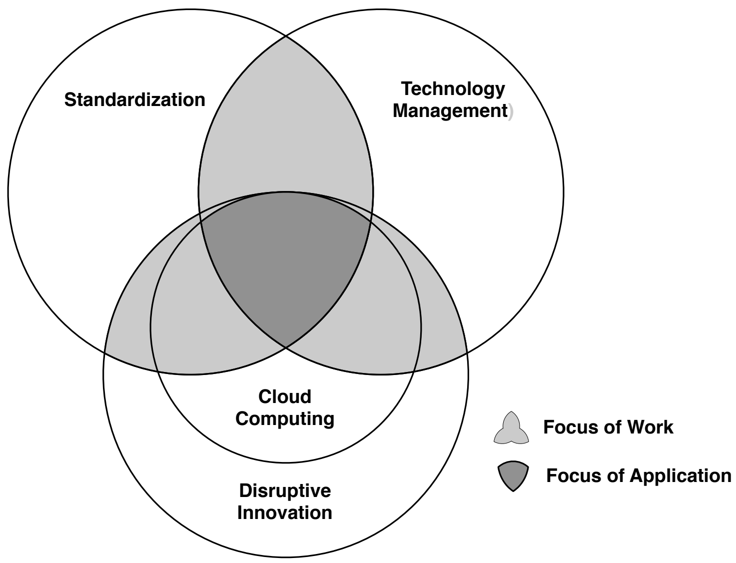


Figure 2.1.: Related Fields of Research

Section 2.3 will introduce *cloud computing* as a domain of disruptive innovation. Section 2.3.1, therefore, presents the basic principles of cloud computing and discusses services that it provides to the market. Subsequently, tasks and perspectives of managing cloud services will be presented in Section 2.3.2. Thereby, we will discuss potential values of standards for managing cloud services.

In this thesis, we aim to bridge technology assessment capabilities to the field of standardizing disruptive innovation, i.e., develop corresponding standards assessment capabilities. Section 2.4 will, therefore, summarize research challenges of method and tool support for standards assessment at the intersections of standardization, technology management, and disruptive innovation. Particular challenges of assessing cloud standards, thus, are to be located at the intersections of standardizations, technology management, and cloud computing (see Figure 2.1).

2.1. Standardization

Definitions of standardization and standards stem from a variety of sources. In summary, they do not clearly distinguish characteristics of standardization from those of standards. In the following, we touch on key aspects of corresponding definitions to illustrate the major viewpoints on standardization and standards. After that, we will derive the definitions of standardization and standards that we will apply throughout this thesis.

Standardization refers to the process of establishing standards. In general, standardization involves conceptualization, discussion, writing, and implementation of standards [39, p. 60]. Actual implementations of a standard, however, are seen required constituent for successful standardization in the long term [110].

Two types of standards setting processes are to be distinguished. *Internal standardization*, on the one hand, addresses the creation of a process "to enhance the use of corporate resources" [39, p. 59]. *External standardization*, on the other hand, is the task of "establishing, with regard to actual or potential problems, provisions for common and repeated use, aimed at the achievement of the optimum degree of order in a given context" [56, 1.1]. Transparency, openness, impartiality and consensus, effectiveness and relevance, and coherence are core principles of external standardization [195]. External and internal standardization provide an overlap, where stakeholders' motivations for external or internal standardization constitute a trade-off [51]. Individual organizations may choose whether internal standardization is sufficient or external accreditation should be pursued according to the benefits that they seek to realize in a given period. Processes for external standardization are formally defined by Standards Development Organizations (SDOs). They typically require consensus among all participants and, thus, tend to have lengthy development cycles [106]. Internal standardization yields quicker results and may still lead to external standardization if, for example, the respective products or services gain market dominance [190].

De Vries provides a scientific definition of standardization:

> "Standardization is the activity of establishing and recording a limited set of solutions to actual or potential matching problems, directed at benefits for the party or parties involved, balancing their needs and intending and expecting that these solutions will be repeatedly or continuously used, during a certain period, by a substantial number of the parties for whom they are meant." [51, p. 13]

Incorporating individual benefits as the motivation for standardization allows for spanning both types of standardization. Also, the definition emphasizes balancing of needs (i.e., consensus and coordination) and repeated and actual use for a given time. The notion of a matching problem, however, remains abstract, referring to any issue that could arise between two or more related entities (e.g., "a person, object, event, idea, process, etc." [51, p. 14]).

The International Organization for Standardization (ISO) defines a *standard* to be a "document, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context" [56, 3.2]. The definition emphasizes the need of a standard to be a document that is approved by a recognized or accepted body, providing rules, guidelines, characteristics, or features for repeated use. At the same time, however, it comprises requirements for standardization, i.e. the process of creating standards. Likewise, standardization research provides a multitude of definitions for standards that include requirements for the standardization process (e.g., [39, 48, 51, 108, 176]). De Vries subsumes a scientific definition of standards:

> "It is an: approved specification of a limited set of solutions to actual or potential matching problems, prepared for the benefits of the party or parties involved, balancing their needs, and intended and expected to be used repeatedly or continuously, during a certain period, by a substantial number of the parties for whom they are meant." [52, p. 4]

As can be seen, de Vries' definitions of standardization and standards are identical in most parts. In consequence, they do not help in distinguishing characteristics of standards from the ones that are inherited from standardization. In the following, we will derive definitions that separate characteristics of standards from those of standardization to prepare the conceptualization of our assessment method.

Since motivations or benefits can be achieved on different levels (i.e., strategical, tactical, and operational, see for example [28]) and are specific to stakeholders, we refrain from including the motivation for standardization into our definition of standardization. Capturing motivations and benefits will, however, be a key aspect of our approach for standards assessment. Moreover, we do not require standardization to be always consensus oriented, i.e., allow for incorporating de-facto standardization.

> **Definition 1** (Standardization)
> *Standardization is the process of creating a standard or of developing products or services using standards.*

Simply put, standards are inputs and outputs of standardization. They address a given subject and applying varying means. ISO/Deutsches Institut für Normung (DIN) names activities or results of activities as potential *subjects of standards* and instructs standards to capture best-practices. This definition, thus, includes products, processes or services as subjects of standards. The *scope of standards* is limited to rules, guidelines, or characteristics. Likewise, the scientific definitions emphasize a defined subject and scope of standards. The abstract notion of a matching problem[2] provides little guidance on the identification of scopes of standards and, thus, hampers applying the definition above for building our method and corresponding tools. Likewise, demanding a substantial number of supporting parties tends to imply successful standardization. An approach to assessing standards, however, should involve measuring a standard's success and, thus, not require a substantial number of parties per se.

Focusing on the scope, the subject, and the parties that support or derive value from a standard, we, thus, derive the following definition for standards:

> **Definition 2** (Standard)
> *A standard is a specification of a limited set of solutions (scope) for a defined problem or a set of problems (subject) that is supported by a set of stakeholders, deriving individual values from repeated use during a certain period of time.*

In the following subsections, we will provide further details on the values of standards and the set of stakeholders that support and derive the values. After that, we will introduce different scopes and subjects of standards and, thereby, discuss different types of standards.

2.1.1. Value of Standards

Economies, industries, organizations, and individuals strive for standardization to realize economic and technical benefits. Standardization as performed by SDOs is to coordinate and harmonize varying solutions based on consensus [92]. It is also "driven by the needs of business to provide some degree of predictability" [39, p. 48] into markets, i.e., to reduce the uncertainty of technology progression. A standard's success, however, mainly depends on the willingness of organizations to implement a standard. A standard may be considered successful, if it achieved design dominance in a given market [173] or if it is applied by a dominant design [79] (see [71] for details). Successful standardization, thus, is to overcome the dilemma of standards development and standards diffusion [134].

Despite omnipresence of standards, research on theories, processes, and organizations driving standardization has long been disregarded [108]. Existing economic research frequently applies market models to conceptualize and model drivers of standardization as well as to simulate and eventually to predict the success of a standards development and diffusion [44]. An overview of respective contributions is given in [23, 48]. These

[2] "A matching problem is a problem of determining one or more features of different interrelated entities in a way that they harmonize with one another, or of determining one or more features of an entity because of its relations(s) with one or more other entities." [52, p. 5]

contributions fall into the research streams of evolutionary, network, and institutional economics. In summary, major drivers of successful standardization are industry mechanisms (e.g., uncertainty and rate of technological change), market mechanisms (e.g., network externalities), as well as strategies and characteristics of organizations (e.g., timing of entry and financial strength) [187].

We refrain from choosing a particular theory but discuss values of standards as the foundations for the development of a method and corresponding tools to support the assessment of standards. In doing so, we aim to incorporate information into our approach that is required to support the assessment of standards based on different theories. We will briefly summarize economic and technological values of standards in the following:

Solution compatibility: Standards are the main drivers of solution compatibility. Compatibility is a characteristic of products or services so that users of one can "enjoy the benefits of the other, in terms of either users to communicate with or of content to consume" [114, p. 76]. *Economically*, compatibility refers to the interconnectivity of products or services and their complements. Thus, it is a prerequisite for network effects to rise [79]. Compatibility, thus, allows market-based models to research the impacts of standardization (e.g., assuming substitution of products or services) [113]. *Technologically*, compatibility comprises interoperability and portability. The former allows products or services to communicate and thus to exchange components while the latter refers to the movement of data, processes, and applications. Compatibility, thus, allows organizations to change flexibly between products or services, or parts of them.

Variety and complexity reduction: Standards consolidate alternative terminology, prescribe interfaces or suggest reference architectures. They may comprise best practices and entire problem solutions.

The economic value of standards, thus, is to "restrict product choice in exchange for the cost advantages of economies of scale" [176, p. 588]. Moreover, standardization can lead the development of technology in an industry towards convergence [82]. Standards, therefore, reduce complexity in technology markets "that results from the large number and heterogeneity of actors and their interdependencies" [89, p. 578]. Technologically, applying standards reduces the complexity of design and implementation decisions when engineering products or services. The function of standards, thus, is similar to the concept of patterns [12] that are frequently applied in software engineering [80, 98]. In contrast to patterns, standards may only provide a common description of the problem while patterns focus on describing the solution [198].

The creation and selection of standards, however, introduces novel complexity to strategic and operational decisions [38]. This complexity stems from assessing the potentially many interactions of independent actors that participate in varying but intersected actor-networks [164] or increased complexity of the technology that is to be standardized [176].[3] Standards that try to be universally applicable, however, tend to be complex, due to broad reach and range [89]. Opening too much room for interpretation, solution compatibility may be compromised by complexity even though standards have been applied [92].

Efficiency gains: Industries and organizations benefit from improved efficiency when creating and using products or services using standards [79]. Also, standards ensure a constant quality of products or services [24]. Certificates, thereby, attest technological conformance [55].

Existing economics works, apply market-based approaches to model standardization as decision problems, optimizing, for example, cost savings [36, 192]. Economic efficiency gains of standardization, however, can hardly be quantified ex-ante due to economies of scale and potentially unstable equilibrium [113, 48].

As indicated in [176], the absence of standards, however, leads to over-verification to ensure the quality of products or services. Rising transactional costs are a consequence, which in-turn increase prices and inhibit economic efficiency.

Define markets and ensure competition: Standards are used to define markets, i.e., set market rules, define barriers to market entry [67], or contribute to establishing a mass market [40].

Regulatory bodies are, thereby, interested in ensuring fair market conditions [172]. Lock-in situations and missing innovation are typical signs of missing competition in markets [10]. If costs of switching to another product or service are higher than the potential of using another product or service, technology users experience lock-in situations [69]. Organizations that succeed in creating lock-in effects benefit from consistent profits while customers experience high switching costs. Standards facilitate the exchange of individual parts of a solution through increased compatibility. Standards, thus, contribute to reducing switching costs and may be used to ensure fair market competition. Therefore, standards are manifested in laws or regulatory and corporate policies.

Organizations may inhibit competitors from entering a market by pushing for standards that require, for example, licensing of particular—potentially self-owned—patents. Besides, they may seek to reduce competitive advantages of competitors by demanding standards for a particular market or use standards to obfuscate technology [132, p. 190]. Organizations, thus, use standards strategically to “compete for the market before they compete in the market” [114, p. 76]. For this reason, standards battles may arise (for examples see [48, 174, 162, 173]).

Compatibility, additionally, enables innovation of components without affecting other system parts [52]. However, there is also a risk of stifled innovation [70], if standardization leads to situations where the search for more suitable or performance-

[3] Using Actor-Network Theory (ANT), complexity of standardization can, for example, be modeled as socio-technological systems, comprising humans, organizations and computer systems [89].

enhanced solutions is prolongated due to the uncertainty over dominant designs [114, 161].

Our summary of existing works indicates that values of standards address decisions on the strategical and operational level, considering economic, business and technological dimensions. A variety of competing and contradictory factors influence the values of a standard that are subjective for individual organizations. Organization, thus, are required to consider varying factors when assessing values of standards. Standards assessment, thus, has to comprise respective information.

2.1.2. Stakeholders of Standards

The values of standards invite a variety of stakeholders to participate in standardization. We consider any participant that influences standardization to be a *stakeholder* of a standard. Based on their interest in standards, stakeholders have different motivations to influence standardization. They collaborate in standards development, for example, only to observe standards evolution, or to actively impede progress in standardization.

Standardization researchers developed a variety of stakeholder models, describing stakeholder roles on different levels of details (see e.g., [168, 185, 109, 24]. Based on these works, we will identify stakeholder types and roles that they enact in standardization in the following subsections.

Types of Stakeholders

Different powers and influences on standardization can be derived, depending on the legal entity of a stakeholder. We identify the following *types of stakeholders* to characterize a stakeholder's legal entity:

Individual

Individuals represent end-users of standardized products or services. They may work for a private company or a public authority, but are not required to have any organizational context. Individuals experience standards in action. Thus, acceptance of the standard by individuals is a key requirement for successful standardization [165]. The needs and requirements of individuals should, therefore, be incorporated in standardization. An individual, however, has very little resources and power to influence standardization. Individual stakeholders, thus, build alliances to ensure representation of their interests in standardization.

Economic benefits of standardization and market-shaping powers are, however, only of secondary interest. Individuals have little knowledge of standards setting processes in SDO and quality of standards. If they experience issues with a product's or service's compatibility, security, privacy, or even safety, individuals typically start demanding for standards. Few individuals are, however, experts in standardization or a particular field of disruptive innovation. They, thus, contribute to specifications of standards but typically are not motivated by economic benefits.

Private Organization

Private organizations provide and consume technology. They seek to realize an economic benefit (i.e., private companies) or strive for a common good (i.e., non-profit organizations) in competition with other stakeholders (see Figure 2.1). These organizations have a deep knowledge of the problems and, potentially, solutions for the progression of emerging technology in disruptive innovation. Their willingness to share this kind of information, however, depends on their market position and the values that they aim to gain from standardization.

The motivation of private companies to participate in standardization is to benefit from economic values of standardization. In doing so, they seek to develop de facto standards or shape the market, according to their requirements. Besides, they may seek for flexibility of IT systems based on interoperability and portability that standards provide. If a private company is dominating a market, however, its product or service may define a de facto standard. The respective company, consequently, has little interest in participating in standardization. If non-profit organizations participate in standardization, their motivation is in shaping a standard in agreement with their mission. Private organizations, both private companies, and non-profit organizations, may only contribute to standardization in SDO if they can afford the resources. Traditionally, only larger private companies contribute to SDOs, having the resources to perform standardization activities.

Public Organization

A national, regional, or international mandate founds the basis for standardization activities of public authorities. Public authorities do not seek to realize individual economic benefits but focus on shaping a market. They participate in standardization to, for example, enable compatibility, repair market deficiencies, or stimulate innovation.

Public authorities do not actively participate in standardization. They delegate standards setting powers to SDOs. Also, they may mandate standards in requests for tenders or public research programs. In doing so, they help standards with entering markets. Finally, public authorities may create regulations that mandate a standard directly or indirect (i.e., requestion usage of state of the art technologies).

Alliance

In general, a private company, a public authority, or an individual cannot achieve successful standardization in isolation. Their influences on standardization are exposed to network effects and, thus, require a critical mass. Individuals, private organizations and public authorities, thus, form alliances to pool their interest in standardization. Alliances may be "horizontal (among competitors), vertical (between integrators and suppliers), or comprised of firms providing complementary products and services" [31, p. 11].

The structure of alliances varies from simple *interest groups* to more formally *defined consortia*. Both types of alliances typically lack standards setting accreditation. Interest groups are loose alliances that typically do not formally define membership rules. They constitute ad-hoc and for a specific purpose, which may be expressed on the basis of mutual letters of intent. Participation in interest groups is typically open to the public. However, initial founders may choose to keep the group closed. On the contrary, consortia aim at longterm alliances and, thus, define membership rules. Consortia may formally define standardization processes, but transparency of consensus processes is no general requirement. Likewise, participation in consortia is not uniformly defined. While some consortia are open for participation of any organization, others may demand participation fees, define obligations (e.g., requirement to implement a reference implementation), or hinder participation.

In addition, interest groups and consortia help individuals and private groups to strengthen their influence on standardization. The powers and the interest in standardization varies, based on the types of stakeholders that participate. Both, however, develop practical reports on standardization, for example, requirements for standards, reference architectures, or draft specifications. Interest groups typically apply an experimental approach, i.e., they build specifications based on prototypes for particular problems. In doing so, their work contributes to a quick evolution of technology in disruptive innovation. Being more formally defined, consortia aim at setting standards, typically de facto standards. They may, however, seek collaboration with SDOs, i.e., to prepare submission of a de jure standards proposal.

Standards Development Organization (SDO)

SDOs create de-jure standards. Standardization in SDOs follows formally defined processes to achieve consensus and ensure conformity of its body of standards (e.g., prevent opposing or duplicate standards). An SDO's power of standardization is defined by its mandate. In consequence, a SDO's power is bound to a domain (see e.g., ISO vs. International Electrotechnical Commission (IEC), Comité Européen de Normalisation (CEN) vs. Comité Européen de Normalisation Électrotechnique (CENELEC), or DIN vs. VDE Verband der Elektrotechnik Elektronik Informationstechnik e. V.) and a particular jurisdiction, i.e., international (e.g., ISO), regional (e.g., CEN), and national (e.g., DIN). While standards are published under the SDO's copyright, participation in standardization activities is generally open for any stakeholder. SDOs, therefore, structure their work using committees.

Bound to their mandates, SDOs are interested in identifying technology fields and standards fields that demand for new standards or for adaptations of existing standards [57, 7.2 a)]. In domains with short product life-cycles—like in the early phases of disruptive innovation (see Section 2.2.1)—SDOs are, furthermore, required to "systematically withdraw, and not replace, standards which have outlived their scientific and technical significance" [182, p. 22]. The speed of standardization in SDO is typically slow. DIN, for example, requires standardization activities to not exceed three years [57, 4.1.2.8].

Roles of Stakeholders

Most basically, standards developers or standards creators are differentiated from standards users (see e.g., [39, 108, 155]). Based on the model developed in [168], we summarize four non-exclusive roles for stakeholders of standards:

Standards Developer

Standards developers create standards for the international, regional, national, or organizational level.

Formal or accredited SDOs, such as the International Organization for Standardization (ISO), the National Institute of Standards and Technology (NIST), the European Telecommunications Standards Institute (ETSI), or the Deutsches Institut für Normung (DIN), create standards, applying pre-defined consensus-based standardization procedures. Other organizations may equally contribute to the standardization of an SDO according to its statutes. An organization's jurisdiction, thereby, defines the authority of a standard, i.e., the area that is bound to the standard. Consortia and individual organizations may also develop standards. Individual organizations typically focus on internal standardization. De facto standards can, however, also be driven by a single organization, if it holds a critical position in the market, i.e., if the organization is a market or technology leader. Microsoft, is a frequently referenced example, demonstrating the standardization power of an individual organization.

Standards Implementer

Standards implementers provide implementations of standards by incorporating standards into technology by developing products or services that conform to standards specifications. Organizations choose to implement a standard to realize benefits of standards as discussed in Section 2.1.1. Organizations frequently enact the roles of standards implementers and standards developers concurrently (e.g., organizations that are involved in interest groups). Thus, standards implementers are a key influencer of standards development. By implementing standards, they contribute to the standards widespread and to the progression of technology in disruptive innovation. If standards have matured, standards implementers may benefit from standards certificates, testifying proper standards conformance.

Standards User

Standards users decide on the eventual success or failure of a standard. They benefit from standards implementers as standards become readily available. Standards users are traditionally classified into *individual*, *department*, or *organizational levels* [168]. End-users resemble the individual level, while corporate users are reflected by the organizational level. The departmental level typically reflects an organization's potentially conflicting viewpoints on standardization. Missing involvement of standards users in standardization is one of the key obstacles to a standard's success. Imbalanced standards are a consequence of, for example, standardization that leans towards benefits of standards developers such as creating market entry boundaries [108].

Policy Maker

Policy makers exercise regulatory functions by "enacting instruments which help to regulate a specific sector" [66]. They find their justification from laws passed by national or regional governments. In contrast to standards developers, policy makers, however, do not create standards. Instead, they influence standardization by creating standardization programs and defining compulsory requirements, referring to standards that have been created by standards developers. In doing so, they define the rules and the boundaries of a disruptive innovation's market.

As discussed, stakeholders participate in standardization to realize different benefits. Thus, their interests can be classified into situations of competition or cooperation (for the following, compare [108, p. 26 ff.]). More precisely, any two or more stakeholders may be characterized to have *common*, *opposed*, *overlapping*, or *destructive* interests. In the situation of common interests, stakeholders have no competing proposal at hand, and, thus contribute to establishing a common good. A situation of overlapping interests involves stakeholders that have competing proposals, but prefer to have any standard available over having no standard available. In such situations, benefits from standards are huge for an entire industry. Conversely, benefits of organizations prevail in situations of opposed interests. Here, typically no consensus can be achieved in standardization, leading to no standard being created. Finally, a stakeholder may participate in standardizations to, purely, protect its—typically—strong position as a market or technology leader. Thus, an organization may participate in standardization to destruct any outcomes from standardization. Table 2.1 summarizes these four interests of stakeholders of standards.

		Proposal	
		Aligned/no	*Competing*
Outcome	*Common good*	Common	Overlapping
	No standard	Destructive	Opposed

Table 2.1.: Interests of Stakeholders

Stakeholders will play different roles, pursuing to realize different interests. Any assessment of standards, thus, has to incorporate these different roles and interests when aiming to provide a holistic picture of the standard to be evaluated. Based on the types and roles of stakeholders, we will derive possible contributions to and interests in standards assessment when developing our method to assess standards in disruptive innovation.

2.1.3. Types of Standards

Classifications of standards allow stakeholders to identify similarities in standards. The purpose of classifying standards, thus, is to provide navigability into the set of standards. In doing so, areas with few standards can be identified, enabling prioritization of future standardization activities, for example.

The International Classification for Standards (ICS) maintained by the ISO, for example, defines a hierarchy of three levels to classify standards. At the time of writing, ICS comprises 40 fields of activity (level 1) that are sub-divided into 392 groups (level 2) and additional 909 sub-groups (level 3). In summary, ICS defines 1157 subjects of standards.[4]

Yet, the subject of standard will not always suffice to identify similarities and relationships between standards. Existing works typically apply custom types or common sense for standards that match their respective context. For example, differences of standards that stem from internal and external standardization, will typically apply the notation of de-jure and de-facto or industry standards. Likewise, standards may be classified to be horizontal or vertical, if they address more than one subject or scope (according to our definition). Stakeholders of standards may, however, regard additional standards-specific characteristics when classifying standards.

Based on the overview of standards classifications in [52], we summarize different standards types as follows:

- *What is the requirement of the standard?*
  Any standard defines a set of requirements for a subject, "since they represent a broad consensus of what is wanted in a given situation" [55, A.1.1]. These requirements may be *basic, requiring, and measurement*. Basic standards provide structured descriptions of products or services and their dependencies. They build the basis for other standards. Basic standards may have different scopes. For example, they may define terminology, reference models, quantities and units, classifications, or systematic data. Requiring standards set performance- or design-based requirements on products or services. Performance-based standards may relate to interference, i.e., a product's or service's influence on another, but also on quality attributes that products or services are required to deliver. Design-based standards describe solutions that enable interrelated products or services to function together (compatibility) or to deliver a certain level of quality. Measurement standards, finally, set metrics and related measurement methods to check whether requiring standards have been met (e.g., quality standards). Standards may, further, describe a subject

[4] Not all groups have sub-groups: "144 of the 392 groups are further divided into 909 sub-groups (level 3)." [102, 2.5] ICS requires standards to be classified using sub-groups, if available (see [102, 3.4]).

at the level of an *implementation* or merely define its *concept*. While an implementation defines a ready-to-use solution, concepts describe features, components or processes that solve a problem.

- *Who is developing the standard?*
  Our discussion of stakeholders in standardization shows the variety of interests driving standards development. Apparently, standards can be classified according to the stakeholders, driving their development. According to the reach of a standards developer, standards exists on the *organizational, national, regional, and international level*. With regard to the standards developer's accreditation, standards furthermore fall into the *formal (de-jure), de-facto, and governmental level*. Only standards that have been approved by an accredited SDO are formal standards. De-facto standards stem from consortia and individual organizations. Formal standards are typically consensus-based. However, even de-facto standards may arise out of consensus. Though, mostly applying less formal consensus building processes. Finally, the *degree of participation* that the development process offers to stakeholders is another characterization of standards. Transparency and openness of standardization are factors that constrain the degree of participation. License agreements, availability of standards documents and membership requirements are exemplary implementations to control transparency and openness.

- *What is the maturity level of the standard?*
  Accredited standards developers apply a staged approach for standardization. Typically, each standard starts being a proposal (proposal stage). Through immediate steps, such as working draft (preparation stage) or committee draft (committee stage), they finally become standards (publication stage). A standard's maturity is, thus, described by its specification's status. More generally, the relation between a standard's life-cycle and the life-cycle of the standardization subject, i.e., technology or business concept, allows for classifying standards as being *anticipatory, concurrent or responsive*. Anticipatory standards define requirements for a problem that is expected in the future. Concurrent standards address problems as soon as they occur. Retrospective standards choose superior design from a set of existing solutions to a problem, consolidation existing knowledge.

- *What is the standard's use?*
  Standards can be classified according their use. Generally, standards implementers and standards users benefit from *intrinsic, extrinsic, and subjective functions*. Intrinsic value stems from describing problems and respective solutions as well as freezing them for a given period of time. Extrinsic functions comprise aspects such as interoperability, portability, transparency, performance or economies of scale. Subjective value derives, for example, from enabling innovations, reducing design and decision complexity, process facilitation or improving maintainability of a system. However, the benefit and importance of intrinsic, extrinsic and—by name already—subjective features, can only be valued individually by each stakeholder.

There are more terms and concepts for typing standards (e.g., DIN's separation of norms and standards [58]). We will use the examples discussed above to develop and validate our approach for classifying standards in disruptive innovation in this thesis.

2.1.4. Standards Assessments

Assessment of standards as typically seen by SDOs refers to compliance assessment, demonstrating "that specified requirements relating to a product, process, system, person or body are fulfilled" [55, 2.1]. Thus, it is closely related to the process of attestation or certification, i.e., issuing a statement to indicate "if the standard is being complied with" [145, p. 72]. The purpose of conformity assessment, therefore, is to proof or at least to document enough evidence that a product, service, process, system, or a person fulfills the requirements of a standard. Thus, conformity assessment will always be an ex-post analysis of an as-is situation. In doing so, conformity assessment assumes that a standard has already been selected.

The purpose of standards assessment in this thesis is to support the overall process of standardization. Standards assessment, therefore, shall contribute to planning a to-be situation. From our definition of standardization, we can deduce two general viewpoints on standards assessment: At first, assessment is required to support the creation of new standards. Thereby, a classification of existing standards builds the basis for the identification of gaps for new standards [180]. In addition, assessment may include testing or reviewing of a product or service against quality requirements [72]. On the other hand, standards implementers might be overwhelmed by the selection of available standards and "might ultimately opt to not use any standard unless a customer or regulatory mandates a particular one" [190, p. 95]. Thus, stakeholders require support for selecting standards for a given development project.

The majority of standards-related research work addresses standards assessment from a theoretical point of view (e.g., using market models), building or testing theories for standards creation and diffusion [187]. In doing so, general propositions for organizational strategy development are developed, for example, to improve the effectiveness of standardization (see, e.g., [162]).[5] However, these research works provide, little guidance on how to classify a portfolio of standards and, thereafter, select and evaluate a standard for a given context.

Standards assessment studies, typically, apply individual approaches for standards assessment (see, e.g., [87, 19, 77, 64, 139, 133, 93]). We generalize the following common approach from these works:

1. *Scoping*: The first step of standards assessment focuses on finding the set of standards that is relevant for the given context. Standards assessment studies typically define their context using reference models of the given domain. Standards assessments that focus on technology standards, use reference models to describe the

[5] According to a systematic literature review of interface format standards, 92% of papers fall into the category of theory, theory building and testing [187].

different aspects (i.e., layers or components) of the technologies that standardization could address. Depending on the maturity of the domain under consideration, there might not even be a common understanding of relevant technologies. The general scoping of standards may, then, be done against a set of challenges or issues that initially triggered the interest in assessing standards. The purpose of the initial screening of standards, thus, is to filter standards that should be considered for further analysis. The set of standards that is considered in scoping, will be identified by screening publication sources of standards specifications (e.g., outlets of SDOs or alliances in the given area). Typically, standards will be included into the assessment that match any of the defined scoping criteria.

2. *Grouping standards:* The second step of standards assessment is to identify the similarity of standards. Initial scoping criteria or refined hierarchies of them are used to group standards according to their subject. In addition, the scope of a standard is typically used to group standards as a second criteria. Moreover, use cases provide another dimension for the grouping of standards. They typically summarize the context of the standard's application, i.e., related or required technologies, features, or organizational constraints [180]. Furthermore, they may introduce different views on the assessment context of relevant stakeholders [133, 64].

3. *Evaluation:* The grouped standards or selections thereof, will typically be assessed in detail, using additional evaluation criteria. Based on this additional information, standards or groups of standards are typically ranked, allowing stakeholders to select standards or prioritize further standardization activities. Evaluation criteria are typically used to estimate the use of a standard, indicate required efforts for implementations, and try to forecast a standard's success [60].

4. *Reporting:* In the final step, results are consolidated and documented accordingly. Reporting typically includes a conclusion on the portfolio of standards that has been assessed, leading to the identification of standardization gaps or particular calls for action. The published assessment reports, however, rarely provide access to intermediate assessment data.

In summary, the efforts in standards assessment are governed by the selection of the initial scope for the assessment. The grouping of standards and their evaluation will only be valid as long as the scope of the assessment remains unaltered. As we will present in the next section, the scope of standards and more generally the environment of standards are, however, subject to frequent changes in the context of assessing standards in disruptive innovation. Disruptive innovation, thus, poses a challenge on the longevity of results that are created from approaches a discussed above.

2.2. Technology Management in Disruptive Innovation

The purpose of technology management is to provide "effective processes and systems for ensuring that technological investments are aligned with current and future business needs" [147, p. 1]. In this regard, technology management has to identify and assess opportunities for new technologies. Therefore, technology management ensures acquisition of relevant internal and external knowledge and drives application of this knowledge in technology exploitation, i.e., internal or external use of the technology [116]. Similarly, innovation management "comprise[s] a set of strategic and operational tasks for the planning, organization and control of innovation processes and the creation of the required operational framework" [81, p. 5]. Innovation management, thus, does not only focus on the acquisition of technological knowledge, but also has to assess potential markets and organizational capabilities for market entry [33]. The activities of technology and innovation management to identify relevant information, however, are closely related [158]. In particular, if technology management has to manage emerging technologies [50], where uncertainty is a major challenge (see e.g., [37]). A combination of capabilities from technology management and innovation management promises to provide effective and efficient methods and tools to address uncertainty [11].

Technology, generally, refers to knowing how to create things, i.e., the "know-how" [50]. Thus, it contrasts with the focus of science (i.e., "know-what"), markets (i.e., "know-where"), and business (i.e., "know-who"). In addition, technology can be understood as a set of coordinated, discipline-bases skills that are applied to a particular product or market [83]. In summary, these definitions provide a broad definition of technology, including business processes or management guidelines. In this thesis, we apply a systems-oriented view of technology, i.e., see products or services to be the results of a "set of interacting components that operate together to accomplish a purpose" [13, p. 37]. Generally, the purpose of a system "can be seen as a specific function or set of functions" [100, p. 73]. Ensuring market-relevance of the systems, our definition demands for products or services, i.e., systems that are available on a market, rather than focusing on systems. For this dissertation thesis we define technology as follows:

> **Definition 3** (Technology)
> *A technology is a product, a service or a component thereof, which a stakeholder of disruptive innovation produces or consumes.*

We will introduce the relevant backgrounds of technology and innovation management to substantiate the challenges of standards assessment in disruptive innovation in the remainder of this section. In Section 2.2.1 we will discuss different concepts of innovation to introduce sources of uncertainty that set the context for standards assessment in disruptive innovation. Section 2.2.2 will summarize how approaches from technology and innovation management address these uncertainties, providing backgrounds for the development of our method to assess standards in disruptive innovation. In Section 2.2.3, we will outline a selection of assessment methods that our standards assessment approach builds upon.

2.2.1. Technology-based Disruptive Innovation

Innovation can be generally understood as a novel combination of purpose and means [90]. The importance of innovations for business success has already been pointed out by

Schumpeter in 1911 [159]. The management of innovation is an ongoing topic of strategic relevance, leading to a variety of definitions of innovation. These, for example, allow for separating invention from innovation on the basis of market availability [90]. As the purpose of this thesis is to assess standards in the disruptive innovation, we focus our discussion of innovation on the different types and the different sources of uncertainty. For an in-depth discussion of innovation processes we refer to the comprehensive body of existing works (see e.g., [81, 91, 196]).

A first dimension of classifying innovations is the separation of process from product innovations. The former defines new combinations of factors that lead to reduced production costs or improved product quality [90]. Product innovation, in addition, brings a new product into market that provides a new solution for given purposes or addresses entirely new problems. Thus, process innovation does not address a market, but helps to improve the production or the quality of an existing product. In this thesis, we, thus, focus on product innovations, i.e., innovations that lead to products or services that can be bought or consumed on a market.

Innovations, furthermore, differ in the subject of innovation. An innovation's subject may fall into potentially many of the following four dimensions [90]:

- Innovations address the *technology dimension*, if they provide new technological systems or components. New architectures, materials, and development or production processes may lead to the development of new technological systems or components. Technology innovations, thus, result from an application of technological know-how that was "completely unknown or was not needed up to this point" [81, p. 6].

- Innovations that contribute to the evolution of a market address a customer need that is new or has not been addressed so far. The *market dimension*, thus, values changes in market structures or business models.

- Innovations fall into the *organizational dimension*, if they change structures, cultures, or processes in an organization.

- Innovations are rarely developed by individual organization. In contrast, they are the results of an interplay of a variety of actors. These actors form alliances to collaborate or compete for market success. The *environment dimension*, thus, captures changes in the relationships among these actors, including regulatory bodies.

Figure 2.2 uses the four dimensions to assess the *novelty of an innovation* (see [81, p. 7]). The degree of novelty is described by the vector of these four dimensions. If an innovation's degree of innovation is little on each dimension, it falls into the category of incremental innovations. Such innovations make "a product or service perform better in ways that customers in the mainstream market already value" [42, p. 5]. An innovation is considered radical, if its degree of novelty is high for each of the four dimensions. Radical innovations create new markets or bring new features to existing markets.

Such discontinuities, however, increase *uncertainty*, referring to the difference between the amount of information required to manage innovation “and the amount of information already possessed by the organization” [78, p. 5]. The degree of uncertainty, thereby, is typically high for innovations that have a high degree of novelty. Alike, uncertainty comprises aspects of technology (i.e., missing knowledge of producing and using the technology), market (i.e., missing information on customers needs, pricing, or sales and distribution methods), organization (i.e., unclear resource requirements, decision criteria, or acceptance), and environment (i.e., changing competitors or uncertain legal and regulator requirements) (see [81, 179]).

A special type of radical innovations are *disruptive innovations* [81]. Performance of corresponding products or services is typically worse “as judged by the performance metrics that mainstream customers value” [42, p. 5]. In consequence, they start off in smaller markets, serving a niche segment that values non-standard performance [9]. These early markets, however, typically promise profit margins that are not attractive for providers of incumbent technologies [42, 30]. Due to steep performance trajectories in technology evolution [30] as well as cost and performance advantages [125], emerging technologies gain sophistication and performance in attributes that are required to enter existing markets. Disruption occurs when the emerging technology displaces the technology of the mainstream market [37]. If technology progress leads to performance oversupply, i.e., consumers primary requirements are met, “evaluation shifts to place greater emphasis on attributes that were initially considered secondary or tertiary” [9, p. 669].

In this thesis, we focus on disruptive innovations that introduce technological change. Considered types of disruptive innovation, therefore, have to introduce novelty in the technological dimension, i.e., an emerging technology. Emerging technology thereby introduces technological uncertainty leading to new potentials for standards. The challenge of assessing standards for emerging technology in disruptive innovation, is furthermore complicated by the combination of uncertainty that accompanies the novelty of emerging technology on the market, organizational, and environmental dimension. As discussed in Section 2.1, these dimensions, however, constitute the environment that is required to assess the value of standards. Thus, we derive a first conceptualization of the prob-

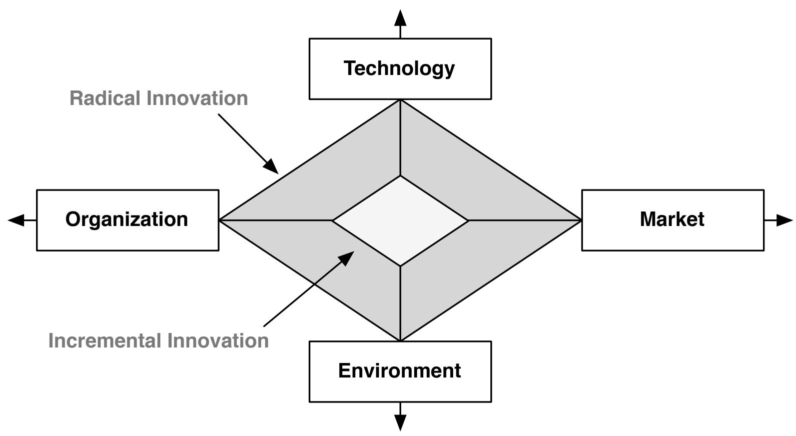


Figure 2.2.: Incremental vs. Radical Innovation: Degree of Novelty [81, p. 7]

lem to assess standards for emerging technology in disruptive innovation as follows (see Figure 2.3).

Reflecting the market dimension of innovation, we conceptualize a disruptive innovation to address an emerging market that is defined by a technology, a business, and a legal and regulatory framework:

- The *technology framework* reflects the technological dimension of innovation (i.e., the emerging technology) as well as standards that are related to the given technology.
- The *business framework* reflects organizational and environment dimension of innovation, summarizing business processes management approaches, but also business or pricing models. While the business framework provides subjects for standardization (e.g., standards for business processes), the assessment of business standards is out-of-scope of this thesis.
- To represent the environmental dimension, we introduce the *legal and regulatory framework*, summarizing the set of laws and regulations that apply for a market.
- In addition, we also regard *public and private actors* that directly influence standards and emerging technology by producing or consuming products or services. In addition, they may influence the business framework (e.g., introduce competing business models) or the legal and regulatory framework (e.g., public institutions may define regulations). Thus, a set of public and private actors shapes the market of a disruptive innovation.

Standards assessment as described in Section 2.1 is to value standards in the context of their environment. As discussed in this section, the environment for standardization in disruptive innovation, however, is characterized by high levels of uncertainty on the technological, organizational, market, and environmental dimension. The challenge of

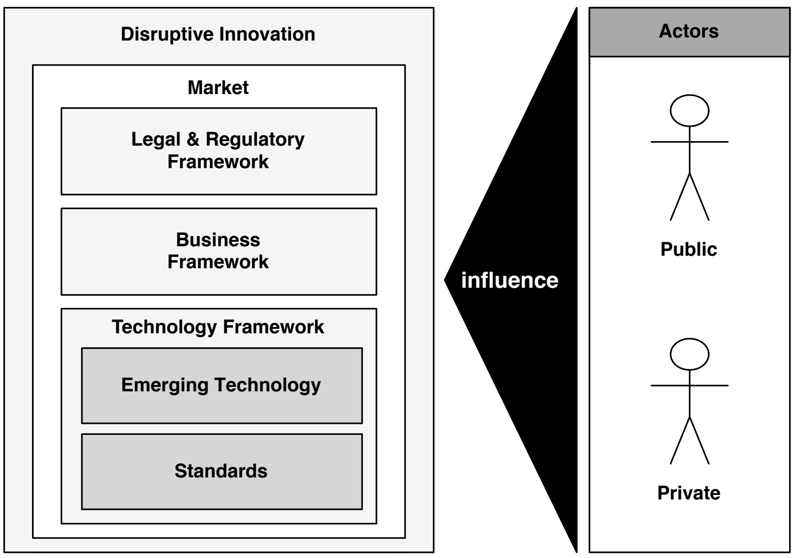


Figure 2.3.: Technology Standards in Disruptive Innovation

assessing standards in disruptive innovation, thus, is to incorporate these uncertainties into an approach for standards assessment. In the next section, we will outline aspects of technology and innovation management to demonstrate how these approaches handle uncertainty when assessing technology and innovation.

2.2.2. Assessment of Technology and Innovation

As discussed in the previous section, decision on technology development and adoption require assessment of market and business factors, the legal and regulatory environment, and influences from a variety of actors. While uncertainty exists in each of the dimensions, dynamics of the increasingly networked economy additionally contribute to the complexity of assessing technology and innovation in disruptive innovation [88].

Literature presents a variety of life-cycle and process models to structure activities of technology and innovation management (see e.g., [11, 88, 91, 83, 196]). In addition, they provide insights on how to implement respective activities into an organization [129]. In doing so, they introduce stage gates, i.e., milestones that require prioritization of technologies or innovation projects [47]. While prioritization is required to support decisions on, for example, resource allocation in organizations, this topic is out of scope of this thesis. We acknowledge that any assessment of technology or innovation has to be incorporated into an integrated technology and innovation management approach. However, an organization's decisions to pursue a particular technology or innovation project ultimately depends on the application of internal factors [173].

We apply a life-cycle model for technology-driven innovation to discuss different aspects and levels of uncertainty in technology-driven innovation from a global perspective. The life-cycle models conceptualize the corresponding path to provide an overview and order of the activities for managing technologies and innovation respectively. We will apply the life-cycle model to position activities of technology and innovation management in respective phases and discuss how they cope with uncertainty. In doing so, we will discuss the different goals of technology assessment in disruptive innovation, leading to the identification of external information that is relevant in assessment activities.

Outlining the life-cycle model, we apply two fictional technologies 'A' and 'B' that compete for market dominance. Figure 2.4 depicts exemplary data for market adoption and performance trajectories for the latency of two fictive technologies. Moreover, Figure 2.4 includes a fictional user demand, describing the maximum latency that a user is willing to tolerate in the given market. We assume technology 'A' to be an incumbent technology. It results from corporate research and development activities that led to its invention in the phase of "Research and development build-up (R&D build-up)". Technology 'A' explores the market as soon as it enters the phase of "technical feasibility", leading to a first notice of demonstrators or working prototypes in the market. If the technology demonstrates feasibility, for example, shows potential to provide the performance as required by the market, the technology enters the phase of "creating the market". At this point of time, the prototype has been turned into a commercial product. Technology 'B' is an emerging technology, having the potential to disrupt the invented market (but may also fail to do so).

In our fictive scenario, the development of technology ‘B’ starts when there are already products on the market that employ technology ‘A’. Technology ‘B’ initially performs lower in respect of latency as the incumbent technology ‘A’ (see Figure 2.4). Through the phase of “technical feasibility”, however, the latency of ‘B’ improves to a point where it finally exceeds market expectations. Technology ‘B’, thus, enters the phase of “creating the market”, providing commercial products to the market. In the meantime, technology ‘A’ managed to build an initial market, having entered the phase of “decisive battle”. Technology ‘B’ likewise manages to enter the phase of a “decisive battle”, looking for rapid market adoption. In our scenario, the battle for technology dominance between technology turns towards technology ‘B’ as soon as ‘B’ provides better latency than its competing technology ‘A’. Consequently, ‘B’ enters the phase of post-dominance, leading to decreasing market adoption of technology ‘A’.

As illustrated by the example, we apply five phases to conceptualize the path from emergence to market success. The phases and the underlying concept of technology dominance are taken from Suarez [173]. We will now characterize uncertainty as well as requirements and scopes for technology assessment for each phase:

Research and development build-up (R&D build-up): Decisions made in this phase heavily influence the key characteristics of the technology [173]. However, the level of uncertainty is highest. Uncertainty encompasses technology, business and legal and regulatory frameworks. The concrete technology is still been developed, while the field of technology starts to establish, summarizing a set of features or an abstract need [127]. The needs of a business framework, thus, can hardly be communicated as use cases for the application of the technology are only to be developed. There may already be laws and regulations affecting the vague technology fields that must be taken into account, if the field of technology is governed by general considerations (e.g., as it is the case for health care [94]). While the market and potential competitors can hardly be known at this stage, building “the ability of any firm to

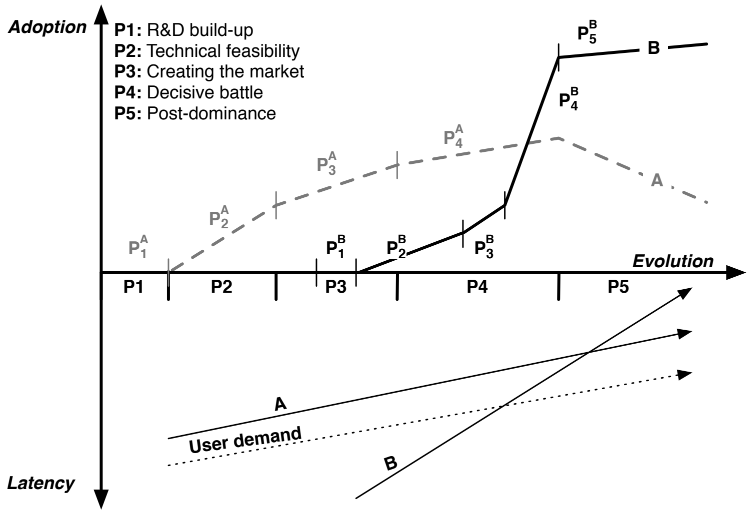


Figure 2.4.: Phases of Technology Development in Disruptive Innovation

progress faster than competitors along a specific technological trajectory is seen as a key element to focus on in this phase" [173, p. 282]. Consequently, assessment of potential markets are of considerations are of subordinate importance. However, preparations for subsequent competition in the market are starting. This includes, acquisition or preparation of required resources as well as looking for potentials to join alliances. Large organizations, having knowledge in related technologies, new entrant firms as well as universities and research groups compose the set of actors that are involved in the early phase.

Technology and innovation management proposes intelligence activities to assess technology in the early phase of technology progression. The goal of these activities is to "exploit potential opportunities and to defend against potential threats, through prompt delivery of relevant information about technological trends in the environment of the company" [128, p. 122]. Ideally technology intelligence builds on a coordinated approach for information collection, processing structural and informal information [127]. Information sources typically include internal or external (e.g., suppliers or consumers) technology experts or researchers, but also research papers [191]. Corresponding assessment methods, thus, comprise expert interviews and workshops, Delphi studies, life-cycle analysis, and morphological analyses [22].

Technical feasibility: The first working prototype of a given technology that demonstrates technical feasibility starts off the dynamics of technology evolution. The uncertainty of the technology framework moves to the level of systems and components. A first picture of the field of the emerging technology manifests, i.e., the set of relevant features conveys. First application scenarios will develop accordingly. However, frequent changes are about to happen as the technology progresses. Uncertainty exists on the processes and costs of production. The existence of a working prototype will, furthermore, call regulators into action. Regulators may act as catalysts for a particular technology, prevent further progression, or constrain the set of alternatives [173, p. 282]. Market studies will be typically initiated to identify market needs, competitors, opportunities, and risks. The set of actors comprises technology leaders, having demonstrated technological feasibility, and followers that have not yet demonstrated feasibility, but still shown interest in the technology. Alliance may be found, if competitors provide systems or components to complement functionality of the technology.

Technology and innovation management proposes the application of experiments or prototyping to overcome uncertainty at the level of the technology and business framework at this stage [179]. Activities of technology planning should be done evidence-based and, therefore, should assess data from experiments. Ongoing technology intelligence complements theses efforts to ensure that internal technology development is aligned with external trends. For this purpose, the inclusion of whitepapers (e.g., on early experiences and lessons learned from prototypes) and patents to the sources of information is required [84]. Intelligence, however, must also be applied to collect information on markets, consumer needs, and production processes to prepare the assessment of the business and market dimensions. The set of methods that is applied for assessment is becoming more quantitatively and focuses on the analysis of alternatives (e.g., technology portfolio assessments [144]). Thus, for example, apply scoring-based methods for evaluating alternative designs, approaches, and strategies [81]. As intelligence processes are ongoing, expert interviews and workshops, Delphi studies, and life-cycle analysis will still be conducted.

Creating the market: “The launch of the first commercial product marks an irreversible change of emphasis from technology to market factors” [173, p. 282]. At this phase, the functionality of the technology field has matured. Thus, a common understanding of systems and components is present. The availability of reference models for systems and components of the technology confirms the shifting focus on creating the market. The focus of this phase is to reduce uncertainty in the business framework. Therefore, predictive models for cost and revenue management will be verified against initial feedback from the market. Business models explore the inclusions of supportive products or services. Marketing activities should support technology diffusion at this stage. Development of sales strategies is a prerequisite for market success [173]. These includes considerations of first mover advantages, pricing decisions, and network theoretic aspects such as the installed base. Regulators now start to monitor the progress of the market and its structures. They may initiate actions to prevent monopoly situations, but also ensure security and safety for consumers. The market has yet to gain mainstream adoption. In consequence, it comprises mainly consumers that derive value from technological novelty. i.e., innovators and early adopters (see [138]).

Aspects of technology management fade from the focus, beginning with this phase. Innovation management approaches suggest focusing on product planning activities. The focus is on how to exploit the technological externally, i.e., designing and bundling products and production processes. Assessments require identification of competitive advantages, product functionalities or the needs for collaboration that are required to create and conquer a market [178]. Extensive information on markets, thus, is to support decisions on timing of market entries [73], opportunities to shape the markets, and the development of complementary products [130]. Moreover, analysis of customer preferences (e.g., conjoint analysis) are applied to transfer technology into products that are required by the market [81].

Decisive battle: Dynamics of technology evolution decrease as the technology enters the decisive battle. The technology’s set of functionalities has matured. The same applies to the set of systems and components. Incremental changes may occur to improve quality. In consequence, the performance of production and sales processes will be increasingly monitored to realize aspired profits or improve efficiency [177]. Consumer’s technology adoption decisions increasingly depend on the installed base and network effects. Moreover, market preferences and needs will shift towards reliability and trust, as the mainstream consumers typically are more averse from risk.

In this phase, innovation management approaches aim at managing growth for as long as possible, leading to best possible market adoption [81]. Related activities include product verification or product relaunches to realize increasing profits. Moreover, licensing of technology may lead to increasing benefits [158]. Market intelligence, thus, focuses on assessing the dynamics in the market, analyzing strength and weaknesses of competitors and collaborators. Additional quantitative assessment methods include aspects of target costing, break-even analysis or net present value analysis [99].

Post-dominance: In the final phase, a dominant technology has emerged in the market, i.e., one that is implemented by the majority of products [43]. The literature suggests different measures for dominance (e.g., a market share of 50 percent [14]). Maturity and faded dynamics characterize the technology and business framework. Installed bases and high switching costs typically complicate market entry of new technology providers. The main factor for business success, thus, are process innovations to gain efficiencies and reduce costs. Technology discontinuities present threats that may lead to a decline of market adoption and a cyclic sequence of disruption.

Managing technology at this stage clearly focuses on controlling efficiency of production and sales processes. Moreover, a combination of innovation and product management approaches focuses on the identification of additional market potentials. These may arise from exploiting the installed base. Complementary products or services that may have initially helped to conquer the market, may now promise additional revenues. However, information from market and technology intelligence is required in identifying overall market decline or technology substitutes. These may lead to the requirement of developing a phasing-out plan [81].

Using the life-cycle model, we discussed the different needs and focus of assessment in the phases that a technology undergoes from emergence to dominance. In order to further understand the information requirements of an approach to support the assessment of standards in disruptive innovation, we will detail a selection of methods inputs in the next section.

2.2.3. Assessment Methods

Reflecting the different scopes and contexts of standards assessment, there is no single method that fits all assessment purposes. As demonstrated in the previous section, the literature proposes a variety of different assessment methods to address specific needs. Addressing uncertainty, the major part of methods focuses on providing estimations in the early phase of technology development. Estimates are, for example, required for performances of technologies, future market needs and requirements, production costs, sales prices, value of the technology, or market adoption [88]. The assessment approach that will be chosen in a given context, however, will always be adapted to the context.

Assessment requires the availability of external and internal information. External information refers to data that is independent of given organization. It typically summarizes assessments of, for example, relevance, characteristics, challenges, and risks of technology progression. Internal information, on the contrary, is required to map this information to organizational capabilities [88]. Thus, the combination of internal and external information is required to support organizational decisions. This thesis is to enable standards assessment by providing a method and tools that reduce assessment efforts while collecting and evaluating external information. We will, thus, focus on respective methods in the following.

Most basically, assessment methods for external information may be classified according to their outcome [144]. Reflecting the different levels of uncertainty of information, technology assessment provides classification, comparison, and measurement methods. We will summarize the basic idea of each type of assessment method in the following:[6]

Classification: Classifications allow for segmenting technologies and sub-components of them. In doing so, they help to structure the initial problem of the assessment. Morphological analysis [150] or the more simplified checklist method [88, p. 326 f.] are examples of problem structuring methods [151].

Generally, classification methods start with identifying a structure of criteria that will be used to characterize an object or the fields of objects (e.g., a field of disruptive innovation) [88]. The identification of dimensions may be performed iteratively by a group of subject specialists, producing hierarchies of dimensions. Countering the exponentials growth of combinations of classification criteria, cross consistency assessment is applied to find dependencies (i.e., logical contradictions and empirical constraints or normative constraints) [150].

Depending on the resulting set of criteria, efforts to perform the classification are comparatively low. Likewise, participants require little methodological knowledge. In addition, classifications are particularly useful in the early phase of technology progression, as the iterative approach allows for adapting the dimensions. However, the approach requires the collaboration of experts to ensure relevance of all dimensions. Typically, these experts meet in workshops or presence meetings.

Comparison: Comparative assessments aim at drawing relations between two or more technologies. They support the prioritization of technology alternatives by aggregating information for a specific purpose (e.g., decisions to continue technology development projects).

Technology and innovation management typically apply technology portfolio analyses for this task [88]. Portfolio analysis methods apply two dimensions to combine internal and external assessment of technology. The combination of both perspectives is required to match organizational capabilities with external success factors such as technology progression and market potentials. Pfeiffer et al., for example,

[6] There is plenty of literature that provides more detailed comparison of assessment methods (see e.g., [91, 88, 83, 84, 99, 144]).

suggest to use technology attractiveness (external view) and resource power (internal view) to measure the attractiveness of a technology for an organization [143]. Technology attractiveness subsumes a qualitative assessment of a technology's potential and demand. Resource power summarizes organizational capabilities (e.g., financial, technological, or human skills) [170].

Portfolio analysis can be seen as specialized methods of general roadmapping methods to align technology developments with organizational or industry-wide capabilities. "The particular feature (and benefit) of the technology road-mapping concept is the use of a time-based structured (and often graphical) framework to develop, represent and communicate strategic plans, in terms of the coevolution and development of technology, products and markets" [146, p. 10]. Roadmapping applies four flexible core elements, i.e., timeframes, structure, process, and graphical format to compare and prioritize technology projects. While there are general guidelines [147], the planing horizon, dimensions to structure the problem, roadmapping processes, and final representations must be adapted for the given application scenario. Therefore, roadmaps are typically developed in a series of workshops [146].

Measurement: The final and most difficult type of assessment aims at predicting or measuring quantitative criteria. If quantitative measures cannot be assessed directly, corresponding methods provide means to quantify qualitative aspects.

Scoring models are typically applied for this purpose [88]. Related methods approximate the relative utility of a technology based on a set of assessment criteria, relative weights, and a subjective evaluation of the technology's utility for each criterion. In doing so, the scoring approach will ascribe an overall utility (i.e., score) to each technology. Scoring models, thus, enable a quantitative comparison of alternatives. They represent a simple approach in the wider field of multiple attribute decision making methodologies [197].

Besides, there are methods that assess technologies using financial data and monetary numbers. Approaches like break-even-analysis, total cost of ownership, or net present value calculation may be applied to assess technologies in the later phases of technology evolution as they require information on prices, costs, and cash-flows [99].

While the methods above provide suggestions on how to build classifications, questions remain on how a common set of dimensions—in particular, for structuring external information—should be derived. That is, how contributions from different actors or functional units of an organization will be consolidated [88]. Concluding our discussion of assessment methods, we will now briefly summarize the concept of Delphi studies that has proven to build consensus in related contexts [153].

Delphi method: The Delphi method is a structured process that is applied to provide forecasts on generic events [183]. Predicting the evolution of industries, technology, and standards is its common application [86]. Four characteristics found the basis of the Delphi method [152]: anonymity in the process, iteration, controlled feedback, and statistical aggregation of group response. In contrast to conducting in-person workshops, Delphi studies ensure *anonymity* using questionnaires to, for example, value the likelihood of an event. In doing so, experts are given the freedom to express their own beliefs without feeling pressured by, for example, dominant individuals. Experts will be requested to repeat and potentially revise their assessment when proceeding through *iterative* rounds of answering questionnaires. Therefore, they will be presented with *feedback*. The feedback includes simple statistics (e.g., median or mean) but may also include a collection of comments or opinions from other experts. A team of moderators typically prepares the feedback at the end of a Delphi round. They may include *statistical group responses*, i.e., statistical information on the degree of consent. If a sufficient degree of consent has been achieved, moderators may stop the Delphi study. The first round of a Delphi study may be used to allow experts to set the scope of the assessment (i.e., using questions that ask for topics that are associated with the field of the study). In such cases, moderators will create questionnaires that demand for quantitative assessment when preparing the second round.

Delphi studies have been reportedly criticized to cause significant costs and take considerable time to complete [152]. In consequence, extensions to the Delphi approach have been suggested towards a real-time Delphi process [85]. Such approaches seek to use the Web for distribution of questionnaires and feedback as well as receiving expert opinions.

In summary, there is a significant amount of work, proposing and describing assessment methods for technology and innovation management. Measurement methods provide most tangible outcomes and, thus, support organizational decisions of technology management most directly. Precise results, however, demand for relatively little uncertainty (i.e., higher quality of information on technology, market, and environment). Moreover, measurements and comparative assessment methods, require classifications of technologies or innovations as input (e.g., information structuring in roadmaps, technology attractiveness in portfolio analyzes, or assessment criteria in scoring models). The Delphi approach shows promise to support the identification and selection of assessment dimensions and assessment attributes that are relevant for the given field of research.

In the course of this thesis, we will build on the fundamentals of assessing technology and innovation presented in this section. In doing so, we aim to provide a foundation for transferring existing best practices to the support assessment of standards in disruptive innovation.

2.3. Cloud Computing

Cloud computing is an example of an emerging technology that has the potential to disrupt existing markets [125]. The constant increase in provisioning and consumption of cloud services is a threat to existing markets for business software, private application, and service hosting [135]. On-demand network services at the infrastructure, platform, and application level, thereby, fundamentally change the traditional model of self-hosted, self-owned IT solutions [16]. Despite its anticipated benefits (e.g., ubiquity, availability, or cost-savings) [62], cloud computing is, however, said to not leveraging its full market potential [68]. Quality issues of cloud services such as reliability, stability, and security pose challenges on mainstream adoption [135]. The related discussions on the inferior quality of focal attributes in existing markets, thus, confirm the argument of cloud computing's disruptive character.

Moreover, the emergence of cloud computing was accompanied by high-level of uncertainty on each of the dimensions of disruptive innovation (see Figure 2.3):

- *Technology framework:* The discussions on technological constituents of cloud computing demonstrate cloud computing to be in an early phase of innovation. Academics, industry and regulatory bodies started defining the basic characteristics and terminology of cloud technology [15, 62, 136, 16]. Based on the reduced level of technological uncertainty, more specific work commenced (e.g., on interoperability and security). While early works were still on the level of concepts and basic terminologies (see e.g., [181] or security [142]), they contributed to reducing technological uncertainty. The availability of prototypes and a variety of different commercial products (see an early overview see [123]) enabled experiments and studies that provided measures to assess the value of cloud services (e.g., on consistency [117]). The increasing amount of cloud service offerings, furthermore, led to growing uncertainty of the needs and requirements for standardization. Consequently, studies to assess the standardization potential have commissioned by nearly all developed economies (see e.g., USA [97, 133], Europe [64], Japan [154].
- *Business framework:* Discussions on differences between cloud computing and traditional outsourcing of Information Technology (IT) are examples of the uncertainty that cloud computing brings the business framework [157, 111]. Consequently, uncertainty address the management of cloud services. Open questions are, for example, raised on approaches to select cloud services [121] or maintain cloud service quality [59]. Moreover, requirements for new business models are frequently discussed [34, 178]. In regards of standardization, the lack of standards for cloud computing is complemented by missing guidance on how to select and apply standards to enable adoption of cloud services [74].
- *Legal and regulatory framework:* The development of markets for cloud computing called governments and agencies to examine the applicability of existing legal and regulatory frameworks. Addressing questions on the appropriateness of existing laws and regulations, governments and agencies developed roadmaps for future standardization activities in cloud computing [166, 64, 119, 97]. Among others, these efforts, for example, demand a thorough assessment of privacy regulations. Moreover, activities on standardization and certifications are perceived to bring trust and control to uncertain markets [175, 120].
- *Actors:* The set of actors that is attracted by the opportunities to conquer promising markets is massive [64]. Incumbent organizations, a great number of start-ups, governments and agencies but also SDO try to influence the progression of cloud

computing to their favor. They may act individually (e.g., exert existing market powers) or collaboratively by creating or joining alliances. In consequence, the type and amount of actors that compete for market dominance has yet to mature.

In summary, cloud computing induces high-levels of uncertainty in every dimensions of innovation. Thus, it presents typical characteristic of disruptive innovation. Cloud computing, however, is yet to prove disruption of existing markets. While it is challenging to forecast disruption [41], first scientific evidence is given [112].

In the remainder of this section, we will introduce the foundations of cloud computing (see Section 2.3.1). In Section 2.3.2), we discuss assessment requirements and the particular use of cloud standards in supporting cloud service management (Section 2.3.2). In doing so, we outline our view on cloud computing that builds the basis for the specification of the problem to assess standards in disruptive innovation and allows for validating our assessment method and tool (see research approach in Section 1.3).

2.3.1. Characterization of Cloud Services

While there is no commonly agreed on definition of cloud computing, consensus on a characterization of the essence of cloud computing has been reached. We will present the essential characteristics, service models, and deployment models of cloud services to briefly summarize the concept of cloud computing in this section. For the following see, for example, [136, 16, 15].

Essential Characteristics: Cloud services can be consumed *on-demand*, using a *self-service* functionality. Computational, storage and other computing resources, thus, can be consumed without human intervention. The respective capabilities are available over the network and accessed through standard mechanisms (*broad network access*). Providers of cloud services apply *resource pooling* to gain economies of scale. The location of resources may be transparent for consumers. Dynamic resource allocation capabilities, allow consumers to scale their applications rapidly (*rapid elasticity*). While the combination of aspects may lead to the perception of unlimited availability of resources, providers and consumers apply metering capabilities to monitor, control, report, and bill resources usage (*measured service*).

Service Models: Cloud services come in three different service models. Infrastructure-as-a-Service (IaaS) offerings provision capabilities to processing, storage, networks, and other fundamental computing resources. Consumers may use the resources to deploy and run arbitrary software. While consumers have to manage their software (incl. operating systems), maintenance of underlying infrastructure is the responsibility of the service provider. Platform-as-a-Service (PaaS) provide capabilities to deploy and run custom-build or acquired applications. These platform-based applications apply programming languages, libraries, services and tools that are supported by the provider. Consumers may configure their applications, computing or storage resources, however, are managed by the provider. Software-as-a-Service (SaaS) offerings provide applications that are accessible from clients such as browsers, mobile, or programming interfaces. Consumers do not have access to required resources. Options to configure application-specific capabilities are typically limited. The three service models are typically conceptualized to build a stack, where the purpose of use turns more specific from IaaS to SaaS. Lower level services (IaaS and PaaS) may provide the infrastructure that is used by higher-level services. However, higher-level service are not required to exclusively build on lower-level cloud services.

Deployment Models: The deployment of cloud services generally characterizes accessibility, property, and mode of operation. *Private clouds* are owned, managed and operated by a single organization, comprising multiple consumers. If access to cloud services is shared by set of consumers from different organizations, services are deployed as *community cloud*. Community clouds are owned or managed by one or more organizations from within or outside the community. *Public cloud* offerings are open for use by the general public. They reside on the premises of a cloud provider, who is in charge of its management. Varying combinations of deployment models are reflected by *hybrid cloud* approaches.

Cloud computing is build on the foundations of three core technologies to provide its beneficial characteristics and to support different service and deployment models. *Virtualization* technology allows for emulating computing platforms that behave like independent systems. Virtualization is a prerequisite for exploiting economies of scale. Moreover, it builds the basis to ease the management and replication of systems and resources. The related concept of *multi-tenancy* provides virtual environments on the level of applications. It provides the concepts that are required for concurrently serving different consumers with one instance of a software application. Finally, *Web service* technology provides the basis for standardized communication and integration of services over the Web. While all technologies have been developed independently, their combination builds the foundation of cloud computing.

2.3.2. Assessment of Cloud Standards

Standards promise to reduce decision complexity by providing concise and accurate descriptions of engineering problems and related solutions (see Section 2.1.1 and Section 2.1.3). Thus, they can help service providers to efficiently develop and provision cloud services. Service consumers, likewise, may benefit from cloud standards managing service consumption. We will introduce a life-cycle model to conceptualize the different activities of managing cloud services in this section. Based on the conceptualization, we will briefly discuss the value of cloud standards for cloud service management. In doing so, we outline the varying scopes of cloud standards assessment. [7]

[7] The following paragraphs reuse material that was previously published in [193]. Reused parts have been revised and contextualized to the management of cloud services.

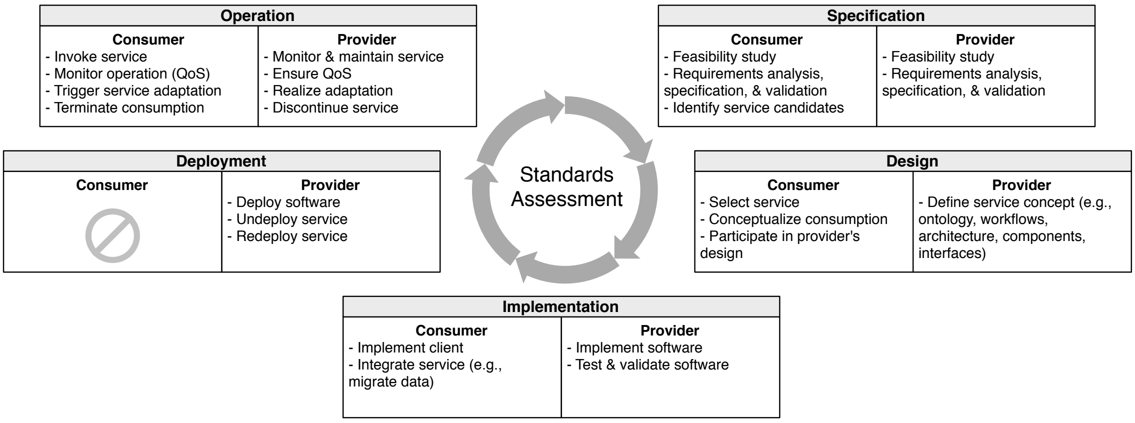


Figure 2.5.: Life-cycle of Cloud Service Management (See [194])

Our life-cycle model for cloud service management is based on existing approaches in software engineering (especially the Rational Unified Process (RUP) [118, 169]) and (Web) service engineering [141]). It considers five types of *activities*, and the two *roles* involved with cloud services. We differentiate five types of activities, namely *specification*, *design*, *implementation*, *deployment*, and *operation* that can be performed by *providers* and *consumers* (see Figure 2.5). While there is a typical sequence of activities, their timely occurrence is dynamic and can even be overlapping. If and when activities occur and if they overlap depends on the type of service development project and on the applied engineering methods. In the following, we describe relevant activities for providers and consumers.

Specification activities: The aim of *specification activities* is to define requirements and constraints on the provision or consumption of cloud services. Both, provider and consumer check the technical feasibility of offering or consuming a given service and perform, for example, requirements analysis, specification, or validation. During these activities, providers will focus on the realizability of a service. Consumer will, for example, specify the required functionality, integration requirements, or regulations that have to be satisfied.

Design activities: Using *design activities*, the service provider conceptualizes the service and its provision. Design activities match to a large amount with the activities performed in software design. They include the description of the service's architecture, components, data models, interfaces, or algorithms [169]. In contrast to software design, service design further includes design of service interfaces, deployment, and runtime methods and tools (for example, how to monitor or maintain the service). The consumer's design activities aim to plan and conceptualize service consumption. Therefore, an assessment of potential candidate services is performed. Service selection approaches support the ranking of service alternatives based on requirements, preferences, or optimizable goals (e.g., costs). Selection criteria may include requirements for new interfaces or even changes to systems that have to work with the service.

Implementation activities: *Implementation activities* of the service provider aim to realize the service based on the priorly defined design. Implementation includes the development of the software artifact, its testing and validation. Depending on the implementation methodology, these activities' order may differ. From the consumer's point of view, the envisioned service consumption must be realized. Contracting must be performed with the provider, specifying for example the service's price or Service Level Agreement (SLA). The consumer's implementation activities also include the creation of client components. Integration efforts may be required to utilize a new service with existing services or systems.

Deployment activities: *Deployment activities* aim to transfer the service implementation to an operational state. The deployment of services is only performed by the service provider. We differentiate deployment activities from implementation activities because they do not necessarily co-occur. For example, recurring deployment of once implemented cloud services is a common approach to realize scalability [16].

Operation activities Continued service provision at a targeted quality level presents the goal of *operation activities* for service providers. The provider maintains quality of service, in response to errors or changing amounts of requests based on performance monitoring. Additionally, customer relations must be handled (including, for example, sales or billing) and support must be provided. If a provider decides to discontinue service provision, corresponding activities, for example data retrieval or consumer notification, may be required. The consumer's operation activities include, foremost, the actual invocation of the service. The consumer may additionally perform activities to ensure ongoing, error-free, and satisfying consumption, for example by monitoring the Quality of Service (QoS). Furthermore, service adaptation can be triggered by the consumer, for example, in response to a changing context. Consumers may have to retrieve their data or actively dissolute running contracts, if a service is terminated.

In summary, the management of cloud services comprises a set of complex operational decisions that could be facilitated by standards. Standards must, however, be taken into account when decisions are made in cloud service management. Assessment methods must ensure that the right standard is chosen, while the complexity of selecting standards has not to compensate the value that is derived from applying a standard.

Cloud service providers or consumers, for example, could use standards in specifying, designing, or implementing services. The use of common taxonomies, reference architectures, protocols, or interfaces, for example, would reduce design alternatives. At the same time, the use of standards would ease management decisions on which standards to use with regard to sustainable development of the organization or regulatory compliance. The decisions made in the early design and implementation phases, thereby, determine the complexity of service deployment and maintenance, for example, by constraining an applications portability or interoperability. Service providers and consumer, for example, are required to decide on a proper architecture of components and their interfaces based on initial requirements. As a consequence, the deployment of the application may require a particular type of Web server, for example, one that supports Web services. When taking decisions in service engineering, the freedom of choice is constraint by the set of available resources (e.g. storage or computing), runtime components (e.g., middleware or Web server) and software services (e.g., user management). Alike, standards ease decisions of sourcing and operating services. They could, for example, benefit from assured compatibility, quality of service, and comparability when using standards to select services [139].

Existing assessment methods to support cloud service management build on the classification of cloud services to enable comparisons of alternatives. Most methods address the problem of cloud service selection, using multi-attribute decisions making techniques (for an overview see [121]). The proposed solutions typically apply general purpose techniques (e.g., Analytical Hierarchy Processing (AHP)) to rank service alternatives. The most frequently used assessment criteria are (see [121]): Security, performance, accessibility, usability, scalability, resource distribution, payment, reputation, and functionality.

In conclusion, assessment methods to support cloud service management implicitly rely on the availability of standards. Each of the above named criteria, for example, constitutes a potential subject of a cloud standard. Assessment methods, however, do not apply standards to evaluate cloud services or incorporate the values of standards into the evaluation of design alternatives. Existing methods do not conceptualize standards as first-class method elements. In doing so, they neglect standards as a viable source of knowledge to reduce decision complexity. The instantiation of our method for standards assessment in disruptive innovation to cloud computing aims at enabling standards-based decisions in cloud service management. Thus, this thesis aims at providing a first step to incorporate standards into operational decisions in the management of cloud services.

2.4. Conclusion

We started this chapter with presenting the foundations of standardization. Next, we presented different values that standards provide to stakeholders. A closer look into different types of stakeholders and standards built the basis to discuss the needs, scopes and procedures of existing standards assessment approaches.

In search for a method for standards assessment, we introduced basic principles of technology and innovation management. In doing so, we discussed how technological innovations can lead to disruptive innovation. Disruptive innovations are said to begin technology exploitation in niche markets before venturing out to capture existing markets, if focal performance attributes satisfy market demands. Handling uncertainty is the major challenge of assessing technologies in disruptive innovation as the interplay of business aspects, legal and regulatory framework, and markets change frequently. Using a life-cycle model, we discussed actual levels of uncertainty in the different phases of technology progression. Concluded the first part of this chapter, we presented an overview of methods for assessing technologies in disruptive innovation. In summary, the combined approach for technology and innovation managements provides guidance on how to assess standards on the strategical level.

The second part of this chapter introduced cloud computing as an exemplary domain of disruptive innovation. We provided a discussion on the disruptive characteristics of cloud computing and outlined an overview of the activities and related assessment needs for managing cloud services. Thus, we provided the backgrounds for the instantiation of our method to assess standards. Moreover, we demonstrated that supporting operational decisions requires consideration of domain-specific assessment criteria that cannot be derived from technology and innovation management approaches. We summarized corresponding criteria that have been developed to support the assessment of cloud services (e.g., cloud service selection support).

Having introduced the backgrounds of standardization and technology and innovation management, we conclude the following *challenges for a method to support standards assessment in disruptive innovation*:

Evolving environment of standards: Knowledge of the general environment in which a standard should provide value is key to a standard's success [163]. Thus, it is key to standards assessment. In disruptive innovation, however, the environment for standards, i.e., market structure, technology dominance, and consumer requirements, is only starting to develop. Existing studies, thus, try to capture the environment of standards, applying varying conceptualizations such as use cases, challenges or reference models. Limited applicability and transferability of results are consequences. The longevity of such standards assessment information is typically high for standards in mature market, where lead time for development of standards varies from several months to years [172]. Development cycles in disruptive innovation, however, are short [67]. The dynamics of technology progression, thus, demand frequent updates of use cases, challenges, or reference models. The validity of assessments is, thus, challenged by the speed of technology progression and standards evolution. Existing approaches, however, to not incorporate these dynamics, rendering their results as isolated snapshots in time, whose perpetuation is costly. Thus, the design of an assessment method that incorporates frequent and continuing updates of information into the assessment standards in disruptive innovation constitutes an open research challenge.

Lack of process support and information modularity: Varying stakeholders show interests in assessing standards in disruptive innovation. Legal and regulatory agencies demand assessments of a standard's use to shape emerging markets, for example, to ensure fair competition on a national, regional, or international level [67, 172, 20]. They, thus, try to assess the value of standards on a macroeconomic level. Standards, thereby, codify the rules of the corresponding markets. Taking a microeconomic view, private organization's interest in assessing standards stems from strategical, tactical, and operative decisions. The management's choice against implementing a standard may, for example, constrains an organization's opportunities to participate in a particular market or prevent vendor lock-in situations. While studies indicate that product or service engineers are willing to use and implement standards [172], they suffer uncertainty about which standards are applicable to their context due to high assessment efforts [68]. A method to support standards assessment, therefore, has to guide the varying stakeholders in defining their respective contexts when evaluating standards. Modularity of results and ease of reuse are proximate requirements that are typically not fulfilled by existing standards assessments.

Dilemma of Small and Medium-sized Enterprises: Incumbent organizations are not capable of deciding under uncertainty in disruptive innovation [41]. Existing value systems, both with external partners (e.g., profit margins) as well as internally (e.g., incentives and benefits), typically require incumbent organizations to gain higher profit margins than achievable in emerging markets of disruptive innovation. Small and Medium-sized Enterprisess (SMEs), start-ups, and spin-offs, however, have demonstrated the flexibility that is required to overcome uncertainty. Standardization, in turn, is dominated by larger corporations leading to standards and standards assessments that, as a result, demonstrate bias towards the needs of incumbent organizations and markets [108]. The role of SMEs in standardization of disruptive innovation, however, constitutes a dilemma: While SMEs are best suited to address challenges in emerging markets of disruptive innovation, their participation in standardization is marginal, due to unavailability of adequate information on standards and lack of resources [172]. In consequence, SMEs miss benefits from standards (e.g, opportunities to shape markets or improve efficiency). A method to assess standards should, thus, has to provide a mechanism to support collaboration of many contributers, inviting SMEs to participate in standards assessment. Therefore, individual assessment efforts should be kept manageable. An assessment method should, therefore, enable knowledge reuse in creating standards classifications or valuing assessment attributes.

We will address these challenges by developing a method to support standards assessment in disruptive innovation in this thesis. Thereby, we seek to identify potential for the automation of assessment tasks and, thus, reduce manual assessment efforts even further.

3. Related Work

In this chapter, we relate our contributions to existing works and tools. As presented in the previous section, the task of standards assessment is a multi-disciplinary effort. We will discuss related works for standards assessment in Section 3.1. In Section 3.2, we will outline the state-of-practice of tools that have been developed to support standards assessment.

In Section 2.1, we already provided backgrounds of standards assessment, focusing on general goals of standards assessment. As demonstrated most scientific works on standards assessment aim at assessing standardization processes, factors of successful standardization, the economics of standardization or classification of standards in general. In doing so, they provide theoretic backgrounds and support prioritization of standardization activities in the large. The methods and tools that we will discuss in this section focus on particular types of standards or have been developed for a particular field of application. Still, they have inspired the development of our contributions.

3.1. Methods for Standards Assessment

In this section, we summarize three approaches that support standards selection in software engineering and health care. In contrast to general-purpose approaches (see Section 2.1.4), these frameworks provide a defined set of fixed criteria and propose particular procedures for standards assessments.

Frameworks related to Software Engineering

In the early 1990s, there has been a vibrant discussion on the use of standards for the professionalization of the software engineering. The goal of approaches that have been developed in this phase was to improve the selection of standards that are relevant to a software development project (see, e.g., Standards and Methods Assessment Using Rigorous Techniques in Industrial Environments (SMARTIE) project [145]). Falling into the same time of these activities the following works are related to our approach, as they aim at guiding user with selecting standards.

Standardization Framework for Software Engineering [180]: The approach proposed by Thornton and Bytheway aims to guide software engineers in selecting standards from the Standardization Framework for Software Engineering.

The method is built on the classification of standards by “the type of standard, the rationale of the standard and the scope of the standard” [180, p. 192]. Considered *types of standards* are normative standards, guidelines, and standard profiles (i.e., standards that extend other standards). The *rational* summarizes the audience of a standard, the needs addressed, and the benefits that can be derived from implementing the standard. *Scope* refers to concepts that allow for positioning of a standard within a given domain.

Possible rationales and scopes are derived from a systems-oriented view of Computer-aided Software Engineering (CASE), applying a hierarchy of three systems (i.e., application system, software development system, software engineering development system). Each system comprises technologies and their respective providers and consumers. Thus, rationales and scopes of standards can be derived from different levels.

The procedure for standards assessment applies questionnaires that summarize the varying aspects to position standards in the framework and to identify dependencies among standards. If standards are to be selected, the questionnaire has to be completed with regards to the given development project (rather that the standards specification).

Evaluation of software safety standards [93]: Stemming from similar activities, the US Food and Drug Administration (FDA) developed a method to assess software standards that are relevant for safety and reliability. The goal of the approach was to assess software standards that are used in software to manage production in regulated industries (e.g., food, cosmetics, or medical devices). Therefore, it was built on a scoring technique and a set of 43 assessment criteria that are structured in the following six categories: General factors (e.g., specificity, verifiability), product characterization (i.e., addressing properties of the final product)[8], process characterization (i.e., addressing the process of software development)[9], personnel characterization (e.g., human factors or training), risk management (i.e., mandated procedures to assess risk)[10], and overall standards framework (i.e., relations to other standards). The assessment procedure demands users to value a standard, using a three-tier scale for each criterion.[11] The sum of points awarded for each category provides a characterization of the standards subject. An overall score is used to rank standards. While assessment of sub-scores (for each subset of criteria) allows for comparing standards, the usefulness of overall scores is questionable, as a standard will only score high if all sub-scores are high. Doing so, however, contradicts with the goal of a standard to be specific.

Both approaches address standards assessment on multiple levels and classify standards, according to scopes and subjects. In this respect, both approaches are similar to our endeavor. The proposed levels, however, only apply to CASE-based software engineering (see [180]), or are restricted to safety and reliability standards in software engineering

[8] For example, safety, fault tolerance
[9] For example, formal proofs, testability analysis, modeling
[10] For example, hazard or cause identification
[11] "The criteria were developed such that they could be measured by a three-tier scale: 0 - not covered, 1 - cursory coverage, and 2 - comprehensive coverage." [93, p. 4]

(see [93]). Moreover, the approaches are not designed to work under uncertainty that may require changes to the criteria that are used for standards assessment. Thus, the adaptation of the questionnaires is not supported. Likewise, the proposed evaluation frameworks do not consider environment factors. Finally, the proposed procedures are designed for human execution. Thus, automation support is missing.

Assessment of Interoperability Standards in Health Care

There is a strong need for standards assessment in health care as it is a highly regulated domain. In accordance with SDO's efforts to provide a unified description of standards for health informatics (see ISO Health Informatics Profiling Framework (HIPF) [103]), Mykkänen et al. propose a framework for evaluating and selecting standards that aim at ensuring interoperability of healthcare information systems [139]. We will outline the proposed "Evaluation and Selection Framework for Interoperability Standards" in the following.

The approach applies a conceptualization of seven levels of interoperability: Technical interfaces, technical infrastructure, application infrastructure, functional interfaces, semantics, functional reference model and application life cycle interfaces. For each level, a set of assessment criteria is developed. These primary evaluation criteria are complemented by additional criteria to assess maturity, diffusion, and additional viewpoints of standards (e.g., relevance to specific software engineering life-cycle phases or specificity to health care). In summary, the approach applies nine questionnaires (called forms)—that add up to 54 questions (not including sub-questions)—to assess a standard in detail.

A procedural model that comprises 17 steps guides the process of completing the questionnaires for standards evaluation and selection. The respective activities are categorized into four phases: Preparation, overview, detailed evaluation, and finalization. The preparation phase is used to define the requirements and to acquire standards specifications and supporting materials. The overview phase is to provide a high-level evaluation of standards, involving an initial screening of the standard's scope. Next to documenting the scope of a standard, the typical use and audience, a primary viewpoint, the level of interoperability as well as maturity and diffusion of the standard have to be evaluated. The overview completes with a decision on whether to further evaluate a standard. A standard qualifies for further evaluation if it addresses the specific needs of the evaluation (as defined in the first phase). In doing so, efforts for initial screenings are kept low (i.e., only requires answering 13 questions). The procedural model demands users to iterate the phases of overview and detailed evaluation of all standards that have been acquired, before entering the phase of finalization. Detailed analysis, requires completion of all assessment criteria (i.e., the remaining 41 questions). Finalization is to collate the collected information and produce the evaluation report. Finalization may apply a scoring technique to rank standards according to the scope of the assessment.[12]

[12] Relevance of criteria has to be defined in the preparation phase. Therefore, a preference weight [1 (desirable), 2 (highly desirable), 3 (mandatory)] and a score [-3 (feature contradictory with the requirements) to 3 (feature is fully supported)] will be assigned to each criterion.

In summary, Mykkänen et al. apply an approach that is similar to the one that we will develop in this thesis. In particular, both approaches apply different phases to separate classification efforts from selection efforts. While the set of criteria has been developed specifically for the assessment of interoperability standards, it covers environmental and life-cycle aspects (e.g., maturity or diffusion of a standard). Thus, the approach partly matches the goal of our approach. A major difference, however, is the missing support to adapt to changes in the environment of standards. Thus, it does not provide support to incorporate changes to the standards environment into questionnaire as it is required to support standards assessment in disruptive innovation. While there is a step to consolidate varying evaluations of standards manually, there is no conceptual model that would support automation of this task. Moreover, filtering of information according to the capabilities of different stakeholders is not supported. In consequence, each assessment will require to answer the complete set of 54 questions.

3.2. Tools for Standards Assessment

In this thesis, we aim to demonstrate how an implementation of our method for standards assessment in disruptive innovation reduces efforts in standards assessment. Enabling a comparison of the features that our prototype will provide for standards assessment, we will summarize the state of practice for standards assessment tools in this section.

We are not aware of any tool that was designed to provide support for frequent classification and evaluation of standards as it is the goal of this thesis. However, we will briefly summarize existing tools that address feature subsets.

Most prominently, SDOs provide tools to identify standards. We will outline respective tools in the following:

- Provided by ISO, the *"standards catalogue"* supports users that are searching a suitable standard from its huge database of standards.[13] The actual support for finding standards is, however, limited. Users may filter standards by ICS classification code or look for standards that have been published by a particular technical committee. Moreover, the "standards catalogue" supports keyword-based searches. Result pages provide an abstract, describing the standard. In addition, information like ICS code, stage code (describing the status of the standard, see [101]), number of pages of the standards specification, and links to previous revisions as well as potential amendments is shown. The user may navigate to related standards that are classified with the same stage code or that have been developed by the same technical committee.
- The *Online Browsing Platform (OBP)*, also operated by ISO, provides capabilities to select standards, using a fulltext search in standards specifications and related documents.[14] Standards documents will be ranked according to a relevance score that is presumably calculated from the number of matching strings in a standards

[13] See `http://www.iso.org/iso/home/store/catalogue_ics.htm`.
[14] See `http://www.iso.org/obp`.

specification. Additional filtering capabilities allow users to filter standards, for example, by language, technical sector, publication year, type of standard, or status.

- The *Perinorm online* tool, operated by Beuth (the publishing subsidiary of DIN), provides capabilities that are similar to those of ISO's "standards catalogue". Thus, it supports text-based searches and filters using meta-data (e.g., classification, type of standard, and status).
- Supporting the dissemination of cloud standards, the "cloud standards wiki" presents an overview of cloud standards[15]. Initiated by the National Institute of Standards and Technology (NIST), the wiki-based approach builds on collaborative efforts to keep information on standards updated. Standards are listed according to their standards developers. The wiki, however, does not provide any classification of standards nor does it provide support for standards selection.
- The "Smart Grid Standards Map" provides a graphical overview of Smart Grids standards, using a reference architecture as classification scheme.[16] Moreover, a mapping view supports selecting standards based on the classification of a standard's relevant clusters or Smart Grid system components. In contrast to ASSET, no procedural support for standards selection is given. Furthermore, no additional classification attributes can be used to filter or prioritize a set of relevant standards. Finally, users may not change a classification. Thus, assessment efforts are not distributed, leading to a concentration of efforts on the side of the provider of the classification (i.e., IEC).

In summary, the tools allow users to search for standards or provide an overview of available standards for a particular domain. The process of finding and selecting a standard for a given development project is, however, not supported. There is no guidance on how to prioritize standards from the list of results. In contrast to the tools named above, the "cloud standards wiki" comprises standards from different standards developers, including alliances and initiatives that are not formally accredited for standards setting. Moreover, it applies a collaborative approach to keep information on standards updated. The list of standards documented in Perinorm, will, for example, be updated at most monthly. The quality of information that "cloud standards wiki" provides, however, may be subjective as it is maintained by representatives of corresponding standardization activities.

Looking for related tools, we identified three commercial available products that provide the possibility to manage standards in corporate environments. While a detailed evaluation of commercial tools is difficult due to little documentation and license constraints, we briefly outline their support for standards assessment. *SAP's Enterprise Resource Planing* solution supports the creation of a material classification system using standards. Standards may be imported to describe characteristics of materials using terminology and characteristics as, for example, defined by DIN.[17] Moreover, *Troux Technologies*, providing tools to support enterprise architecture management, offers the Troux Standards

[15] See `http://cloud-standards.org/`.
[16] See `http://smartgridstandardsmap.com/`
[17] See `http://help.sap.com/erp2005_ehp_05/helpdata/en/56/d5e4535dd4414de10000000a174cb4/content.htm`.

product [1]. The software component aims at managing dependencies of IT assets and technology standards, using a holistic conceptual model. We could, however, not perform an evaluation of the functionality. Finally, InConTec operates "Standards DB", providing an overview of standards in the field of long-term preservation. Using the concepts of standards areas, "Standards DB" allows for classifying standards according to processes, projects, formats, and derivation from previous standards.[18] Additional meta-data is used to provide additional information. However, we could not identify community aspects or features to incorporate the uncertainty of disruptive innovation.

[18]See `http://fenugreek.fernuni-hagen.de:8080/StandardsWeb/home/standardsRegister.xhtml`

Part II.

Method Engineering

4. Cloud Standards Study

We have been monitoring cloud standards in a continued effort of the German Federal Ministry for Economic Affairs and Energy (BMWi). The cloud standards study "Das Normungs- und Standardisierungsumfeld von Cloud Computing" is a particular achievement of our comprehensive efforts to assess cloud standards (see [20]).

Figure 4.1 summarizes the focus areas of our cloud standards study. The study's goal was to assess the situation of standardization in cloud computing. Therefore, an overview of standards was to be developed. Providing a holistic picture of standardization efforts, the study considered the standardization environment of cloud computing to comprise actors, standardization activities, and standards artifacts. The main focus was put on technical standards, but aspects of business standards, laws, and regulations have also been incorporated. Being integrated into the ministry's Trusted Cloud program, the results of the study were to support the evaluation of cloud standards from a German perspective. Providing recommendations on standards selection and synergies in standards development of Trusted Cloud projects were secondary goals of the study. We, therefore, conducted the study in close collaboration with stakeholders of the 14 Trusted Cloud projects. Thereby, we applied a mix of empirical methods, including interviews, workshops, and questionnaires, to gather information, analyze potentials of standards and to derive targeted recommendations. Moreover, recommendations were to support roadmapping of strategic standardization activities. The analysis of strategic developments in the standardization of cloud computing, therefore, was another focus area. The definition of an analytical framework provided a sound methodological for performing the study.

The study was started in June 2011, and we published the final results in March 2012. Initially, we discovered around 140 actors that conducted around 165 standardization activities, driving more than 160 proposals for standards [20]. We developed and validated a classification scheme to classify the standards and, thereupon, select a set of 20 most relevant cloud standards. For these standards, we created detailed standards profiles, enabling evaluation of their values for cloud computing. Moreover, we rated the relevance

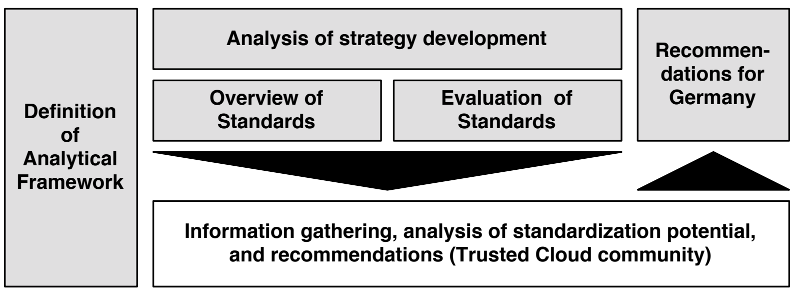


Figure 4.1.: Study Approach (see [21, p. 5])

of the 20 cloud standards for each of the 14 research projects that have been funded in the ministry's Trusted Cloud technology program [27]. We verified our approach and intermediate results using expert interviews and a series of 14 workshops with cloud and standards experts from the community. Results have been validated in a half-day workshop with more than 40 representatives from the Trusted Cloud program. Final results have been presented at CeBIT 2012 and discussed with decision makers of BMWi, the European Comission (EC), European Telecommunications Standards Institute (ETSI) and Deutsches Institut für Normung (DIN).

In this chapter, we will briefly summarize the study's approach, report on a selection of results, and discuss the lessons-learned. We clarify the study's research approach in Section 4.1 (see analytical framework in Figure 4.1). In Section 4.2, we will report on a selection of the study's results that is of relevance to this thesis. Finally, we reflect on lessons learned from our continued efforts in monitoring standardization in cloud computing and derive requirements for a method to support standards assessment disruptive innovation (see Section 4.3).

This chapter reuses material that was previously published in [20, 75, 76]. Applied questionnaires and aggregated results are documented in Appendix A.

4.1. Approach

The study's varying goals demanded a holistic approach to assess the situation of standardization in cloud computing. We developed an analytical framework, aiming for clarity and replicability of the study's results. Defining the set of attributes to classify and document respective artifacts consistently, the framework provided the common basis for all analyses performed in the study. Also, it guided the selection of few but representative standards for detailed analysis. The framework, therefore, comprised a set of criteria to focus, select, assess and provide conclusions about actors, standardization activities, and standards.

The analytical framework, thus, comprised a taxonomy, comprising challenges of cloud computing, fields of standardization (i.e., means to address these challenges), and additional attributes to classify cloud standards. In summary, the *analytical framework* defined the following steps and criteria for standards assessment[19]:

- *Focus:* In the first step, the study classified standards based on their specificity to cloud computing. Their "cloud aspect" was, thereby, defined to be explicit, implicit, or not existent. Besides, standards were classified according to their field of standardization. Standards were considered to address technology, management or legal aspects. Moreover, standards were classified to be industry-specific or valid across industries. Standards passed the focus stage if they demonstrated explicit reference to cloud computing across industries. Industry-specific standards that only

[19] A comprehensive description of the analytical framework is beyond the scope of this thesis. Details on the criteria to focus, select, assess, and draw conclusions about actors and standardization activities are given in [20]).

implicitly referred to cloud computing were considered on a case-by-case basis if we identified a potential for the standard's future use in cloud computing. In the study, around 160 standards passed the focus step.

- *Selection:* Choosing the standards that the study would assessed in detail, we analyzed the standards' comprehensiveness and diversity in a selection step. In demanding comprehensiveness, we aimed at covering the majority of aspects of standardization for each field standards field in cloud computing. Thus, the study was to cover a preferably broad picture, comprising a variety of standards. Applying the taxonomy, standards were selected for the assessment step if they addressed different challenges or fields of standardization. Using this approach, we finally selected 20 cloud standards for detailed assessment.

- *Classification:* In the classification step, we created standards profiles, using the assessment attributes of the analytical framework. A standards profile comprised information on a standard's status, its type, the initiator, and a link to the location of the specification. Next, we classified cloud-specific aspects like service model, user group, and deployment as well as applicability and information like industry, jurisdiction, and company size. Finally, we evaluated maturity, market potential, and degree of participation. See section 4.2 for details.

- *Evaluation and Conclusion:* Finally, we performed a gap analysis of the portfolio of standards to identify a potential for new standards. Applying the taxonomy, we conducted surveys to ascertain the general potential of standards to address a given challenge of cloud computing (see Appendix A.1). Combining aggregates of these estimations with the amount and the maturity of standards, we were able to assess gaps of standardization. In addition, we applied the developed taxonomy to classify each of the 14 Trusted Cloud projects. Matching the project classification with standard profiles, we were able to identify suitable standards for each Trusted Cloud project. Using a Likert-scale approach, we ranked the relevance of the 20 standards, based on the standards profiles and the project's description. Thus, we derived recommendations for standard's relevance and the portfolio of standards, supporting strategic decisions on future standardization activities.

We verified the criteria and results of all steps, using questionnaires (see Appendix A), expert interviews, and workshops with members of the Trusted Cloud program. Based on the feedback, we revised criteria and consequently iterated the focus, selection, assessment, and conclusion steps.

4.2. Selected Results

We will summarize a selection of final results of the clouds standards study in this section. In doing so, we report on lessons learned and build the basis to derive requirements for an approach to assess standards in disruptive innovation. Focusing on the assessment of standards, we limit the presentation to standards-related aspects. Thus, we will present the taxonomy for cloud standards, the template for standards profiles, the maps of cloud standards, and the project-specific assessments of cloud standards.

4.2.1. Taxonomy for Cloud Standards

As demonstrated above, we developed a taxonomy for the assessment of cloud standards. Developing the taxonomy, we created a synthesis of existing works on challenges and opportunities of cloud computing (e.g., [157, 62]) and existing standardization works ([97, 45, 166, 65, 107]). Interviews that we conducted with experts of cloud computing complemented our desk research. The relevance of our classification was evaluated using questionnaires. 14 Trusted Cloud projects were, therefore, asked to value the importance of identified standards, standards fields, and challenges in cloud computing (see , Appendix A.1 and Appendix A.2).

The taxonomy comprised two dimensions to classify cloud standards in terms of challenges ("Why?") and fields of standardization ("How?"). The final taxonomy consisted of two *levels of challenges*, providing nine top-level challenges and 19 sub-categories. We, furthermore, discovered, 14 fields of standardization, characterizing the scopes of standards.

In the following subsections, we will summarize the taxonomy for cloud standards.

Challenges

The taxonomy comprised the following challenges of cloud computing:

- Standards may improve *efficiency of service provisioning* based on four sub-categories: Firstly, the usage of standardized *development tools and components* may reduce efforts in developing services. Secondly, standards may help in the *creation of scalable architectures*, focusing on cloud characteristics like, for example, redundancy, fault tolerance, and multi-tenancy. Thirdly, *resource management and flexibility* of service provisioning benefits from standardization due to improved capacity planning and homogeneous quality requirements. Especially, *availability of services* could be addressed by standards.

- Improving the *effectiveness of service usage and control* requires solutions to actually deploy services. Standards are especially required to address the sub-challenges of *contracts (including questions of liability)*, *control of services by users*, and *governance or escalation mechanisms*.

- *Transparency of service delivery and billing* simplifies complex and often impersonal relationships between provider and consumer of cloud computing. This includes transparency in *billing (including license management)*, *quality assurance and monitoring of Service Level Agreements (SLAs)*, and the management of the *type and location of data processing*.

- *Information security* is one of the mos frequently mentioned challenges of cloud computing. It comprises aspects of *identity and rights management*, *confidentiality and integrity*, *access control, logging, and attack prevention*, and *verification and certification*.

- Ensuring conformity to *data privacy* regulations is a challenge due to data federation and ubiquitous data access. Standards could contribute to data privacy, providing support for provider selection, audits, and transparent documentation.

- Cloud services challenge *interoperability* in three major contexts. Firstly, *migrating into or out of the cloud* requires capabilities to move data or applications from or to on-premise Information Technology (IT). Secondly, the *ability to integrate on-premise IT* ensures co-existence of legacy systems and cloud services. *Cloud federation*, finally, aims at composing cloud services from a variety of providers or across systems. Standards that, for example, define homogeneous interfaces or protocols, thus, address this challenge.

- *Portability* addresses the fear of lock-in situations in cloud computing. *Service portability* refers to the capabilities of moving services between providers, while *data portability* allows for moving data.

- *Ensuring fair competition in the market* constitutes a challenge of cloud computing, due to the network effects and first-mover advantages.

- Finally, *compliance with regulatory requirements* is the challenge of adhering to laws, regulations, and industry agreements. Standards provide a basis to overcome the competition of national laws and regulations that result from the ubiquity of cloud computing.

Fields of Standardization

The taxonomy for cloud computing distinguishes technology, management, and legal aspects as the main fields of standardization in cloud computing. We will briefly characterize these fields in the following:

- *Technology* comprises technological fields of standardization in cloud computing. Standards may define *file and exchange formats*, specifying the data structures for communication purposes. Standardized *programming models* provide the basis for the development and (remote) execution of source code. *Protocols and interfaces* define interaction aspects of cloud services and are, thus, required for cloud services to be able to communicate. *Standard components and reference architectures* ease the development of cloud services and ensure the quality of service. Finally, standards for *benchmarks and tests* allow for comparing the performance of cloud services.

- Standards that fall into the *management* field of standardization address business aspects of cloud services. Standards for *business models* provide the foundation for business success of cloud services. *Service Level Agreements (SLAs)* define quality of service characteristics in agreements of providers and consumers. Standards that define *conditions for contracts* provide templates to build licenses or contract agreements. *Management models and processes* allow organizations to apply uniform operations, terminology, and best practices to manage their cloud services. Similarly, *controlling models and processes* provide uniformity to accounting, risk management, and auditing. *Guidelines*, finally, are a means for standards to guide organizations on managing aspects that arise from the combination of the mentioned fields of standardization.

- Standards, finally, address legal aspects of cloud services. Therefore, they may define or may be used to define *legal requirements*, *self-obligations*, or *corporate policies*.

4.2.2. Cloud Standards Profiles

A classification of standards against the taxonomy of challenges and fields of standardization provides an overview of standards and supports the identification standards that address the same category. More comprehensive assessments, however, require additional information on a given standard. We, therefore, developed a *standards profile* that comprises additional attributes to classify standards. Next to the taxonomy elements, a standards profile provides information on basic information, the standard's fields of application, and assessment information.

We derived these attributes from existing literature on standards, aspects of cloud computing, and theoretical work on diffusion of standards. We verified the suitability of the classification attributes in workshops with experts from the Trusted Cloud community.

Figure 4.2 depicts the template for standards profiles that we used to describe cloud standards in the cloud standards study. We will briefly outline standards profile template's attributes and possible values in the following.

Basics

Basic information summarized key facts of standards. Corresponding attributes were:

- *Status:* A standard's status relates to the maturity and, thus, to the amount of changes that are to be expected. A profile distinguishes draft, work in progress and published status of standards specifications.

- *Type:* While the status attribute relates to the maturity of a single specification of a standard, the type of standards relates to its formalization. In the study, we categorized standards as best practice, reference implementation, specification, industry standard, standard, or EU-norm.

Taxonomy	**Challenge**	Efficiency / Effectiveness / Transparency / Information Security / Data Privacy / Interoperability / Portability / Competition / Compliance
	Field of Standardization	File & Exchange Format / Programming Models / Protocols & Interfaces / Standard Components & Reference Architectures / Benchmarks & Tests / Business Models / SLA / Condition of Contracts / Management Models & Processes / Controlling Models & Processes / Guidelines / Legal Requirements / Self-obligations / Corporate Policies
Basics	**Status**	Draft / Work in Progress / Published
	Type	Best Practice / Reference Implementation / Specification / Industry Standard / Standard / EU-Norm
	Cloud Aspects	Implicit / Explicit
	Initiator	< Name of Standard Development Organization >
	Participants	#Participants + Big Players
	Link	< Link to Documents >
Field of Application	**Service Model**	IaaS / PaaS / SaaS / All
	User Group	Provider / Intermediary / Consumer / All
	Industry	Industry Name / Independent
	Deployment	Private / Public / All
	Jurisdiction	DE / EU / International
	Company Size	Small / Medium / Big / All
Assessment	**Maturity**	Low / Medium / High
	Market Potential	Low / Medium / High
	Participation	None / Restricted / Open
Related Standards		< List of related Standards >

Figure 4.2.: Template: Cloud Standards Profile

- *Cloud aspect:* As motivated above, a standard's relation to cloud computing may be implicit or explicit.[20]
- *Initiator:* The name of the organization or consortium that develops the standard.
- *Participants:* The market success of a standard depends on the support by its participants. The names of supporter are, thus, listed in a standards profile.
- *Link:* Easy access to a standards specification builds the basis for further analysis. The study, thus, provided a link to the standards specification in each standards profile.

Field of Application

Next to basic information, the standards profile provides information that describes a standard's fields of application:

- *Service model:* A standard may only apply to a particular service model of cloud computing. The service model attribute, therefore, characterizes the applicability of a cloud standard for any combination of Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS), and Software-as-a-Service (SaaS) (see Section 2.3.1).

[20] In the focus step, we furthermore classified standards to have no relation to cloud computing. However, these standards were excluded from the study, which is why a standards profile only considers the values implicit and explicit.

- *User group:* A standard may not apply to all users of a cloud service. Thus, the standards profile names relevant user groups based on the model of the service provider, the service intermediary, and the service consumer.

- *Industry:* If a standard was specifically designed for a particular industry, these industries are named by the industry attribute of the standards profile.

- *Deployment:* Similar to service models, a standard may not apply to all deployment models. Therefore, the standards profile denominates a standard's relevance for private and public cloud services (see Section 2.3.1).

- *Jurisdiction:* A standard may only apply to a particular geographic region, depending on the origin of its initiator. Assessing standards with a focus on German and European aspects, the study classified jurisdiction using German, European, and international as possible values for the jurisdiction of a standard.

- *Company Size:* The implementation of standards may demand particular organizational structures or involve high costs due to license fees. In consequence, standards may only apply to organizations that can afford standardization. The study classifies the applicability of standards, according to small, medium, and big companies.

Assessment

The last category of attributes captures aggregated information, enabling the assessment of standards. In the cloud standards study, we applied the following three assessment attributes:

- *Maturity:* Based on the status of a standards specification and its type, we derived a rough assessment of the standard's maturity. Corresponding values describe low, medium, and high maturity. Standards should only be classified to have a high maturity if their status is published. The existence of a set of reference implementations was an additional requirement for a classification of high maturity.

- *Market Potential:* Considering the standards developer, additional stakeholders, and the need for standardization, the study classified a standard's market potential. Therefore, low, medium, and high market potentials have been ascribed to standards.

- *Participation:* The degree to which an organization may participate in the development of a standard heavily depends on the organizations that develop a standard. Deriving participation restrictions from the standards developer, a standards profile classified the potential for participation to be none, restricted, or open.

4.2.3. Maps of Cloud Standards

We performed a gap analysis of the portfolio of standards, using a series of maps of cloud standards. The maps present the status quo of cloud standards, summarize the potential of cloud standards and concluded opportunities for the development of additional cloud standards.

We build the maps, using the challenges and fields of standardization of the taxonomy for cloud computing as two dimensions. Combining each challenge and field of standardization, we developed a classification matrix. The set of first-level challenges was, therefore, used to label one dimension while the fields of standardization labeled categories of the other. The classification matrix built the common basis to assess the portfolio of standards, using the above-named series of maps (see Figure 4.3 and Figure 4.4).

We briefly report on the study's maps that summarize the status quo and potentials of cloud standards as well as the opportunities for additional cloud standards. In doing so, we aim at demonstrating the concept of the classification matrix in the following subsections. A detailed interpretation of the respective maps is presented in [20, 75].

Status Quo and Potential of Cloud Standards

Combining the classification of standards with the assessment of a standard's potential to address a given challenge, we developed a map of the status quo and the potential for cloud standards.

Figure 4.3 presents both results, using a combined illustration of the map. The map provides a quick overview of standards that address a given combination of a challenge and field of standardization. Also, it indicates the potential of standardization for all combinations of challenges and fields of standardization. Dark colored boxed, thereby, indicate significant potential, while gray and white shaded areas depict little potential to address a challenge with cloud standards.

Opportunities for new Cloud Standards

Comparing the maturity of cloud standards with the potential of standardization and taking existing standards into account, we performed a gap analysis that presents opportunities for new cloud standards. The map, thus, provides the basis to prioritize and derive future standardization activities. Therefore, it may be used to develop a roadmap for cloud standards.

Figure 4.4 presents a combination of the gap analysis and the potential for cloud standards. High potential for new standards is, thereby, depicted in red. Shades of orange represent vague opportunities. Gray boxes, again, indicate no potential to address a particular challenge with cloud standards.

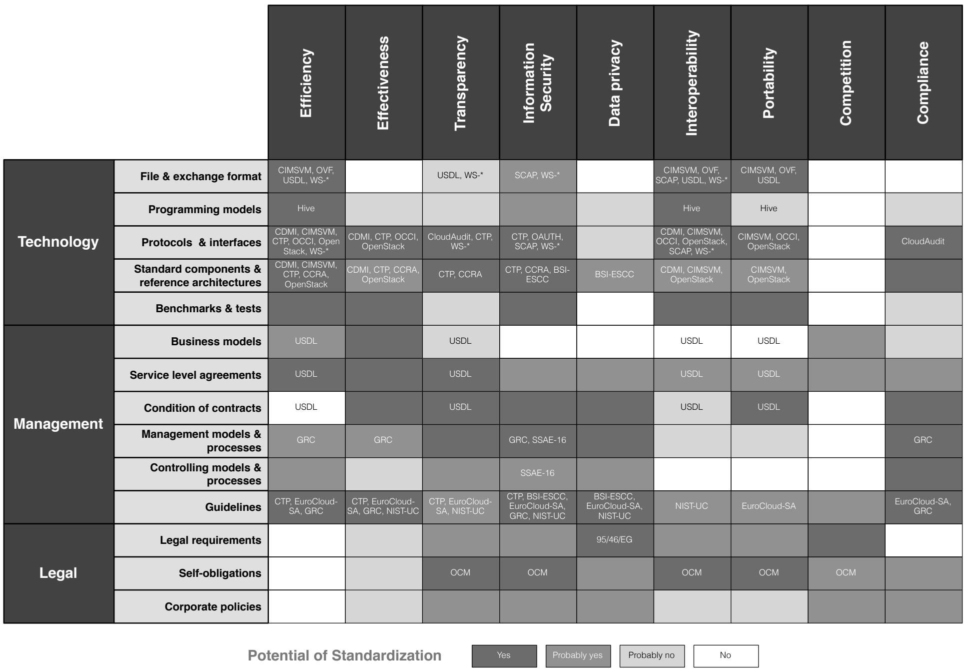


Figure 4.3.: Map: Status Quo of Cloud Standards (2011)

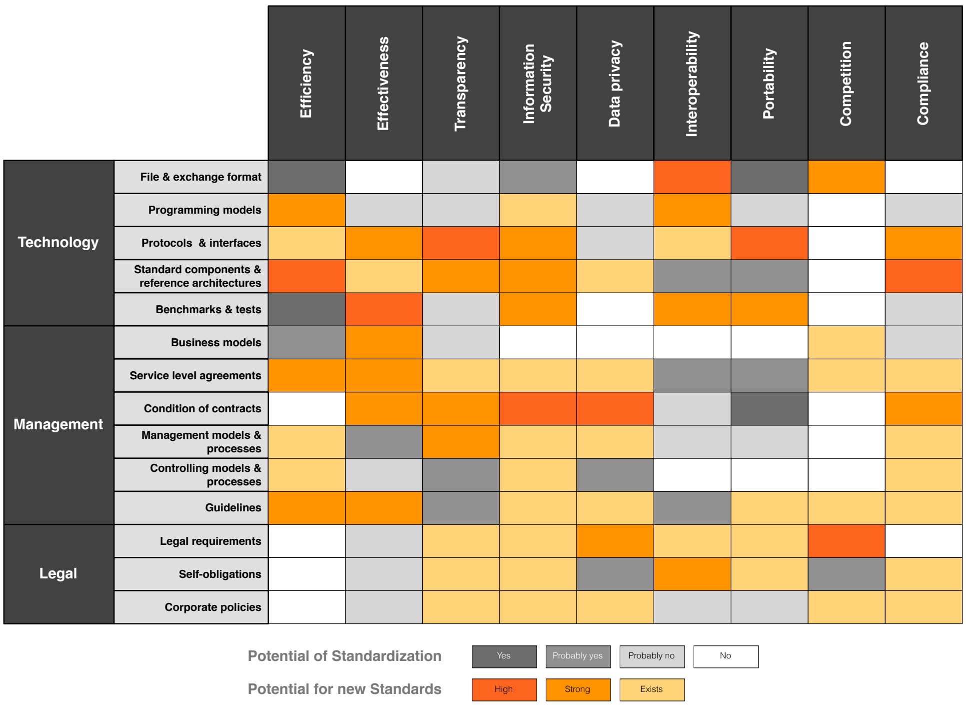


Figure 4.4.: Map: Opportunities for Cloud Standards (2011)

4.2.4. Project-relevance of Cloud Standards

Next to the assessment of the general environment of cloud standards, the study comprised a non-public part that analyzed the relevance of cloud standards. Moreover, we analyzed project-specific potentials for exploiting project results in cloud standardization for each of the 14 Trusted Cloud projects. The results were presented as ordered lists, summarizing the relevance of cloud standards of for each of the Trusted Cloud project.

Generating the list of relevant standards, we screened the documentation for each of the 14 Trusted Cloud projects. We applied questionnaires to assess the project-specific relevance of challenges and fields of standards (see Appendix A.1). Based on this information, we classified the focus of each Trusted Cloud project, applying the taxonomy of cloud standards. Similar to the classification of cloud standards, we, thus, created short characterizations of the projects that prioritized challenges and fields of standardization for the respective project. Finally, we created a ranking of standards that appeared relevant to a project by matching standards profiles and project descriptions. Relevant standards were, thereby, ranked based on a four-point Likert-scale, where Level 4 indicated high-relevance. Level 1, consequently, indicated little relevance. Standards without project-specific relevance were not included (i.e., the results did not state Level 0 relevance).

Due to confidentiality requirements, we cannot disclose specific recommendations that we made to the Trusted Cloud projects. Figure 4.5, however, presents the template summarizing the project-relevance of cloud standards.

Standard	Relevance
Name of Standard #1	Level 1 / 2 / 3 / 4
...	Level 1 / 2 / 3 / 4

Figure 4.5.: Template: Project-relevant Cloud Standards

4.3. Reflection and Lessons Learned

In this chapter, we presented a summary of the cloud standards study that was conducted in the first phase of this dissertation thesis. Through reflection and learning, we will now refine the research challenges presented in Section 2.4 that motivate the development of our method to assess standards of emerging technology in disruptive innovation. In doing so, we add a practical and experienced-based perspective to the foundations that we derived from state-of-the-art literature. Based on the learnings, we generalize method requirements that will guide the development of our conceptual information model (see Chapter 5) and the assessment method (see Chapter 6).

4.3.1. Modularize Assessment Information

Building a commonly agreed classification scheme was key to the successful assessment of cloud standards (see Section 4.2). In the study, we developed a taxonomy for cloud computing that comprised validated sets of potential scopes and subjects of cloud standards using challenges and fields of standardization (see Appendix A.1). Additional assessment information was included into the standards profile to enable the varying evaluation purposes (see Section 4.2.2).

Reflecting our approach, we identify two challenges when building a common classification scheme for standards assessment in disruptive innovation:

- *How to enable information reuse?*

  We segmented information into basic information, fields of application, and assessment information. The segmentation, however, was only performed to structure sets of related information. In particular, we did not respect dependencies of assessment information when building cloud standards profiles in the study. In consequence, classifying standards using cloud standards profiles lead to excess efforts. The jurisdiction of a cloud standard and opportunities to participate in standards development depends on, for example, the type of the standards developer. Likewise, there is a dependency between the maturity of a standard and its status and type. In addition, the assessment of a standard's market potential requires a prior assessment of maturity and network effects (e.g., amount and types of supporting stakeholders). If dependencies between assessment attributes are known, information could be reused when classifying or evaluating standards. In consequence, there arises the challenge of how to enable information reuse in standards assessment.

- *How to enable collaboration among stakeholders?*

  Finding a standard that matches the requirements of a particular product or service is a challenging task. Strategic decisions on the portfolio of standards (e.g., "who supports the standards?") and operational decisions on individual characteristics of a standard (e.g., "which technology does the standard apply to?") have to be taken into account. We aggregated initial information on standards assessment from Questionnaires A.1 and A.2 and presented the results to members of each of the 14 Trusted Cloud projects in face-to-face workshops (see Section 4.2.4). Reflecting the results generated in these workshops, we identify that stakeholders could more easily argument against existing assessments of standards than developing an assessment of standards from scratch. However, not all experts were equally capable of providing feedback using complete standards profiles. They demanded capabilities to filter information, according to their expertise or scope of standards assessment. The latter is determined by the scope of the cloud service for which standards should be assessed. Consequently, the question arises on how to enable collaboration among stakeholders in standards assessment in a way that enables stakeholders to contribute their different competencies.

Modularization of assessment information, i.e., segmentation of information into subsets, is a means to enable information reuse and collaboration among stakeholders. Based on our learnings from the cloud standards study and the foundations presented in Chapter 2, we derive information requirements for supporting classification and evaluation of standards in disruptive innovation in the following.

Information Requirements

Table 4.1 summarize the information requirements for assessing standards in disruptive innovation described in the following.

A method to support the assessment of standards has to create a common classification scheme that comprises technology, fields of standard, and type of standard (*IR-1*). The goal of developing the classification scheme is to find the set and structure of categories that are relevant for the given domain of disruptive innovation. Relevance should be assured with regards to technology and standards evolution as well as the purpose of using the classification.

Standards build dependencies to other standards. The classification and evaluation of these dependencies is an important task to understand the value of a standard or predict its potential for market success. The assessment of standards in the cloud standards study only considered related standard on the basis of shared subjects or scopes. A method to assess standards in disruptive innovation, however, should classify standards according to their dependencies (*IR-2*). In doing so, subsequent evaluations of standards and portfolios are supported.

The interplay of technology and standards differs with the domain of disruptive innovation. Thus, classifications of standards will involve different attributes for different domains of disruptive innovation. A method to assess standards in disruptive innovation, therefore, should support the integration of domain-specific attributes into the classification schema (*IR-3*). In doing so, the method will apply to different domains of disruptive innovation.

ID	*Requirement*	*Rationale*
IR-1	Support classification of scope, subject, and type	Scope, subject, and type are key characteristics of standards, enabling a variety of analyses.
IR-2	Support classification of standards dependencies	The relation of two or more standards may be described from different viewpoints.
IR-3	Support domain-specific classification attributes	Different domains of disruptive innovation demand different classification attributes.
IR-4	Support measures for network effects	The value of standards is determined by network effects. Thus, information to evaluate network effects is required.
IR-5	Support stakeholders and roles	Stakeholders can only classify a subset of information.

Table 4.1.: Information Requirements

Standards derive values from network effects. The amount of stakeholders, their types, and the count of a standard's implementations constitute information that could be used to estimate network effects. While these effects are hard to quantify, a method to assess standards should incorporate information that allows for deriving measures of network effects (*IR-4*)

Stakeholders are only able to contribute to the classification of standards based on their expertise. Stakeholders choose varying organizational forms, enact different roles with varying, potentially opposing motivations to participate in standardization [109]. A method to support standards assessment, thus, should incorporate the viewpoints of different stakeholders to distribute classification efforts among the stakeholders, and filter information according to their needs (*IR-5*).

4.3.2. Coordinate Assessment Tasks

Classifying and evaluating standards in disruptive innovation are difficult as the environment that defines the context of standards only starts to develop. In the early phases of disruptive innovation, technology, concepts, or terminology evolve quickly (see phases inception, traction, and hypergrowth in Section 2.2.2). The assessment of standards in disruptive innovation, thus, is required to cope with the dynamic environment. Specifically, we identify the following challenge:

- *How can the iterative execution of assessment steps be coordinated?*

  The approach to assess cloud standards applied steps to the generic scope, group, evaluate, and report approach (see Section 2.1.4). We manually adapted the taxonomy to changes of the environment according expert feedback. As long as standards profiles had not been fully completed, changes to taxonomy and standards profiles were manageable. However, changing the taxonomy or the set of additional classification attributes at a later point of time resulted in considerable efforts. We stopped updating the taxonomy to changes in the environment, being limited in time and budget. Applying a fixed taxonomy, we, thus, assessed a snapshot of cloud standardization. Dynamics of disruptive innovation, however, led to a situation where some of the information was already outdated at the time of publishing the report. Also, standards that appeared prior to the release of our study could not be considered.[21] Assessment of standards assessment in disruptive innovation, thus, demands iteration of the tasks to develop or update the classification scheme, classify standards, update standards profiles, or evaluate standards. Thus, the question arises how the iterative execution of assessment steps can be coordinated in standards assessment. In particular, sequential constraints of assessment steps should be identified and managed.

[21] In a subsequent publication, we included the Topology and Orchestration Specification for Cloud Applications (TOSCA) standard to our portfolio of standards. While the standard was released after publishing the initial study, our criteria to focus and scope standards would have considered TOSCA to be included in the results (see [75]).

Processes allow for defining sequential constraints on activities. Generally, a method to support standards assessment in disruptive innovation is to incorporate perspectives that reflect the capabilities, motivations and drivers of stakeholders while guiding classification and evaluation activities. In the following, we will formulate process requirements that guide the development of our method to support standards assessment in disruptive innovation.

Process Requirements

The process requirements described in following are summarized in Table 4.2.

A method to support the assessment of standards in disruptive innovation is required to guide stakeholders in updating the classification scheme if the environment of standards changes (*PR-1*).

As the concepts mature, standards become more comprehensive and evolve from definitional work into detailed specifications of technological components. In consequence, standards specifications may vary significantly in scope and detail from draft to publication. Even in the short time-frame that was covered by the cloud standards study, we experienced standards that changed names, significant stakeholders, subjects, or scopes. A method for standards assessment, therefore, should provide support for changing the classification of standards (*PR-2*).

Continued assessments of standards in disruptive innovation, however, demand the participation of different stakeholders that may not be familiar with standards development or the approach of standards assessment. Therefore, a method to assess standards in disruptive information should coordinate updates to the classification scheme and classifications (*PR-3*). In doing so, classifications are kept in sync with changes to the classification scheme.

ID	*Requirement*	*Rationale*
PR-1	Support updates of the classification scheme	Dynamics of disruptive innovation require adaptations of the classification scheme.
PR-2	Support updates of classifications	Classifications might change over time.
PR-3	Coordinate updates	Changes to the classification scheme require re-classification and re-evaluation. Classification and evaluation may trigger changes to the classification scheme and vice versa.
PR-4	Support contextualization	Applying the same classification scheme to characterize the purpose of the evaluation supports the selection of standards profiles.

Table 4.2.: Process Requirements

Stakeholders should be guided in the process of evaluating standards. In the cloud standards study, we classified the Trusted Cloud projects, according to the taxonomy of cloud standards. A method to support the evaluation of standards, thus, should support the creation of a contextualized classification scheme, comprising the subset of categories and attributes that are relevant in the situation of the evaluation (*PR-4*).

4.3.3. Improve Efficiency by Task Automation

Reasoning over objects makes use of abstractions and generalizations to counter complexity [46]. A method to support standards assessment, thus, is to support aggregation of assessment information. Based on our experiences from the cloud standards study, we formulate the following challenge:

- *Can standards assessment efforts be reduced by task automation?*

  In the study, applying changes to the taxonomy and standard profiles were taken care of manually. In doing so, we were required to consolidate and harmonize the different artifacts such as questionnaires or expert feedbacks. Matching project profiles and standards profiles, likewise, was done manually by the researchers that conducted the study. In addition, the aggregation of information to develop maps to support strategic decisions required manual efforts (see Section 4.2.3). The nature of the respective tasks, however, required only little human reasoning, which is why we identify the challenge of reducing assessment efforts by task automation.

A method to support repeated assessments of standards should target at minimizing manually efforts to coordinating and aggregation assessment contributions. However, only tools that implement the assessment method will realize automation. In the following section, we will derive automation requirements that aim at reducing assessment efforts.

Automation Requirements

Table 4.3 summarizes the automations requirements discussed in the following.

Using questionnaires leads to varying assessments. In the context of the study, we had to consolidate different classifications of standards, mostly, by using scoring-based techniques. A method to support the assessment of standards, however, may automate the aggregation of classifications *(AR-1)*.

The classification of standards may apply attributes that infer their values from other attributes. In the cloud standards study, we, for example, derived a standard's potential for market success based on the assessment of its stakeholders and the principal potential of standardization as defined by its scope and subject. Likewise, we determined related standards by manually identifying standards with similar scopes and subjects. A method to support the assessment of standards, thus, may automate the determination of attributes value and related standards (*AR-2*).

ID	*Requirement*	*Rationale*
AR-1	Consolidate values from multiple classifications	Varying stakeholders provide classifications that should be consolidated.
AR-2	Support determination of dependencies and attributes	Identification of dependency and standards attributes is well structured but tedious.
AR-3	Aggregate standards	Aggregation is required to summarize portfolios of standards.
AR-4	Rank standards	Ranking enables prioritization of standards.

Table 4.3.: Automation Requirements

Likewise, aggregation activities to create maps, depicting dependencies of standards or potential for new standards, were done manually in the study. A method to support the assessment should provide capabilities to automate required aggregations, using the common classification scheme (*AR-3*).

Due the multitude of standards that should be considered in supporting the assessment of standards, an evaluation of standards for a product or service will result in a set of matching standards. Ranking of standards according to the stakeholder's preferences, thereby, supports ordering of the standards' applicability to the given context. A method to support the evaluation of standards, therefore, may automate the ranking of standards, providing an ordered list of matching standards (*AR-4*).

4.4. Conclusion

In the previous sections, we presented a summary of our study of standards in cloud computing. Based on the reflection of the study's approach and results, we refined challenges and derived requirements that motivate the development of a method and tools to support standards assessment. While our findings result from experiences in the Trusted Cloud program and focus on cloud standardization, the features integrate practical experience with requirements of standardization, disruptive innovation, and technology management. Thus, we believe that the features can be applied to other disruptive innovations (see Chapter 9).

According to the identified requirements, a corresponding method should focus on assessing standards based on observing and classifying their dynamic environment. Furthermore, it should support decisions that require the assessment of a portfolio of standards. In addition, the method should provide support to automate the coordination and aggregation of contributions from a community of stakeholders in disruptive innovation. In doing so, the method may contribute to reducing related standards assessment efforts.

In the following chapters, we develop a conceptual information model (Chapter 5) and a corresponding method to assess standards (Chapter 6). The conceptual information model defines the common structure to manage classification and evaluation information. The method covers dynamic aspects of standards assessment and provides features to automate coordination and aggregation in standards assessment.

5. Conceptual Information Model for Standards Assessment

In this chapter, we will present a conceptual information model to support the assessment of standards of emerging technology in disruptive innovation. The model structures the data that is required to classify and evaluate standards. Thereby, it ensures homogeneity of data structures and provides a basis for reusing assessment information. In doing so, the conceptual information model founds the basis for the development of our method for Assessing Standards of Emerging Technology (ASSET) (see Chapter 6) and development of standards assessment tools (see Chapter 7).

We use class and datatype diagrams as defined in [140] to present our conceptual information model. Additionally, we use examples from cloud computing to substantiate our conceptual discussion with practical evidence. In doing so, we briefly introduce selected aspects of cloud computing and cloud standards in this chapter. A detailed discussion the model's application to the domain of cloud standards, however, will be given in Chapter 8.

We present a conceptualization of the problem to assess standards in disruptive innovation in Section 5.1. Next, Section 5.2 discusses entities for modeling standards and the technology framework of disruptive innovation. In Section 5.3, we detail how the model represents different types of standards. The model captures different dependencies between standards, the set of corresponding relationships will be presented in Section 5.4. A conceptualization of stakeholders and their roles in standards assessment will be introduced in Section 5.5. The conceptual information model comprises a conceptualization of classification attributes and their valuations by stakeholders. Section 5.6 presents the corresponding concepts. We will complete the conceptualization of the model by presenting the representation of the technology typology in Section 5.7. Our summary discusses the main contributions of the conceptual information model in Section 5.8.

5.1. Conceptualization

Applying the definition of a standard given in Section 2.1, any model to represent information on standards is to capture a standard's *scope*, its *subject*, and its *environment*. Subject, scope, and environment of a standard, however, vary in different fields of application. Thus, different domains of disruptive innovation are characterized by different scopes, subjects and environments for standards.

Based on the basics of disruptive innovation, presented in Section 2.2, a domain of disruptive innovation consists of a technology framework, a business framework, and a legal and regulatory framework (see Figure 2.3). The technology or business framework comprises technologies and business aspects respectively. Standards can be defined for technologies or business aspects of a disruptive innovation. In addition, any standard may found the basis for a legal and regulatory framework that constrains the market of a disruptive innovation.

Domain Typology

A typology structures conceptual categories for classifying real world objects (e.g., standards or technologies). Typologies, in contrast to taxonomies, are not required to build only on observable characteristics of real world objects, but allow for creating ideal types that may currently not be present in the real world (see [167]).

A *domain typology*, thus, provides the classification scheme that is required for classifying standards in a domain of disruptive innovation. Conceptionally, a domain typology consists of two sub-typologies: one for technology aspects (i.e., *technology typology*) and one for business aspects (i.e., *business typology*). Figure 5.1 depicts the relationships between real-world objects (e.g., standards or technology) and their conceptual counterparts (i.e., technology typology and business typology). Conceptual constructs are depicted in gray boxes while real world objects are represented in white boxes.

In this dissertation thesis, we focus on assessing standards of emerging technology in disruptive innovation. In doing so, we focus on developing a conceptual information model to represent a technology typology (see dashed area in Figure 5.1).

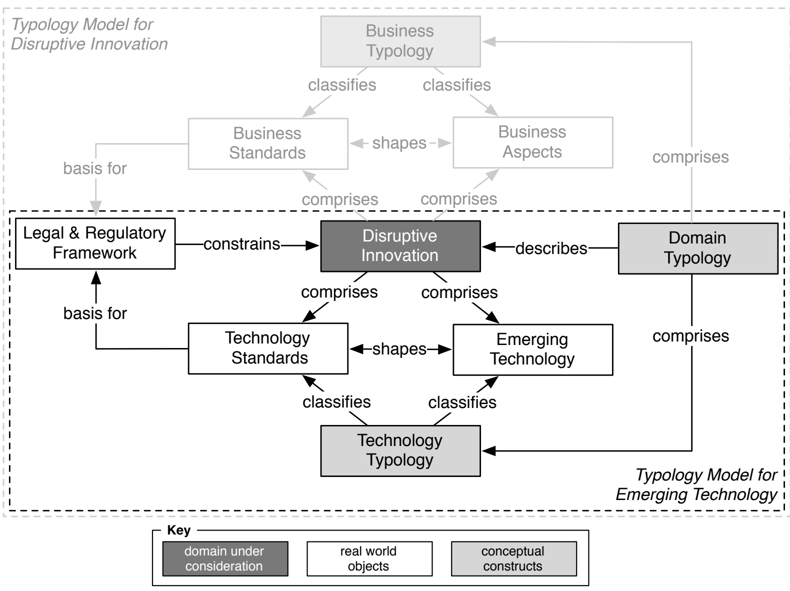


Figure 5.1.: Concept: Assessing Standards of Emerging Technology

Typology Instantiation

Methodologically, the conceptual information model constitutes a meta-model, providing types of entities and their relationships that define a language to model a domain-specific typology (see, e.g., [171, 17, 104] for detailed discussions of meta-modeling).

In consequence, the conceptual information model, however, does not comprise entities that describe a given application domain of disruptive innovation. Using the information model to assess standards in a domain of disruptive innovation, thus, requires instantiation of the conceptual information model.

Figure 5.2 illustrates the instantiation of the information model for assessing standards in cloud computing. A cloud technology typology comprises, for example, technologies, technology fields, and standards fields that build the technology framework of cloud computing.

5.2. Technology Framework

The conceptual information model represents the technology framework of a disruptive innovation using an entity for standards (see *Standard*), a StandardsField[22] entity, a Tech-

[22] Throughout this thesis, we will apply camel case when referring to the entities and instances of entities of the conceptual information model.

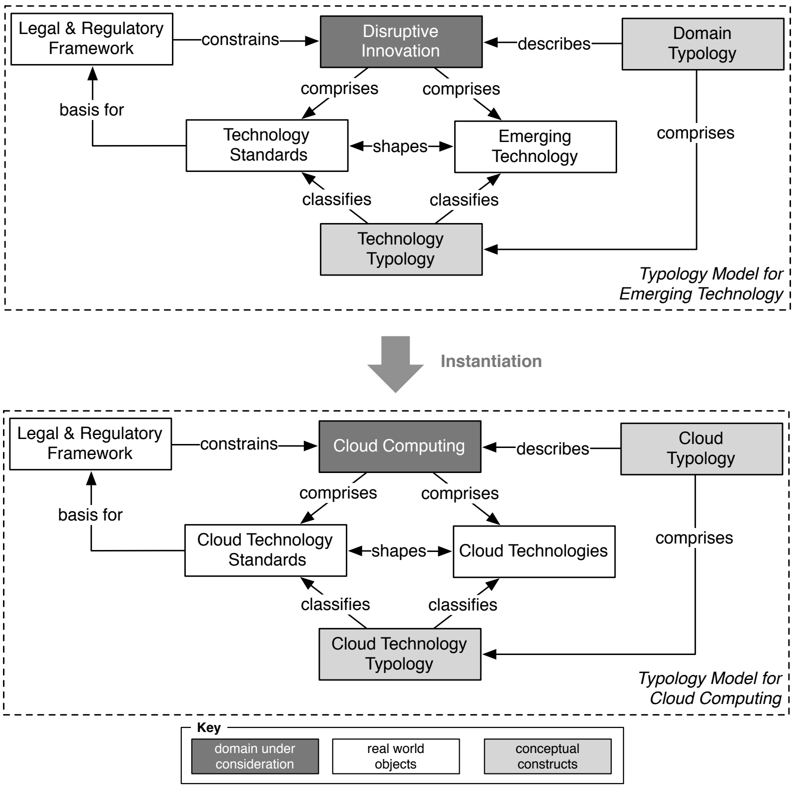


Figure 5.2.: Concept: Domain-specific Information Model

nology entity, an entity for TechnologyFields, and an entity to represent implementations of standards and technologies (see *Implementation*). In addition, the model comprises an entity to represent standards that are used to define the legal and regulatory framework of a disruptive innovation (see *LegalAndRegulatoryFramework*).

Figure 5.3 depicts the set of entities applied to model the technology framework of a disruptive innovation. We will introduce each entity and its relevant relationships in the following.

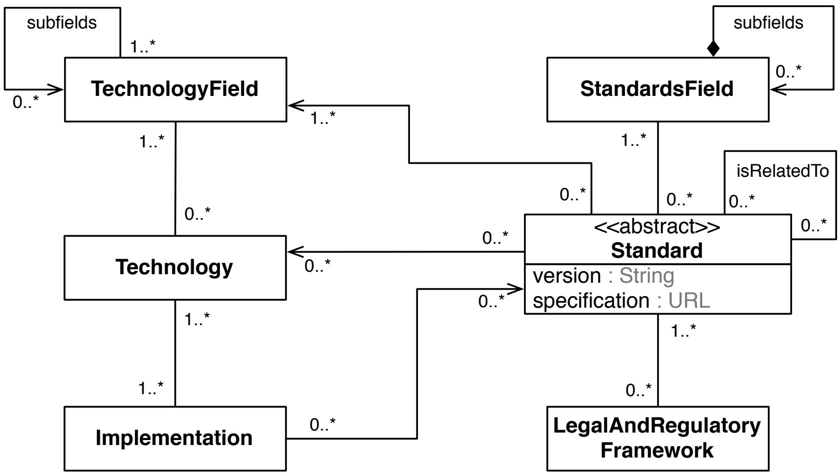


Figure 5.3.: Conceptual Information Model: Technology Framework

Standard

The *Standard* entity is the conceptual information model's most central element. It represents de jure or de facto specifications of a standard as well as best practices, guidelines, vocabulary, taxonomies, and reference models. Conceptionally, the Standard entity is an abstract class. Therefore, an instantiation of the conceptual information model will not create Standard instances directly, but is required to instantiate the BaseStandard or StandardProfile entity (see Section 5.3).

We designed the model to keep a classification for every version of a standard, supporting the coexistence of multiple versions of a standard at the same time. Next to the *inherited basic properties*[23], a Standard entity, therefore, carries a *specification-* and a *version-*property.

Both, the version, and the document property are defined final—i.e., will be supplied if a standard is classified for the first time—and should not be changed after that. In doing so, we aim at freezing a snapshot of a standard at a given point in time and at supporting concurrent versions of a standard. Information and Communication Technology (ICT) provides plenty of examples, where different versions of standards coexist for years after

[23] Parent of all entities in the conceptual information model is the *BaseObject* entity. Every entity, thus, inherits a basic set of *id-*, *name-*, and *description-*properties (see Appendix B.2).

a new specification was available. The versions 1.1 and 2.0 of the Web Service Definition Language (WSDL) specification provide a primer example, demonstrating how two versions of the same standard differ, co-exist, or even compete over years. Similar arguments can be made for Business Process Model & Notation (BPMN) versions 1.1 and 2.0. As indicated by these examples, different versions of a standards specification may differ significantly in scope and subject. Conceptualizing the model to handle coexistence of multiple versions of a standard, thus, provides the basis for analyzing differences.

The conceptual information model captures a standard's scopes, subjects, and environment, defining associations from the Standard entity to all remaining entities that constitute a standard's technology framework. We will now introduce these entities and describe the information that is captured by their relationships to the Standard entity. Dependencies between standards—as modeled by the reflexive *isRelatedTo*-association—will be detailed in Section 5.4.

StandardsField

The StandardsField entity represents the scope dimension of classifying standards. The scope of a standard, for example, is a data and exchange format (see, e.g., the Open Virtualization Format (OVF) standard in Section 8.4). We define a structure of StandardsFields entities to represent varying hierarchies of a standard's scope (see *subfields*-association). A StandardsField instance may comprise many sub-fields. However, only one parent StandardsField instance is allowed.

Following the typology concept (see Section 5.1), the StandardsField entity is a theoretical construct. Therefore, there may be instances of the StandardsField entity that anticipate scopes of future standards. A StandardsField, thus, may not classify any standard at a given point in time. A standard must always be categorized by at least one StandardsField. Also, a standard may describe a solution comprising more than one scope, i.e., a standard may describe a data and exchange format and an Application Programming Interface (API). Thus, there might be more than one StandardsFields that a standard is ascribed to. The conceptual information model, consequently, models a many-to-many-relationship between Standard and StandardsField entities. Standards, thus, must be classified by at least one StandardsField instance. In turn, not all instances of the StandardsField entity are required to refer to instances of the Standard entity.

Technology & TechnologyField

Modeling the technology framework of disruptive innovation, furthermore, requires a representation for emerging technology (see Figure 5.1). The conceptual information model, therefore, introduces *Technology* and *TechnologyField* entities.

A *Technology* entity represents any technical system or sub-system of a product or a service (see Section 2.2.2). Technology, thus, is directly perceived by consumers of the product or service.[24] The Technology entity represents the subject of a standard. Technology instances, thus, complement the characterization of standard's scope using StandardsFields.

A standard may, however, standardize a set of technologies. Reference models or vocabularies, for example, typically apply not only to one single technology, but to a set of technologies. We apply the *TechnologyField* entity to structure technologies. TechnologyFields, thus, allow for aggregating the subject of a standard. In cloud computing, virtualization could be a TechnologyField that comprises, for example, machine image technology. Another technology within the virtualization TechnologyField is, for example, hypervisor technology. Providing aggregation support, the model defines the *subfields*-association for structuring technology fields.

The subject of a standard, thus, can be modeled as follows:

- Firstly, a Standard instance can be directly associated to a Technology instance. A standard may, thereby, refer to zero or more Technology instances. Thus, there may be standards that are not directly related to a particular technology. Likewise, Technology may relate to zero or more Standard instances.
- Secondly, a standard can be developed to guide an entire TechnologyField. Thus, the model comprises a relationship between the Standard entity and the TechnologyField entity. Again, zero or more instances of the TechnologyField entity can be related to one Standard instance.

Since, both, the associations between the Standard and Technology entities and the Standard and TechnologyField entities do not define minimum cardinalities, the conceptual information model may capture technologies or fields of technology that are not (yet) standardized. An instance of the Standard entity must, however, relate to at least one TechnologyField instance. In doing so, all standards comprise a subject and, thus, are consistent with this thesis' definition of standards (see Section 2.1).

Implementation

The success of a technology or a standard depends on its widespread. Both, technologies and standards, therefore, must be implemented in products or services. The number of available implementations may, for example, be used as an indicator of market success. The conceptual information model defines the *Implementation* entity to represent a product or a service.

Every Technology instance requires at least one implementation. Standards, likewise, require implementations. There are, however, standards that are not at the level of concrete implementations. Best practices may, for example, define guidelines on how to develop a highly-secure cloud storage service. Referring to the respective cloud storage services as being implementations of the best practice, however, is far-fetched.

[24] Technology in the broader sense comprises processes as well as tools and methods that are required to build the product or service. See Section 2.2.2 for further details of this distinction.

An implementation may not only implement one technology nor may it be governed by only a single standard. For example, OpenStack Compute provides an operating system to offer on-demand computing resources.[25] In doing so, OpenStack Compute constitutes an implementation of both hypervisor and machine image technology. In addition, its API for managing the state of virtual machines was designed according to the Open Cloud Computing Interface (OCCI) standard. OVF will eventually be a machine image format that is supported by OpenStack Compute.[26] The example of OpenStack Compute, thus, illustrates the need for an implementation to be able to build an association to more than one Standard instance.

Legal & Regulatory Framework

Standards found the basis of the disruptive innovation's legal and regulatory framework, comprising laws, acts, and regulations. Public authorities may cite or demand standards to do so. Health care is a sector, where standards are, for example, heavily involved in defining the legal & regulatory framework (see, e.g., [89]). The classification of standards in disruptive innovation is, therefore, required to trace the legal and regulatory framework that influences technology progression.

The conceptual information model, therefore, defines a *LegalAndRegulatoryFramework* entity. Instances of this entity may represent any national, regional, or international law, act or regulation. While a standard may be referenced by many LegalAndRegulatoryFrameworks instances, the model requires a LegalAndRegulatoryFramework instance to relate to at least one Standard instance. In doing so, only laws, acts, and regulations will be considered that are relevant to assessing standards in disruptive innovation.

5.3. Types of Standards

Section 2.1.3 provided an overview of state-of-the-art classifications for standards. Conceptually, these types of standards are, in fact, not characteristics of the Standard entity, but are determined by the relationships that a Standard instance builds to instances of other entities. Modeling these characteristics as individual types of standards, therefore, would complicate the model due to duplication of information.

As presented in Figure 5.4, the model, therefore, only comprises base standards (see *BaseStandard*) and standard profiles (see *StandardProfile*). This distinction roots from the dilemma of standardization, i.e., standards that aim for broad applicability while trying to create specifications that are as precise as possible. Separating specifications into base standard and standard profiles is a common means to overcome this dilemma [4]. While base standards are broad in their applicability (e.g., by defining a meta-model), standard profiles provide application-specific extensions.

[25] See `http://www.openstack.org/software/openstack-compute/` for more details.

[26] At the time of writing, OpenStack Nova did not yet support OVF as a format for machines images. The use of OVF required manual extraction of image files.

We will summarize specifics of the respective entities to represent base standards and standard profiles in the following.

BaseStandard

The *BaseStandard* entity represents a standard that does not specialize concepts that are defined in another standard. Instances of the BaseStandard entity are, thus, self-contained, i.e., describe all information that is required to understand the standard.

Most available standards are considered base standards. Applying the model, the standards mentioned above, OVF and OCCI, for example, would be represented by creating instances of the BaseStandard entity.

StandardProfile

Standard profiles are a means to adapt a generic and, thus, broad specification for a given application field. In doing so, a StandardProfile entity is not self-contained but has a reference to one instance of the BaseStandard entity. The StandardProfile entity, thus, represents a standard that adapts a BaseStandard entity, i.e., "identifies the classes, properties, methods, and values that should be instantiated and manipulated to represent and manage a given domain" [3, p. 17].

The standards published by the Distributed Management Task Force (DMTF) for the management of computing resources present examples for StandardProfile instances in the context of cloud computing (e.g., [5] is a profile for [2]).

5.4. Dependencies of Standards

Standards do not stand in isolation. A set of standards, rather, forms a *complex system*[27], where standards interact to accomplish the task of standardization [31]. The conceptual information model, therefore, describes dependencies between standards from a *content-related*, a *market-related*, and a *temporal* dimension:

[27] In the context of standardization, a complex system is understood as "a set of interacting components that operate together to accomplish a purpose." [186, p. 1].

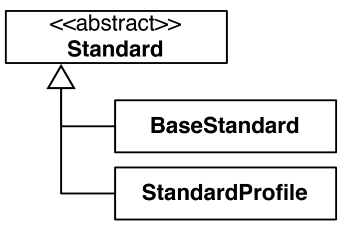


Figure 5.4.: Conceptual Information Model: Types of Standards

- *Content-related dependencies* arise if a standards specification refers to the content of another standard. These referrals may be *explicit* or *implicit*. Instances of the StandardsProfile entity, for example, explicitly refer to a BaseStandard instance. Likewise, there are standards that endorse an international or regional standard on the national level. Such endorsement standards, refer to international standards and republish identical content or content that is translated into a local language. Implicit referrals are the results of standards specifications that address different aspects of a technology. Conceptually, two standards implicitly depend on one another, if they address the same TechnologyField or Technology instance, but fall into different StandardsField instances. In addition, implicit dependencies between standards exist, if two or more standards from the same StandardsField describe different technologies of the same TechnologyField instance.

- Moreover, standards are exposed to *market-related dependencies*. The development of standards can be understood as the conquest establish dominance of a technology given in a given market (see Section 2.1.1). Especially, in the early phases of technology development a multitude of competing standards approaches exist. The model allows for conceptualizing market-related dependencies of standards using instances of the *StandardsField*, *Technology*, and *TechnologyField* entities. Competing standards are characterized by addressing the same Technology or TechnologyField instances, but different StandardsField instances. Moreover, two or more standards may constitute complements. Complementing standards address different aspects of a disruptive innovation, i.e., address different StandardsField instances, but share the same Technology or TechnologyField instance. Complements can, additionally, be found, if standards from the same standards field address different Technology or TechnologyField instances.

- Finally, there are *temporal dependencies* between standards. The coexistence of different versions of the same standard may, for example, be frequently observed (see Section 5.2). Different versions of the same standard may appear to be, both, content- and market-related. More important, however, is their sequential temporal dependency. Any two standards may be described to have a *concurrent* or *sequential* dependency.

Figure 5.5 summarizes the perspective and parameters of the varying dependencies of standards. We will use this template to describe the five types of dependencies that the model defines in the following.

<table>
<tr><td>Content</td><td colspan="3">Implicit</td><td colspan="3">Explicit</td></tr>
<tr><td>Market</td><td colspan="2">StandardsField</td><td colspan="2">Technology</td><td colspan="2">TechnologyField</td></tr>
<tr><td>Temporal</td><td colspan="3">Concurrent</td><td colspan="3">Sequential</td></tr>
</table>

Figure 5.5.: Template: Standards Dependencies

The conceptual information model defines a structural *isRelatedTo*-association to represent the varying optional dependencies of standards (see Figure 5.6). Conceptually, any Standard instance may be related to zero or more other Standard instances. The abstract

RelationshipType entity is used to characterize defined relations between Standard instances. Sub-types of the RelationshipType entity, however, define the concrete type of the dependency of standards.

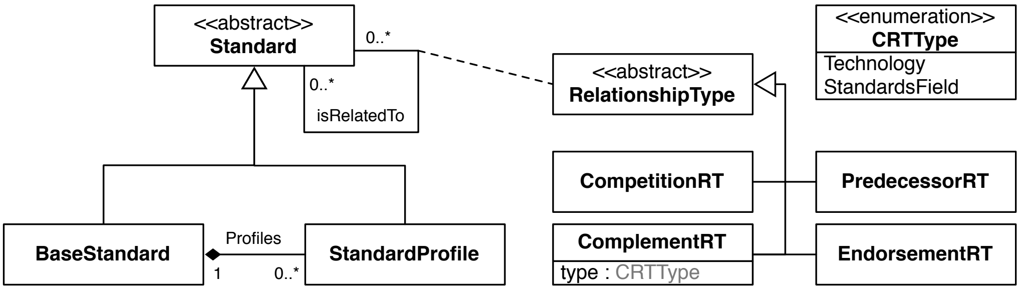


Figure 5.6.: Conceptual Information Model: Dependencies of Standards

Profile Dependency

In standardization, profiles are used to tailor a standard to a particular application domain. The extensibility of standards is typically achieved through profiling. A standard profile can only be understood in the context of its base standard (see Section 5.3).

A *profile dependency*, thus, is characterized by explicit content dependencies, i.e., StandardProfile instances that refer to BaseStandard instances. They address different Technology or TechnologyField instances but share the same StandardsField instance. From a temporal perspective, a StandardProfile instance and a BaseStandard instance have to be available concurrently. Figure 5.7 summarizes the characterization of a profile dependency.

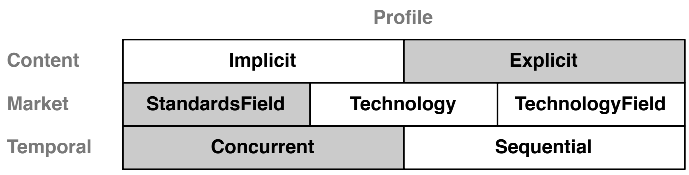


Figure 5.7.: Characterization: Profile Dependency

The conceptual information model applies a *Profiles-composition* to represent the mandatory dependency of standard profiles and base standards (see Figure 5.6). Using a composition, an instance of the StandardProfile entity cannot exist without its corresponding BaseStandard instance. A StandardProfile instance is, therefore, required to have exactly one relation to a BaseStandard entity. A BaseStandard instance, obviously may refer to zero or more StandardProfile instances.

Competition Dependency

Standards compete for market dominance. This applies particularly during the early phases of disruptive innovation, i.e., before the technology framework has stabilized.

Here, a plurality of specifications can be found, being issued by a variety of stakeholders.

A *competition dependency* demonstrates an implicit content-dependency of standards, i.e., standards do not explicitly refer to competing standards. Competition can be identified, if any two standards address the same Technology instance with the same scope (i.e., same StandardsField instance). Two standards share the scope if they apply the same StandardsField instances. The temporal perspective is concurrent, i.e., regards standards that are available on the market at the same time. Figure 5.8 illustrates this characterization of the competition dependency.

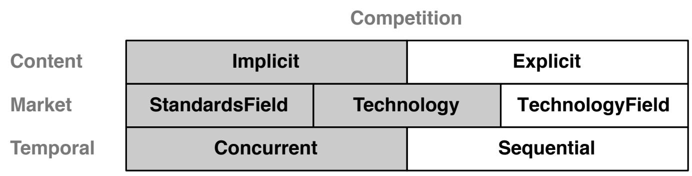


Figure 5.8.: Characterization: Competition Dependency

The model represents competing standards by typing the *isRelatedTo-association* with an instance of the *CompetitionRT* entity.

Complement Dependency

Complementary standards address different aspects of the same problem domain. They are typically developed by different organizations. Typically, however, individual and autonomous working or task groups will handle the development of each standard. Complementary standards do at least differ in scope or subject and have, typically, not been developed with the goal to complement one another. The management of complementary standards becomes particularly important as soon as a disruptive innovation enters the phase decisive battles (see Figure 2.4). Here, complementary standards help in reducing the cost of standardization as they might be applied to different products or services [177].

There are two types of complementing standards: Standards may complement scopes or the subjects. Two or more standards build a *StandardsField complement*, if they differ in their StandardsField instances, but share the same Technology or TechnologyField instance (see Figure 5.9). *Technology complements*, on the other hand, share the same StandardsField instance but differ in their subject. Thus, they address different Technology or TechnologyField instances (see Figure 5.10). Both types of complements share the content-based and temporal dependency. They do implicitly reference related standards, and their market presence is concurrent.

The conceptual information model introduces the *ComplementaryRT* entity for typing structural association of the abstract Standard entity (see Figure 5.6). The model reflects differentiation of StandardsField complements from Technology complements using the “CRTType” entity.

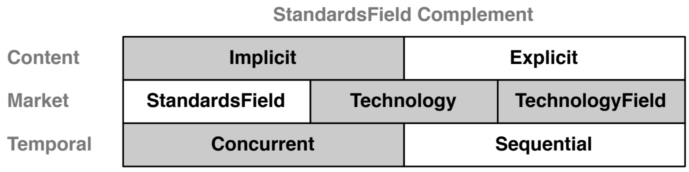


Figure 5.9.: Characterization: StandardsField Complement Dependency

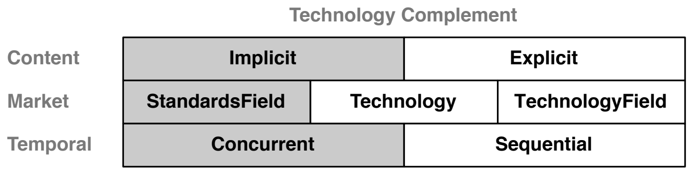


Figure 5.10.: Characterization: Technology Complement Dependency

Predecessor Dependency

Standards specifications, once published, cannot be altered. The only option to alter a standard is by issuing a new version of the standard. Standards implementers and standards users benefit from the continuity that is achieved by this approach. In consequence, varying versions of a standard may co-exist. Older versions might be revoked by standards developers, but multiple versions of the same standard might compete for market shares at the same time. Including information on predecessor relationships, thus, allows for monitoring standards evolution.

A predecessor dependency represents this kind of a dependency between standards. A standard preceding another standard is characterized by an implicit or explicit content-dependency. There are standards that explicitly refer to another standards (e.g., to revoke the preceding standard). Standards might, however, be implicitly content-related (e.g., if a newer version is created by another standards developer). Thus, content-based dimension cannot be said to be decisive for the identification of predecessor relationships.

Standards that have a predecessor dependency target the same standardization subject, i.e., address the same TechnologyField instance. In addition, there must be a sequential dependency between two standards, if a predecessor relationship is to be defined. A preceding and a current version of a standard may well address the same market at a time, if there are, for example, implementations of older versions available. Still their version information will identify them to bear a predecessor dependency.

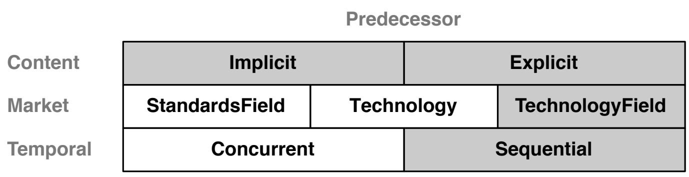


Figure 5.11.: Characterization: Predecessor Dependency

The conceptual information model supports temporal dependencies between standards by defining the type of the *isRelatedTo*-association to be of type *PredecessorRT* (see Figure 5.11). The many-to-many cardinality of the association, thereby, allows for modeling structural dependencies of preceding standards, i.e., allows one standard to relate to zero or more predecessors. A predecessor, in turn, might have zero or more successors.

Endorsement Dependency

Finally, a standard may be developed to endorse another standard. An endorsement of standard, typically, leads to an identical or translated replication of a standards specification by an Standards Development Organization (SDO).

The reasons for the endorsement are twofold: Firstly, jurisdictions mandate standardization powers to corresponding SDO. In consequence, SDO only hold standardization authority for the local jurisdiction. For international standards to come into effect, they, thus, require endorsement by regional specifications, which in turn require endorsement of nationally accredited SDO. Secondly, consortia may seek formal accreditation of standards. If consortia manage to pass the standardization processes, a standard may be created that endorses a previous de facto version of the standard.

An endorsement dependency, thus, is explicitly defined. Endorsements by regional or national SDO, typically, reference international and regional standards. The same applies, if an SDO publishes a consortia-developed standard, i.e., industry or de facto standard. Endorsement standards are, furthermore, characterized by strict market-based dependencies. Since endorsements standards are typically replications of other standards they share the StandardsField, Technology, and TechnolgoyField. Finally, two standards must be concurrently available in the market to constitute an endorsement relationship. Figure 5.12 illustrates this characterization.

	Endorsement		
Content	Implicit	Explicit	
Market	StandardsField	Technology	TechnologyField
Temporal	Concurrent	Sequential	

Figure 5.12.: Characterization: Endorsement Dependency

As for competition, complementary, and predecessor dependencies, the conceptual information model allows for creating endorsement dependencies by creating an instance of the *EndorsementRT* entity (see Figure 5.6). Thereby, the *isRelatedTo-association* can be defined to represent an endorsement dependency.

5.5. Stakeholders and Roles

In the previous sections, we presented the conceptual information model's capabilities to structure the technological environment of standardization in disruptive innovation.

We will now introduce the entities that allow for characterizing a standard, based on the dependencies to its stakeholders. In doing so, we present the models capabilities to model influences on standards.

The conceptual information model is based on two basic assumptions: Firstly, stakeholders that participate in standardization enact a standards-specific role. Secondly, the value of a standard in disruptive innovation depends the context of its application, being characterized by a domain-specific role.

Consequently, the model comprises a *Stakeholder* entity and a *Role* entity. The Role entity is abstract (see Section B.2), defining common properties and relationships for its specialized entities *StandardsRole* and *DomainRole*. The *StandardsRole* entity characterizes the different influences that stakeholders exert on standardization. Defining the *DomainRole*, the model supports classification of standards according to domain-specific stakeholder roles.

Figure 5.13 summarizes the entities that model standards, stakeholders, and their roles. We will discuss the named entities and their relationships in the following subsections.

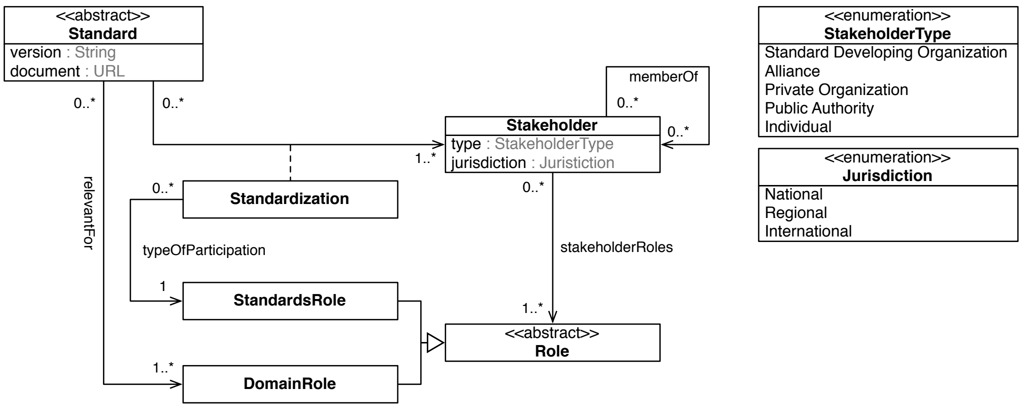


Figure 5.13.: Conceptual Information Model: Stakeholders and Roles

Stakeholder

The *Stakeholder* entity represents any actor that participates in standardization of disruptive innovation. Obviously, every standards is required to have at least one relation to Stakeholder instance. Not all Stakeholder instances, however, are require to build relations to Standard instances as their association to a standard might be transient (see *memberOf-association* below).

The conceptual information model incorporates types of stakeholders by defining the Stakeholder entity to comprise a *type* property. The allowed values of the type property are defined by the *StakeholderType* enumeration, defining the data type that is assigned to the type property of the Stakeholder entity. Reflecting the state-of-the-art types of stakeholders in standardization (see Section 2.1.2), the *StakeholderType* enumeration defines five types of stakeholders. Consequently, *SDO*, *alliance*, *private organization*, *public authority*, and *individual* are possible values.

The *jurisdiction* defines the range of a stakeholder's activities. The model assumes the jurisdiction of a stakeholder that develops a standard to define the jurisdiction of the standard. The jurisdiction of a standard, thus, is defined transitively. Similar to the type property, the set of allowed values is constrained, as its data type is defined by the *Jurisdiction* enumeration. A stakeholder's jurisdiction can be set to the *international*, *regional*, or *national* level.[28]

Stakeholders join forces to increase their influence on standardization (see Section 2.1.2). The model incorporates a reflexive *memberOf-association* for representing structures of Stakeholder instances. Every Stakeholder instance might be member of potentially many other Stakeholder instances. However, not every stakeholder is required to build a relation to other Stakeholder instances (see zero minimum cardinality of the *memberOf-*association).

Stakeholders enact different roles in standardization of disruptive innovation. The model, therefore, defines a *stakeholderRoles-association* between the Stakeholder entity and the abstract Role entity. Applying a minimum cardinality of one and a maximum cardinality of many, every Stakeholder instances has to enact at least one role, but may enact potentially many different roles. The model, thus, only recognizes stakeholders that participate in the market of a given domain of disruptive innovation or its standardization.

The model captures a stakeholder's specific involvements in standardization, using the correspondingly named *Standardization* entity. Stakeholders may enact different influences depending on their role. Therefore, the *Standardization* entity is modeled as an association class, enabling characterization of a stakeholder's potentially varying influences on a particular standard. Instances of the *StandardsRole* entity, thereby, characterize a standard-specific stakeholder's involvement, using the *typeOfParticipation-association*.

StandardsRole

A *StandardsRole* entity represents a standards-specific role that a stakeholder might enact to influence standardization. Thus, a StandardsRole instance characterizes a stakeholder's primary goal of participating in standardization. In general, stakeholders participate in standardization to create, implement, or use standards (see Section 2.1.2). In addition, they may seek standardization to set policies and rules for a disruptive innovation's market. The conceptual information model, thus, defines the StandardsRole entity to be a sub-type of the abstract Role entity. Moreover, the StandardsRole entity defines a stakeholder's type of involvement in developing a particular standard by typing the association class *Standardization* that types relations between *Standards* and *Stakeholder* entities.

Illustrating this conceptualization we apply the following example: A Stakeholder "A" enacts a "StandardsDeveloper" role to participate in the development of a standard "S". Using the model, representing this exemplary scenario requires the creation of a Stakeholder

[28] Note, the *description-property* that is inherited from the BaseObject entity can be used for providing details on the region or national jurisdiction of a Stakeholder instance.

instance “A” and a “StandardDeveloper” StandardsRole instance. The StandardsRole instance, thereby, types the association of the Stakeholder instance “A” and the Standard instance “S”. In addition, the Stakeholder instance “A” defines a relation to the StandardsRole instance “StandardsDeveloper”. The model, thus, allows to answer queries of, for example, the set of standards developers of a given standard.

DomainRole

In addition to the standards-specific roles, domain-specific roles aim at representing a stakeholder’s position in the market of disruptive innovation. In doing so, a *DomainRole* entity represents any Role that a stakeholder may enact in a market. They provide stereotypes that guide private organizations or individuals in selecting a standard for providing or consuming technology in disruptive innovation. In contrast to standards-specific roles, domain-specific roles may only stabilize over time. Domain-specific roles will, therefore, only be determined in the process of instantiating the information model for its application in a field of disruptive innovation.

The conceptual information model defines the *relevantFor-association* for Standard and DomainRole entities. In doing so, a Standard instance can be marked relevant for only a subset of the DomainRole instances that are available in a given domain of disruptive innovation. In consequence, the set of standards can be filtered according to the DomainRole that is ascribed to a stakeholder.

A Standard instance should be relevant for at least one instance of the DomainRole entity. Otherwise, a standard would not provide value to any of the participants in the market of the disruptive innovation. Not every DomainRole instance is, however, required to build a relation to a Standard instance.

5.6. Assessment Attributes

Varying domains of disruptive innovation requires different classification attributes that are not related to the entities presented so far:

- An attribute might, for example, describe the status of a standard, depending on its life-cycle phase or more generally on the applied life-cycle model of standardization.
- In addition, a standard might not be applicable for all industries that a disruptive innovation addresses. There are, for example, particular data privacy standards that are only applicable in health care (see, e.g., [54]).
- Finally, attributes might characterize standards that interpret more basic attributes. For example, predicting the market potential of a standard could be done as a function of a standard’s status and the amount and type of stakeholders that participate in its standardization.

We defined the conceptual information model to comprise an *Attribute* entity, an abstract *AttributeType* entity, and three sub-types entities *DescriptiveAT*, *ApplicabilityAT*, and *InterpretativeAT* (see Figure 5.14). Using these model entities, different sets of assessment attributes can be instantiated for varying domains of disruptive innovation. We will introduce each of the entities in the following sub-sections.

Attribute

An *Attribute* entity represent a value of a given type of an attribute that is ascribed to a standard at a given point of time. Therefore, it comprises a *value*-property of arbitrary type.

The Attribute entity complements the static properties that are defined for the Standard entity. Therefore, the model defines an *attributes-composition* of a Standard entity and the Attribute entity. In doing so, an instance of the Attribute entity must only exist, if it is ascribed to a Standard instance. At the same time, an Attribute instance may only relate to one Standard instance. A standard may be characterized by zero or more instances of the Attribute entity.

AttributeType

An *AttributeType* entity represents a type of an attribute that can be used to classify a standard in disruptive innovation.

The abstract AttributeType entity defines a set of properties that support the modeling of a variety of attributes: Introducing the *attributeCardinality-property*, the model allows for restricting the amount of Attribute instances that can relate to one Standard in-

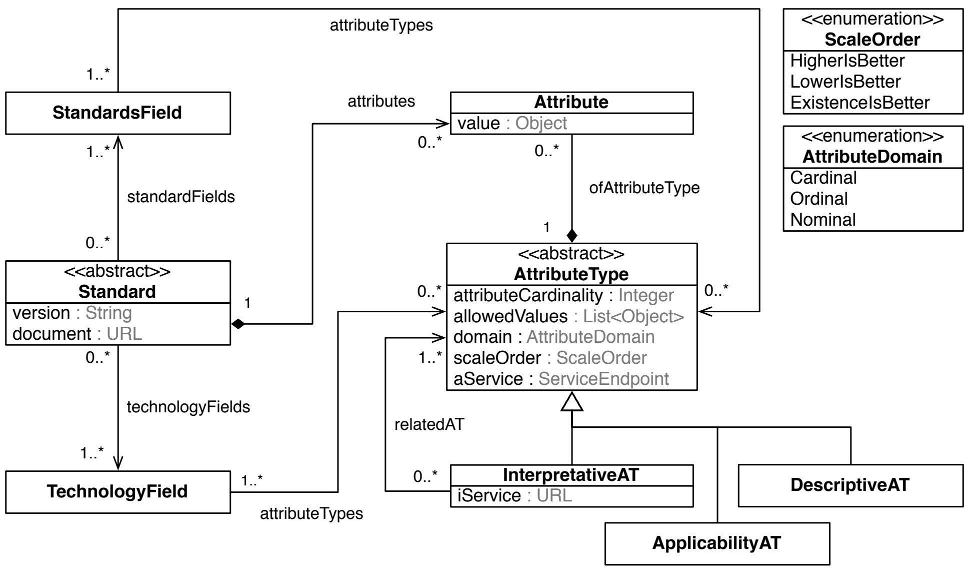


Figure 5.14.: Conceptual Information Model: Assessment Attributes

stance. While the status of a standard, for example, will only be ascribed once to standard, there might, however, be multiple industries to which a standard is applicable to. The *allowedValues*-property defines a list of, typically, string values that constrains the set of possible values of an Attribute entity. The different values of a status attribute, for example, could be defined, using the *allowedValues*-property. If constraining possible values is necessary, however, depends on the domain of the values of the AttributeType entity. The model supports nominal, ordinal, and cardinal scales for representing values of an Attribute entity. Obviously, only nominal and ordinal attribute domains should define list of allowed values. The AttibuteType entity, therefore, comprises a *domain*-attribute that is typed by an instance of the AttributeDomain entity. The *AttributeDomain* enumeration, in turn, defines corresponding scale orders. Referring to the example of a standard's status, the corresponding AttributeType instance could be modeled to be of ordinal scale. Yet, the question remains if higher-values of a given AttributeType instance should be considered better or worse than lower values. The *scaleOrder*-property allows to define this information. The corresponding *ScaleOrder* enumeration, therefore, defines the possible orders (i.e., higherIsBetter, lowerIsBetter, existenceIsBetter). For a status AttributeType, the list of allowed values could be defined to have a higherIsBetter order of scale. The *aService*-property (short for aggregationService) constitutes the last property of the AttributeType entity. It allows for defining a service endpoint that provides logic on how to aggregate valuations of an AttributeType's Attribute instances. According the AttributeType's value AttributeDomain, values of AttributeInstance instances could, for example, be aggregated using services that provide functionality such as calculating majority votes or thresholds as well as maximum, minimum, or average values.

The AttributeType entity is only related to the StandardsField entity and the TechnologyField entity, while there is no direct association of the AttributeType entity and Standard entity. Thus, we conceptualized the model to only transitively assign AttributeType instances to standards. In doing so, comparability of standards within the same StandardsField and the same TechnologyField is maintained, while flexibility of the assessment is given. The model, thus, comprises two *attributeTypes*-associations. One between the StandardsField entity and the AttributeType entity and the second between the TechnologyField entity and the AttributeType entity. Both *attributeTypes*-associations require an AttributeType instance to relate to at least one StandardField and TechnlogyField instance. Maximum cardinalities are set to many, i.e., an AttributeType instance may refer to more than one StandardsField or TechnologyField instance.

Structuring of Attributes

Defining AttributeType instances when instantiating the conceptual information model provides flexibility to incorporate domain-specific aspects. Growing numbers of AttributeType instances, however, lead to increased complexity of the domain-specific information model and, thus, of assessing standards. Based on the experiences from the cloud standards study (see Section 4.3), we designed the conceptual information model to type the AttributeTypes entity and, thereby, reduce the complexity of assessment and increase reuse of assessment information. The following sub-types of the AttributeType entity realize classification and structuring of attribute types:

- The *DescriptiveAT* entity gathers standards-specific information, i.e., information that is independent of the disruptive innovation's context. Links to standards specification, a standard's life-cycle status, or its license model are examples of DescriptiveAT instances.

- On the contrary, the *ApplicabilityAT* entity captures characteristics that are domain-specific, i.e., characteristics of the standard that particularly address aspects of the disruptive innovation. Information as, for example, the relation to the disruptive innovation (i.e., is the standard being developed specifically for the disruptive innovation?) or its suitability for a specific industry could, thus, be provided by instances of this sub-type.

- Finally, instances of *InterpretativeAT* entity provide additional information that either helps evaluating a standard or deriving higher level information based-on interpreting one or more attributes. In addition, the InterpreativeAT entity may be used to derive information based on interpreting a standard's relations to other instances of model entities. The model, therefore, defines the InterpretativeAT entity to build relationships to zero or more abstract AttributeType instances, using the *relatedAT-association*. The values of an InterpretativeAT's attribute can be calculated automatically, based on simple calculations. Therefore, the model anticipates a service-oriented approach in contrast to introducing a language or even a logical formalism. The InterpretativeAT entity, thus, defines an *iService-property*. In doing so, a Uniform Resource Locator (URL) can be provided. A service request may then be used to retrieve the value of an attribute of this type.

Valuation and Filtering of Attributes

Next to the capabilities to structure attributes, the model defines entities and relationships that represent how stakeholders value attributes and provide capabilities to filter Attribute instances. Valuation and filtering, both, has to account for the role that a stakeholder enacts. We will introduce the corresponding entities and relationships in this sub-section.

Figure 5.15 depicts the already known AttributeType, Attribute, Stakeholder, and Role entities as well as their respective relationships. The new *AttributeInstance* entity represents a single valuation of an attribute by a stakeholder at a given point of time. Each time a stakeholder provides a new value for an attribute, an instance of the AttributeInstance entity is created to keep this information. Next to the obligatory *value*-property, the AttributeInstance entity comprises a *timestamp*-property, maintaining the date at which the value has been provided.

Tracking valuations on a per stakeholder basis, each instance of the AttributeInstance entity will relate to exactly one Stakeholder instance. A Stakeholder is not mandated to value an attribute, but may provide multiple valuations over time. Thus, the *valuations*-association between the Stakeholder entity and AttributeInstance entity constitutes a one-to-many-association having a minimum cardinality of zero per Stakeholder instance.

The *assessedBy-association* models the dependency between the abstract Role and the abstract AttributeType entity, using a many-to-many-relationship. An AttributeType instance may, therefore, be assessed by zero or many Role instances. Roles, in turn, may provide valuations for zero or many AttributeType instances.

5.7. Technology Typology

Based on the entities above, we will now introduce the conceptual information model's representation of a technology typology.

A technology typology constitutes the conceptual counterpart for describing the dependencies of standards and emerging technology in disruptive innovation (see Figure 5.1). Instances of the StandardsField entity, thereby, classify and structure the scope of a standard. Likewise, TechnologyField instances describe and structure the constituents of an emerging technology that is used to classify the subject of a standard. In addition, instances of the Technology entity provide another means to classify a standard's subject. Instances of the AttributeType entity allow for representing domain-specific assessment attributes. Using Role instances, the model is capable of maintaining valuations of attributes from varying stakeholders while reducing complexity, applying Role-based filters.

Different domains of disruptive innovation, however, require different instances of the StandardsField, TechnologyField, Technology, Role, and AttributeType entities. Conceptually, a *TechnologyTypology* entity, thus, represents a selection of StandardsField, TechnologyField, Role, and AttributeType instances. A TechnologyTypology entity, consequently, builds relationships to both StandardsField entities and the TechnologyField

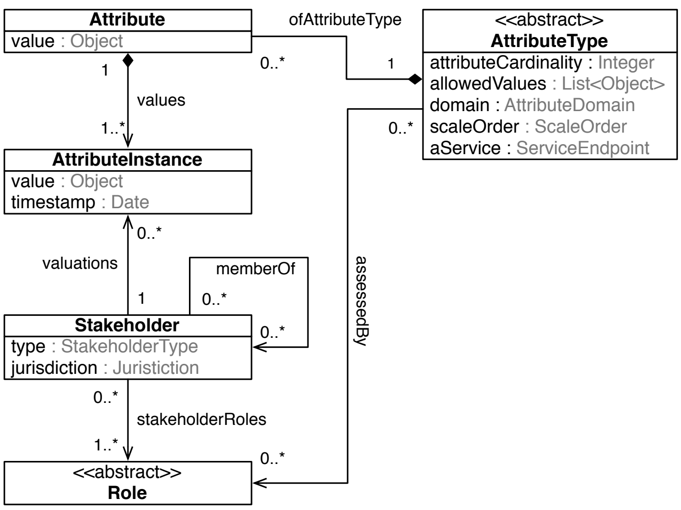


Figure 5.15.: Conceputal Information Model: Valuation and Filtering of Attributes

entities. Obviously, a TechnologyTypology instance should relate to at least one StandardsField and one TechnologyField instance. Typically, however, there will be relations to many instances.

Next to StandardsField and TechnologyField entities, a TechnologyTypology entity comprises instances of the Role entity that a stakeholder may enact in the disruptive innovation. The model, thus, defines a one-to-many association between the TechnologyTypology entity and the DomainRole entity. In doing so, domain-specific roles of a disruptive innovation can be defined.

Finally, the TechnologyTypology entity builds relations to the abstract AttributeType entity. The association between the AttributeType and TechnologyTypology entities allows for selecting attributes that should be considered in a given domain of disruptive innovation. In doing so, the model supports reuse of AttributeType instances across different domains of disruptive innovation. As with the associations to the StandardsField and TechnologyField entities, a TechnologyTypology entity is required to refer to at least one instance of an AttributeType entity, i.e., instances of its concrete sub-types.

5.8. Conclusion

In this chapter, we presented a conceptual information model to structure the information that is required to assess standards in disruptive innovation. Methodically, the conceptual information model constitutes a meta-model. Therefore, it only defines type of entities and their relationships. These entities provide the basis for the development of methods and tools that support assessment of standards in different domains of disruptive innovation. While final validation of method requirements will be done in Chapter 7 and Chapter 8, will we conclude intermediary results on our model's relevance in the following.

The conceptual information model realizes the information requirements (see Section 4.3) as summarized in Table 5.1. Specifically, the model supports the characterization of standard's scopes and subjects (IR-1) using the StandardsFields, Technology, and TechnologyField entities. Moreover, different types of standards (IR-1) are reflected, applying BaseStandard and StandardProfile entities. Sub-types of the RelationshipType entity allow

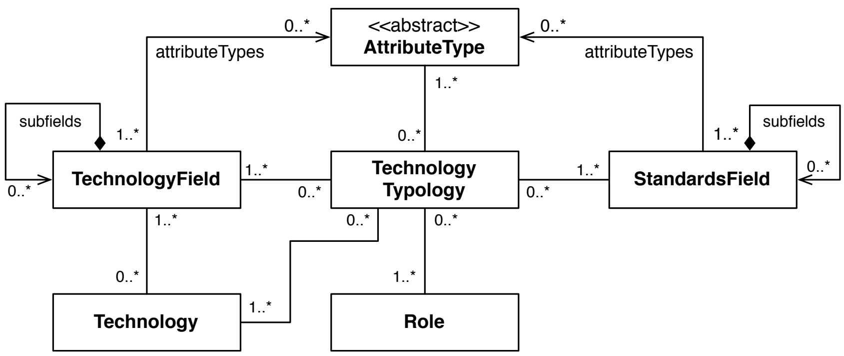


Figure 5.16.: Conceptual Information Model: Technology Typology

ID	*Requirement*	*Realization*
IR-1	Support classification of scope, subject, and type	Technology typology defines scope and subject of a standard. BaseStandards and StandardsProfiles define the type.
IR-2	Support classification of standards dependencies	Dependencies of standards stem from content, market, and temporal aspects. Sub-types of the RelationshipType entity provide categories.
IR-3	Support domain-specific classification attributes	AttributeType entities provide flexibility to assess different domains of disruptive innovation.
IR-4	Support measures for network effects	Standardization and Implementation entities enable measurements.
IR-5	Support stakeholders and roles	Model entities enable filtering of standards and attributes when classifying or evaluating standards.
AR-1	Consolidate values from multiple classifications	AttributeInstance entity and aggregationService-property provide foundations. Execution of aggregation must be managed by a method and automated by tools.
AR-2	Support determination of dependencies and attributes	Service concept of InterpretativeAT and AttributeInstance entity provide foundations. Services must be provided by tools and incorporated into a method.

Table 5.1.: Realization of Method Requirements: Conceptual Information Model

for classifying dependencies of standards (IR-2). In addition to properties of model entities, the AttributeType entity enables flexible definition of domain-specific assessment attributes (IR-3). Standardization and Implementation entities capture information that may be used to calculate measures for network effects (IR-4). Finally, the combination of Stakeholder and Role entities (i.e., DomainRole and StandardsRole entities) allow for filtering relevant information according to a stakeholder's expertise and its purpose of standards assessment (IR-5).

In addition, the combination of AttributeInstance and Stakeholder entities provides potentials for automating the aggregating of attribute values by tools that support standards assessment (AR-1). This may even include, features to automatically track the evolution of a standard's attributes. Therefore, the InterpretativeAT entity and its service-oriented concept allows for including external automating logic (AR-2).

Moreover, the model provides first answers to the challenges of modularizing assessment information (see Section 4.3.1):

- *Enabling information reuse:* Our conceptual information model explicitly defines dependencies of assessment information that we have anticipated from the learnings of the cloud standards study. While a standard's jurisdiction, for example, has been classified manually in the cloud standards study, the model allows for inferring this information with the help of the Standardization entity. Similarly, assessment attributes to, for example, measure network effects or market potentials can be derived from information that is captured by model entities (i.e., Standardization, Implementations, and InterpretativeAT entities). Standards assessment tools may, furthermore, use the model to implement automation support for consolidation of attribute values as well as determination of standard's dependencies and attribute values (see AR-1 and AR-2 in Table 5.1).
- *Enabling collaboration among stakeholders:* Defining filtering capabilities according to different stakeholders and their roles in disruptive innovation (see IR-5), the conceptual information model provides tailor provided and requested information for individual stakeholders. Complementary assessment methods, thus, may only demand valuations of attributes from stakeholders that are capable of providing the relevant information (see Chapter 6). Likewise, the above discussed consolidation capabilities enable aggregation of standards assessment information from individual contributions of stakeholders. In doing so, the conceptual information model builds the basis for coordinating a community of stakeholders in assess standards of disruptive innovation.

Moreover, the conceptual information model contributes to reusing methods and tools by providing an domain-independent conceptualization of assessment information. Building upon the conceptual information model, a method to support assessment of standards, however, has to support the identification of domain-specific instances of the model entities. In the following chapter, we will present ASSET. The method that complements the conceptual information model.

6. Method for Standards Assessment

In this chapter, we present our method for *Assessing Standards of Emerging Technology (ASSET)* in disruptive innovation. The method builds upon our conceptual information model for standards assessment that ensures homogeneity of assessment information among the steps of the assessment process and the stakeholders involved (see Section 5). Applying process models, ASSET instructs stakeholders in assessing standards while regarding dependencies of assessment information as defined by the information model. Moreover, the process models build the basis for identifying functionality that standards assessment tools are required to provide.

The dynamics and uncertainty of disruptive innovation lead to an ongoing evolution of the technology framework that provides potential subjects of standards. While technology evolves, standards develop as well. In consequence, changes to standards and, thus, a standard's scope are common in disruptive innovation. The assessment of standards in disruptive innovation, therefore, has to support an iterative approach of classification and evaluation steps, including updates to the classification scheme.

ASSET's goal is to improve the efficiency of standards assessment. We will, therefore, identify potentials for the automation of the iterative assessment process, particularly for coordinating relevant stakeholders and aggregating assessment information.

The remainder of this section is structured as follows: Section 6.1 will provide an overview of the basic conceptualization of ASSET. Summarizing the stakeholder's interest in assessing standards, we present ASSET's stakeholder model in Section 6.2. Section 6.3 presents ASSET's procedural model, defining sequences of activities, events, and corresponding assessment artifacts. Section 6.4 presents ASSET features to support in the automation of standards assessment. The features and contributions of ASSET are finally concluded in Section 6.5.

6.1. Overview

ASSET partitions the process of assessing standards into phases: The *classification phase* comprises the *"Create Technology Typology"* and the *"Classify Standard"* steps. The former defines a procedure that guides the community of stakeholders in creating the classification scheme for a domain of disruptive innovation. The latter defines the classification procedure for standards. Therefore, it builds the foundation to coordinate the efforts of creating standards profiles by assigning attributes to standards. The subsequent *evaluation phase* uses standards profiles as input and individually guides stakeholders in the process of evaluating standards.

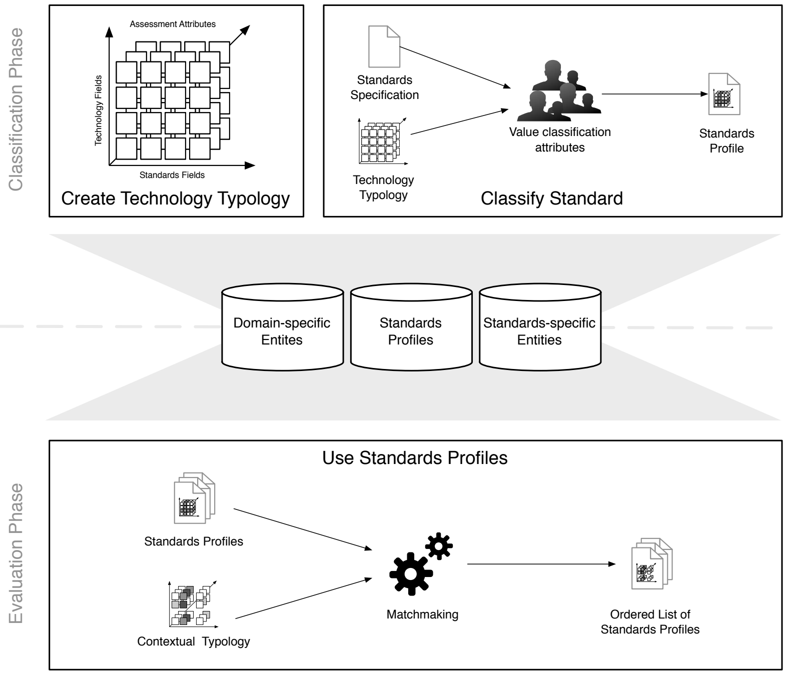


Figure 6.1.: ASSET: Outline

Figure 6.1 summarizes ASSET's two phases of standards assessment, the classification and evaluation steps, and respective input and output artifacts. We will now briefly introduce each of ASSET's assessment steps and discuss respective input and output artifacts:

- Applying ASSET for a new domain of disruptive innovation, begins with performing the *"Create Technology Typology"* step. Stakeholders, thereby, identify technology fields and standards fields that are relevant to the disruptive innovation under consideration. The stakeholders, furthermore, create corresponding hierarchies of technology fields and standards fields. ASSET, thus, defines the abstraction and generalization capabilities that are required for classification. Creating the technology typology, ASSET develops the domain-specific classification scheme for standards in disruptive innovation.

- As soon as an initial technology typology has been created, stakeholders may commence to classify standards. Next to the technology typology, a standards specification document is required as an additional input to this step. The execution of the *"Classify Standard"* step results in the creation of a standards profile or an update of an existing standards profile. ASSET provides support to filter assessment attributes according to the different assessment capabilities of stakeholders. The *"Classify Standard"* step may be executed concurrently by different stakeholders. In doing so, ASSET distributes the efforts of classifying standards in disruptive innovation, depending on the different perspectives of stakeholders. ASSET provides aggregation capabilities based on the information model that supports aggregation of multiple assessments of a standard.[29]

- The goal of standards assessment varies per stakeholder and depends on the level of decision making (e.g., strategy or operation). Thus, the relevance of assessment attributes can only be determined on a case-by-case basis. ASSET defines a generic *"Use Standards Profiles"* sub-process to guide stakeholders in performing their respective evaluations and maximizing the utility of standards profiles, domain entities, and standards entities. A set of standards profiles is the primary input for any evaluation. Domain entities and standards entities provide secondary inputs. Stakeholders use them to describe the context of their evaluation, creating a *contextual typology*. Based on these inputs, ASSET supports the *matchmaking* of the evaluation context and standards profiles. As a result, ASSET generates an *ordered list of standards profiles* that match the contextual typology. The selected standards profiles will only contain assessment information that matches the given context based on the information filtering capabilities of the information model.

There are sequential constraints on the order of executing the *"Create Technology Typology"*, the *"Classify Standard"*, and the *"Use Standards Profiles"* steps. The *"Classify Standard"* step, certainly, requires the *"Create Technology Typology"* step to have been completed once. Likewise, using standards profiles is only possible, if the technology typology has been created and standards have been classified. After an initial execution of each step, all steps can be iterated in isolation. Changes to the technology typology, however, imply re-classifications and, potentially, re-evaluation of standards. Based on the procedural model, ASSET provides coordination capabilities that allow ASSET to address the dynamics of standardization (see Section 6.4). We will introduce the ASSET's coordination mechanisms in Section 6.3.

ASSET separates domain-specific and standards-specific entities. This classification is applicable to both, real world objects and conceptual constructs (see Figure 6.1). *Domain-specific entities* refer to any real world object or element of the typology that is specific to the domain of disruptive innovation under consideration. Technology fields, technologies, their implementations, and domain-specific assessment attributes are examples of domain-specific entities. *Standards-specific entities* are domain-independent entities, describing aspects of standardization that are valid across domains of disruptive innovation. Classification attributes, describing the status of a standard or dependencies between stakeholders and standards, are examples of objects of standards-specific entities. The set of standards-specific entities can be reused in different domains of disruptive innovation. Additionally, applications of ASSET may select suitable domain-specific entities to facilitate the creation of the technology typology. Using ASSET, stakeholders of standards build databases of domain- and standards-specific entities.

[29] Applying the information model, each assessment of a standard results in the creation of new objects of the AttributeInstance entity. A standards profile, conceptually, only comprises aggregated values of assessment attributes that are calculated by applying associated aggregation rules (see Section 5.6).

6.2. Stakeholder Model

Stakeholders have different intentions, needs, and capabilities to influence standardization (see Section 2.1.2). A method to support the assessment of standards, thus, has to address different stakeholder perspectives (see *IR-5* in Section 4.2).

We will introduce ASSET's stakeholder model (see Figure 6.2) in this section. The model provides standards-specific types and roles that are complemented by a domain-specific perspective to characterize a stakeholder's position in the market. Thus, it allows for defining the information that a stakeholder can contribute in the classification phase as well as the information that is of potential interest when evaluating standards. The model describes the dependencies of stakeholders and defines the roles, which stakeholders may enact while influencing the evolution of standards, using the entities of the information model.

Based on the introduction of types and roles of stakeholders in standardization in Section 2.1.2, we will describe which the stakeholder's interest of evaluating standards and their potential contributions to the classification of standards in disruptive innovation in the following sub-sections.

Types of Stakeholders

Types of stakeholders characterize a stakeholder's legal entity and, thus, their powers to influence standardization. We will now analyze the contributions and information needs of the stakeholders types that we identified in Section 2.1.2. Thereby, we build the foundation for the development of ASSET's procedural, defining the stakeholder's respective activities.

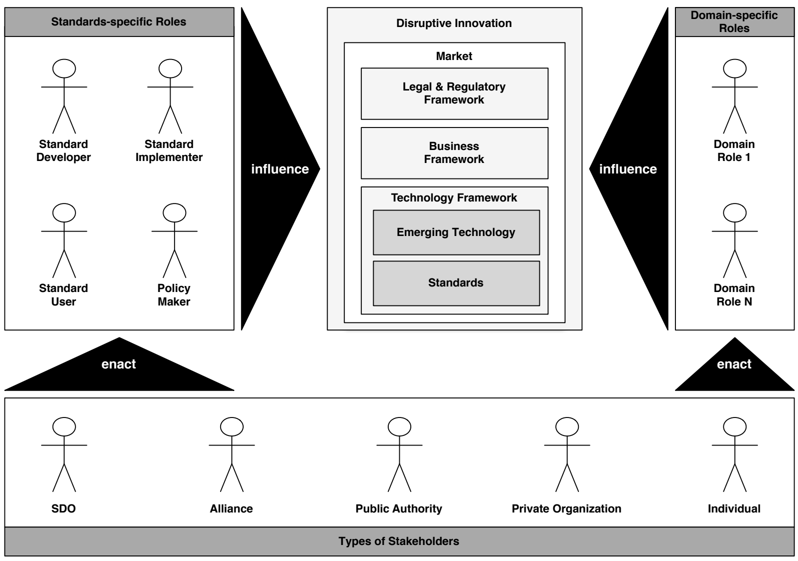


Figure 6.2.: ASSET: Stakeholder Model

Individual

Individuals contribute to ASSET's classification phase by providing input from an end-user perspective. Based on their experience of the standard in action, they may value the impact of standardization. They are less interested in evaluating standards as they, typically, do not develop products or services. Likewise, they have little interest in roadmapping standards. Individuals, however, are interested in evaluating products or services, based on the standards that they support. However, they typically prefer certificates for standards compliance rather than performing individual assessments.

Private Organization

Providing and consuming technology, private organizations are an important stakeholder for ASSET. The participation of private organizations in the classification phase of ASSET is of particular importance as they provide technological expertise. In doing so, they contribute to the development and evolution of the ASSET's technology typology and help to value attributes in standards classification. Private organizations are interested in ASSET's evaluation phase to facilitate decisions in projects to develop new products or services or adapt existing ones.

Public Authority

Controlling standardization initiatives, public authorities require an overview of the portfolio of standards. In doing so, they are highly interested in support for roadmapping activities as provides in ASSET's evaluation phase. They do, however, not actively participate in the development of a technology typology or the standards profiles. Likewise, they are less interested in finding standards for a particular development project.

Alliance

In the early phases of disruptive innovation, both, interest groups and consortia are an important source of information on technologies, technology fields, and standards fields of a disruptive innovation. ASSET requires this kind of information while creating a technology typology in the classification phase. If the focus of interest groups and consortia is to evaluate a standard's applicability for a given scenario, they may provide information on the applicability and the suitability of a standard. In ASSET's evaluation phase, both types of alliances benefit from ASSET's roadmapping support. In doing so, they can identify competing or complementary standards.

Standards Development Organization (SDO)

The work of SDOs is particularly important to ASSET's classification phase. Here, they provide the basis for the development and validation of the technology typology. Also, their expert knowledge on standardization is an important source of standards-specific classification information. This includes, for example, information on the status of a standard, its technology fields, related standards, or the targeted user group (for examples see Section 8.1.3). SDOs do not evaluate the use of a standard for a particular development project. They are, however, required to assess the requirements for standardization when evaluating proposals for standardization. In doing so, they only present little interest in actively participating in the evaluation phase of ASSET, except for roadmapping activities.

Roles of Stakeholders

In addition to the organizational classification of types of stakeholders, ASSET applies roles to characterize the motivations of stakeholders (see Section 2.1.2). The roles characterize a stakeholder's participation in the standardization of disruptive innovation or describe their function of providing or consuming emerging technology. In the following, we may, therefore, derive the information needs of stakeholders according to their roles.

Following ASSET's general conceptualization to distinguish standards-specific entities from domain-specific entities, ASSET defines four instances of the StandardsRole entity (see Figure B.2). In addition, an unspecified amount of instances of the *DomainRole* entity, will be created when instantiating ASSET for given domain of disruptive innovation. These domain-specific roles can, for example, be derived from use cases models of the emerging technology. In doing so, functional requirements of end-uses (i.e., private organizations, public authorities or individuals) can be identified, which in turn provide valuable input for standardization. The amount and the types of domain-specific roles are subject to changes as the disruptive innovation evolves. However, ASSET's information model requires a domain-specific technolgy typology to comprise at least one instance of a DomainRole entity to be model-compliant (see Figure 5.16).

Based on the roles of stakeholders presented in Section 2.1.2), we will now discuss the contributions and information needs of standards-specific roles in ASSET's classification phase and evaluation phase:

Standards Developer

The contribution of standards developers in the classification phase of ASSET is twofold: Firstly, standardization efforts like vocabularies, taxonomies, or reference models provide inputs for the identification and structuring of technology fields and standards fields when creating the technology typology. Secondly, standards developers contribute descriptive classification information, for example, the scope of a standard, its standardization subject, or the standard's status.

The participation of standards developers in ASSET's evaluation phase is little. Standards developers, typically, do not perform product or service development projects. Thus, they rarely search for a particular standard from a portfolio of standards. Roadmapping activities, however, are of interest for standards developers, if they are to assess the need for new standards or adaptation existing ones.

Standards Implementer

When classifying a standard, standards implementers may judge the comprehensiveness of a standard. They may, for example, identify weaknesses in standards specifications such as inconsistencies or under- and over-specification of concepts respectively in standards specification. In addition, they may provide information on the suitability of a standard's license model for a given domain of disruptive innovation or, more generally, on the cost of its implementation and operation.

Standards implementers are the primary beneficiaries of ASSET's evaluation phase. They are supported when searching for standards that apply to their development projects. Using the technology typology, standards implementers may describe the scope of their development projects, rank their requirements and, finally, receive a list of standards that fits their project.

Standards User

Standards users help in classifying standards, primarily with valuing the effect of standardization. If, for example, a standards specification is too generic, any two implementations of the standard will still not be able to communicate or exchange data appropriately. Such information, however, can only be gained from experiences of using standards. Standards users, therefore, may provide information on the value the degree of interoperability or portability that can be achieved across implementations when using a particular standard.

When selecting a particular standard, standards users may benefit from status quo and roadmapping support on the strategical level. The maps of standards provide a quick overview of the comprehensiveness and maturity of standards.

Policy Maker

While they are interested in the technology typology to assess the disruptive innovation's portfolio of standards, policy makers do not actively participate in ASSET's classification phase. They, particularly, do not contribute to the task of classifying standards.

Policy makers, benefit from ASSET's roadmapping capabilities. In addition, they are particularly interested in finding standards that are suitable for defining policies, i.e., to define market rules Policy makers, however, are not interested in assessing standards for a given development project.

As we have demonstrated in this section, stakeholders have different information needs and the varying capabilities to support the assessment of standards in disruptive innovation. The information model's modularity and its capabilities to filter information according to information needs (see Section 5) provide the basis to address these requirements. In the next section, we will present ASSET's procedural model, supporting stakeholders with the assessment of standards in disruptive innovation. Defining a procedural model, we will incorporate the varying stakeholder perspectives and provide a means to automate the coordination of their contributions.

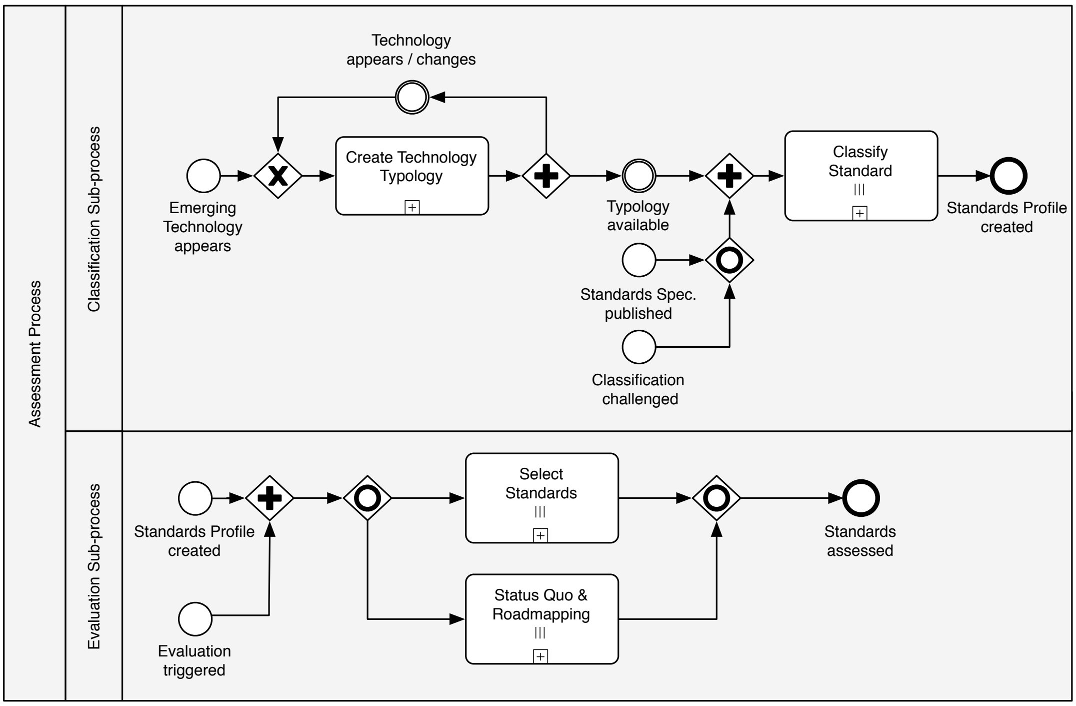


Figure 6.3.: ASSET - Procedural Model: Overview

6.3. Procedural Model

The information model, presented in Chapter 5, defines the entities and their relationships that ASSET may apply for assessing standards of emerging technology in disruptive innovation. Building upon these entities and ASSET's stakeholder model, we will now present ASSET's procedural model. The procedural model provides the basis to coordinate stakeholder's efforts of classifying and evaluating standards in disruptive innovation. Moreover, its defines tasks that could be automates to reduce assesment efforts.

In the next section, we will outline the overall *"Assessment Process"*, defining ASSET's procedural model. The following sections will provide the details of the creation of a technology typology (Section 6.3.2, the classification of standards (Section 6.3.3), and the use of standards profiles for evaluation purposes (Section 6.3.4).

6.3.1. Assessment Process

Figure 6.3 illustrates ASSET's *"Assessment Process"*, using the Business Process Model & Notation (BPMN) [105] standard as modeling notation. Thus, we model the steps of the procedural model as process activities and use sub-processes to structure the overall procedural model.

Following the conceptualization of ASSET's two basic phases (see Section 6.1), we divided the process into two sub-processes:

- The *"Classification Sub-process"* defines the sequences of activities to create a technology typology and to classify standards. The goal of the first step, i.e., *"Create Technology Typology"*, is to develop the artifacts that ASSET requires as input when performing the classification of a standard in disruptive innovation. Stakeholders must perform the subsequent *"Classify Standard"* for each standard that emerges in the domain of disruptive innovation. However, classification may only start once an initial technology typology has been created. An instance of the *"Classification Sub-process"* starts as soon as signals of an emerging technology are recognized that could lead to disruptive innovation (see start-event *"Emerging Technology appears"* in Figure 6.3).[30]

  The constituents of an emerging technology cannot be stated clearly in the early phases of disruptive innovation. Due to uncertainty, some concepts will only arise later while other concepts disappear. ASSET, thus, allows for iterating the *"Create Technology Typology"* sub-process. In doing so, the appearance of new technology or changes to a technology may trigger the re-creation of the technology typology (see intermediate-event *"Technology appears / changes"* in Figure 6.3).

  Each completion of the *"Create Technology Typology"* sub-process triggers the event *"Typology available"*. If a specification of a standard is published (see start-event *"Standards Spec. published"* in Figure 6.3) or the classification of a standard has been challenged (see start-event *"Classification challenged"* in Figure 6.3), an instance of the *"Classify Standard"* sub-process will be executed per standard. After a successful classification of a standard, i.e., termination of the corresponding sub-process, the classification sub-process completes by reaching the *"Standards Profile created"* event. As a result, classifications of standards (i.e., standards profiles), as well as domain-specific and standards-specific entities, have been created.

- Making use of these artifacts, stakeholders of standards in disruptive innovation can start to evaluation standards. ASSET applies the start-event *"Evaluation triggered"* to represent a stakeholder's need for an evaluation of standards. An evaluation may, however, only be started, as soon as standards have been classified (see start-event *"Standards Profile created"* in Figure 6.3)

  As defined in the *"Evaluation Sub-process"*, ASSET supports two evaluation scenarios: Firstly, ASSET supports stakeholders with selecting standards for a given development project (see activity *"Select Standards"* in Figure 6.3). Secondly, status quo and roadmapping activities are supported based on standards profiles (see activity *"Status Quo & Roadmapping"* in Figure 6.3).

In summary, ASSET's *"Assessment Process"* is designed to support the concurrent execution of classification and evaluation sub-processes, if a standard was classified once and a domain typology has ever been created for the domain of disruptive innovation. This conceptualization allows for adapting the domain typology and re-classifying standards, while existing profiles can be used for the evaluations supported.

[30] For details on how to monitor signals of emerging technology see Section 6.3.2 and the backgrounds on technology management provided in Section 2.2.2.

6.3.2. Sub-process: Create Technology Typology

The information model requires an instantiation for a given domain of disruptive innovation. The goal of developing a domain-specific technology typology, thereby, is to find the set and structure of categories that are relevant for the given domain of disruptive innovation. Relevance of its entities must be assured with regards to technology and standards evolution as well as the purpose of using the classification.

The *"Create Technology Typology"* sub-process guides the stakeholders of a domain of disruptive innovation on how to perform this instantiation. The sub-process, therefore, comprises activities to identify and structure the technology framework as well as to define the types of attributes that can be used to assess standards in the given domain of disruptive innovation.

Two events trigger the execution of a *"Create Technology Typology"* sub-process:

- If standards are to be assessed in a new domain of disruptive innovation, the *"Emerging Technology appears"* event is triggered. Identifying the appearance of a new domain of disruptive innovation, however, is a challenging task. Traditional technology management approaches propose structured technology scouting [88] or technology intelligence [127] processes to identify emerging technologies (see Section 2.2.2). In doing so, management science considers different types of signals from the technological (e.g., performance improvements, patents, and new product announcements), economic (e.g., resource allocations, governmental spending), social (e.g., demographic factors, interest groups), and political (e.g., public hearings) environment [32]. Supporting the variety of corresponding analyses, however, is beyond the scope of ASSET. We, thus, assume a positive decision to assess standards in disruptive innovation to trigger the execution of ASSET. Such decisions may origin in organizational contexts (e.g., management decision in a private organization) or by public interest (e.g., decision by public authority or consortia to assess standards). They are, however, external to ASSET, i.e., cannot be controlled by ASSET.

- A major challenge of assessing standards in disruptive innovation are changes to the environments for standards (see Section 2.4). ASSET allows for tracking such changes using the *"Technology appears / changes"* event. In doing so, ASSET provides means to adapt to changes by adding, changing or removing technologies and as a consequence the entire technology fields, if new technology concepts arise or existing technology concepts change over time. Again, controlling the process of identifying new technology concepts as well as changes to them, is out of ASSET's scope. Here, ASSET assumes traditional technology management approaches to be in place (see above). Changes to the environment of a standard may, however, also be identified when standards are classified. In such cases, no appropriate or not enough Technology, TechnologyField, StandardsEntity or Implementation entities may be identified. Issuing a *"Technology appears / changes"* event is such cases, ASSET supports monitoring of changes to the technology typology.

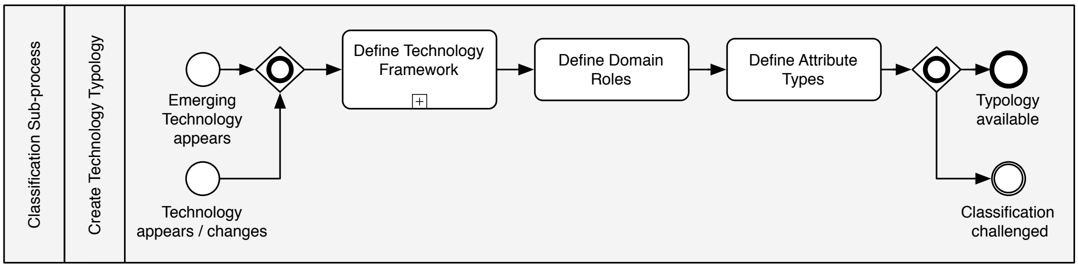


Figure 6.4.: ASSET - Procedural Model: Create Technology Typology Sub-process

Once the execution of ASSET classification sub-process has been triggered, ASSET's procedural model requires the stakeholders of standards in disruptive innovation to identify the entities of the technology framework, including changes thereto. In addition, they have to define the domain-specific roles and the types of attributes that the domain of disruptive innovation comprises.

In the subsections, we provide details on the corresponding *"Define Technology Framework"* sub-process, the *"Define Domain Roles"* activity, and the *"Define Attribute Types"* activity.

Define Technology Framework

Being the first sub-process in ASSET's *"Assessment Process"*, the execution of the *"Define Technology Framework"* sub-process is triggered by the same start-events as the classification sub-process (see *"Emerging Technology appears"* and *"Technology appears / changes"* start events in Figure 6.4).

Triggered by either event, stakeholders perform the *"Define Technologies"* activity. The purpose of the activity is to define Technology entities that constitute the emerging technology at the time of process execution. Following the information model, a technology typology does not comprise technologies directly (see Section 5.7). The relations of Technology entities to the TechnologyTypology entity are defined transitively instead, i.e., by grouping Technology entities into TechnologyField entities.

Starting with the definition of relevant Technology entities, the procedural model applies a bottom-up approach for the definition of TechnologyFields. In doing so, ASSET ensures that all Technology entities will be grouped by at least one TechnologyField entity (see Figure 5.3). In the early phases of disruptive innovation, only a few technologies may be known with certainty. In consequence, ASSET does not require Technology entities to be defined for a technology typology to be complete. The existence of TechnologyField and StandardsField entities for a given domain of disruptive innovation, however, is a prerequisite of ASSET.

A disruptive innovation's TechnologyField and StandardsField entities can be defined concurrently by participating stakeholders. The *"Define Technology Fields"* and the *"Define Standards Fields"* activities involve screening of references models, vocabularies, research reports, white papers as well as monitoring the disruptive innovation's market

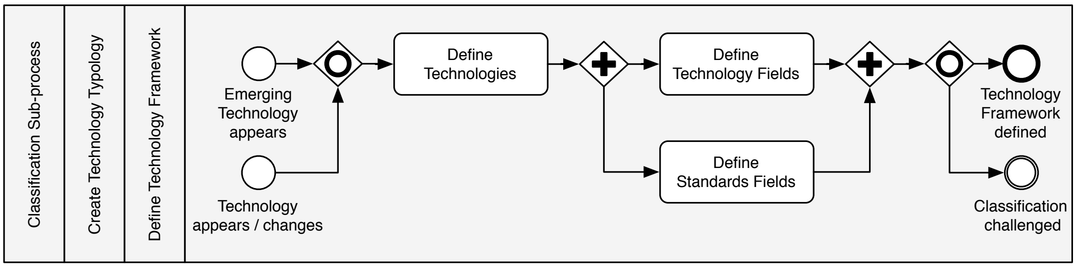


Figure 6.5.: ASSET - Procedural Model: Define Technology Framework Sub-process

for new products or services. In doing so, an initial list of candidate TechnologyField and StandardsFields entity is developed. Next, the candidates are classified, structuring the candidates into corresponding TechnologyField and StandardsField hierarchies (see Section 5.2).

Like most technology intelligence tasks [129], the individual tasks to define Technologies, TechnologyField, and StandardsFields entities involve human creativity. In doing so, an iterative sequence of identify, structure, and consolidate activities is performed by individuals that can hardly be automated. Literature proposes to consult experts, using questionnaires and scoring-based techniques to do so [88]. ASSET, consequently, focuses on providing a conceptualization of the technology framework in a way that enables discussion among the stakeholders of the innovation, supports tracking of changes to the technology framework, and propagates change events to trigger re-classifications of standards (see Section 6.4.1).

Creating the entities of the technology typology, the distinction between Technology and TechnologyField entities is another challenge of defining the technology framework. The uncertainty of future technology progression is the major factor in this regard, especially if there do not yet exist implementations of a technology. Following the information model, the existence of an implementation is a requirement for a technology do be considered. Using ASSET, we can, thus, conclude that an implementation must eventually be found for any Technology entity. If no implementation can be found in the classification step (see Figure 6.7), ASSET supports revising the technology framework by triggering the *"Technology appears / changes"* event.[31]

The *"Define Technology Framework"* sub-process terminates when reaching its end-events *"Technology Framework defined"* and *"Classification challenged"*. The former triggers continuation of the *"Create Technology Typology"* sub-process, i.e., leads to the execution of the *"Define Domain Roles"* activity. If changes to the technology framework have been applied, triggering the *"Classification challenged"* starts the execution of the *"Classify Standard"* sub-process. ASSET, thus, coordinates the re-classification of standards profiles and, therefore, contributes to keeping them up-to-date.

Defining the technology framework is a cooperative effort in ASSET. Since it requires profound technological knowledge, it is, however, mainly done by a small group of

[31] Depending on the implementation of ASSET, *"Technology appears / changes"* events may be triggered only periodically.

experts, leading a community of stakeholders in the disruptive innovation. Standards-specific and domain-specific roles play a minor role. ASSET, thus, assumes an alliance of experts to drive the creation of the technology typology, regardless of their respective roles.

Define Domain Roles

Stakeholders enact domain roles when influencing emerging technology from a market-based perspective (see Section 6.2). An instantiation of ASSET, thus, requires the identification of DomainRole entities to provide stakeholders of disruptive innovation only with information on standards that is relevant for them.

The goal of the *"Define Domain Role"*, thus, is to create the DomainRole entities that ASSET applies to filter standards according to their relevance for a given stakeholder. The set of roles can be derived from life-cycle models that describe the processes of developing and consuming the constituent technologies (see Section 2.3.2 for an example). Also, a variety of use case models are typically present in the early phases of disruptive innovation, defining domain roles. However, use case models tend to lean towards the industry that they come from. Their granularity, thus, tends to be very fine grained, increasing the complexity of standards assessment.

As with the activities to define technologies, technology fields, and standards fields, defining domain roles is a creative task. ASSET, thus, may only support the definition of domain roles by capturing its outcome, providing modeling flexibility and propagating resulting changes. A *"Classification challenged"* event will, thus, be triggered, if changes to the set of DomainRole entities have been made in this step.

Define Attribute Types

Creating attribute types completes ASSET's instantiation for a given domain of disruptive innovation.

The goal of the *"Define Attribute Types"* activity is to define the attribute types that can be used to classify standards. Stakeholders, therefore, have to create instances of the AttributeType entity. In doing so, they may add descriptive information (DescriptiveAT), assess its applicability (ApplicabilityAT), or to derive additional information (InterpretativeAT). Defining AttributeType instances, furthermore, requires stakeholders to define *attributeCardinality*-, *allowedValue*-, *domain*-, *scaleOrder*-, and *aService*-properties (see Section 5.6).

Following ASSET's separation of domain-specific and standards-specific aspects, AttributeType entities assess standards from a domain or a standards perspective:

- Using ASSET, *domain-specific attributes* aim at capturing the new paradigm that is introduced with the disruptive innovation. With cloud computing, for example, new types of services (e.g., Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS), Software-as-a-Service (SaaS)) and new opportunities for the delivery of services (e.g., public, private, hybrid clouds) have been introduced.[32] Similar to the definition of technology fields and standards fields, this kind of information of information must be derived from references models, vocabularies, research reports, white papers as well as monitoring the disruptive innovation's market for new products or services.

- *Standards-specific attributes* capture information that allows for assessing a standard's characteristics that are independent of a given domain of disruptive innovation. ASSET, thus, incorporates information like, for example, the status of a standard, the document type, or the rules to participate in standardization into the assessment of standards for disruptive innovation. In contrast to domain-specific attributes, the types of standards-specific attributes hardly change over time. A database of standards-specific AttributeType entities may, thus, develop as a result of ASSET's application to different domains of disruptive innovation. The task of defining standards-specific AttributeType entities may, therefore, transforms into selecting suitable attribute types from the database rather than creating new standards-specific AttributeTypes each time. In doing so, ASSET reduces efforts of future instantiations.

Not all attributes—and, thus, attribute types—are of equal relevance for all stakeholders, technology fields, or standards fields. The second goal of ASSET's *"Define Attribute Types"* activity, therefore, is to define the specific relevance of an AttributeType entity. Thus, stakeholders have to define the AttributeType's dependencies to TechnologyField and StandardsFields entities (see "attributeTypes"-relation in Figure 5.14). Moreover, they have to define which instances of the Role entity a capable of assessing a given AttributeTpype instance (see "assessedBy"-relation in Figure 5.15). Using these relationships, the relevant set of attributes that stakeholders have to value when classifying a standard in the second step of the *"Classification Sub-process"* can be determined at runtime (see Section 7.3.2).

6.3.3. Sub-process: Classify Standard

The *"Classify Standard"* sub-process describes the sequence of ASSET's activities to create standards profiles. The technology typology that was created in the previous step is used as the classification scheme.

An instance of the *"Classify Standard"* sub-process will always be performed by one stakeholder. However, multiple stakeholders may perform multiple instances of the *"Classify Standard"* sub-process. Thus, multiple classifications of standards will exist, eventually. This may include multiple classifications of different stakeholders, but also more

[32] More examples are given in Section 8.1.3.

than one classification of the same stakeholder. ASSET provides capabilities to consolidate the many, potentially conflicting classifications (see Section 6.4.3 for details).

If a standard is to be classified for the first time, a new standards profile is created by defining basic information (see *"Define Basic Information"* activity). A stakeholder has to assign the appropriate technology framework, i.e., assign Technology, Technology-Field, and StandardsField entities as well as define the implementations of a standard (see *"Assign Technology Framework"* sub-process). Next, the standard's dependencies and relevance have to be defined, using the technology typology (see *"Define Dependencies and Relevance"* sub-process). Also, the stakeholders are required to provide values for each of the relevant attributes (see *"Value Attributes"* sub-process).

ASSET's procedural model defines an instance of the *"Classify Standard"* sub-process to be executed on the combination of three start-events (see Figure 6.6):

- Defining the *"Technology available"* start-event, ASSET's procedural model represents the requirement of a technology typology to have been created before stakeholder can perform classifications. ASSET defines the technology typology to be mandatory for the classification of standards, by synchronizing the control flow using an AND-Gateway. In consequence, classifications will only start if any of the following events is triggered. Defining the *"Classify Standard"* sub-process to be executed in multiple instances, the *"Technology available"* event remain triggered once the first instance of the *"Create Technology Typology"* sub-process has been executed.

- The development and progression of standards in disruptive innovation are out of ASSET's control. As a consequence, ASSET must provide a capability to react to events of new standards specifications being published. Applying the *"Standards Spec. published"* (short for *"Standards Specification published"*) start-event, ASSET provides this capabilities. For every specification of a standard, this event will only be triggered once, ensuring that every standards specification is only considered once in ASSET.

- The *"Classification challenged"* start-event, on the contrary, is an event that is internal to ASSET. Using this event, ASSET ensures up-to-date standards profiles, as changes to the technology typology may trigger the event's occurrence. Also,

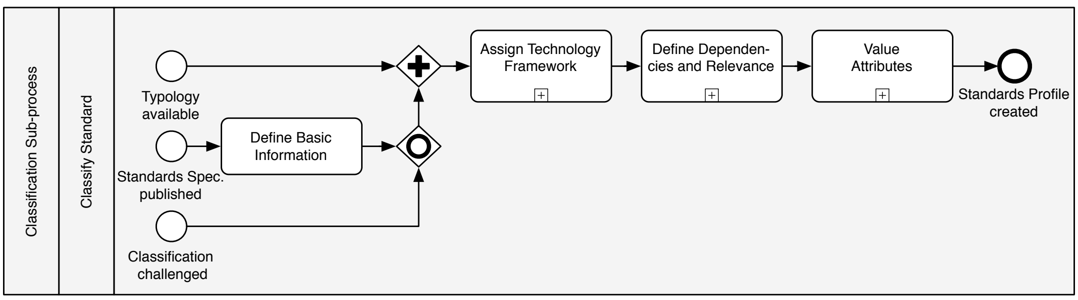


Figure 6.6.: ASSET - Procedural Model: Classify Standard Sub-process

stakeholders may trigger the *"Classification challenges"* event at any time, creating a new classification of a standard.

In the remainder of this section, we will present details of the individual steps of ASSET's *"Classify Standard"* sub-process.

Define Basic Information

A standards profile comprises basic information in addition to the domain and standards entities of the technology typology. Being defined in the information model, this information comprises the name of the standard, a short description, the version number, and the link to the document of the standards specification (see Section 5.2). The information model defines these properties of a standard to be final, i.e., they may not change over time. Thus, only the first stakeholder to classify a standard has to define basic information.[33]

Assign Technology Framework

The goal of the *"Assign Technology Framework"* sub-process is to characterize a standard, using the entities of the technology framework. All stakeholders are, therefore, required to select instances of the Technology and, after that, TechnologyField and StandardsField entities that are addressed by the standard. In doing so, a standard's scope and subject are determined. In addition, ASSET uses the selected instances of the technology framework entities to guide stakeholders in classifying standards. The attributes that a stakeholder should value in the classification are, therefore, derived from, for example, the technology fields and standards fields that the standard addresses (see Section 5.6).

ASSET's procedural model defines the *"Assign Technologies"* activity to be performed before a standard's technology fields and standards fields will be assigned (see Figure 6.7). Applying the same order of activities as in the *"Define Technology Framework"* sub-process (see Figure 6.5), ASSET guides stakeholders to be as precise as possible. Since standards may, however, guide entire fields of technology, assigning the corresponding TechnologyField instances is done subsequently (see *"Assign Technology Fields"* activity). Concurrently, stakeholders select the standard's StandardsField instances (see *"Assign Standards Fields" activity*) and add references to its implementations if available (see *"Assign Implementations"* activity).

Stakeholders require two types of information to complete the four steps of assigning the technology framework: Obviously, the content of the standard must be understood for selecting and assigning technologies, technology fields, and standards fields. Moreover, stakeholders require information on the technology, technology fields, and standards fields to select and, then, assign matching instances. ASSET maintains access to both types of information. Firstly, every instance of an entity is required to provide a short

[33] We assume that an implementation of ASSET will automatically assign identifiers to standards profiles (i.e., the *id-property*). See Section 5.2 for details.

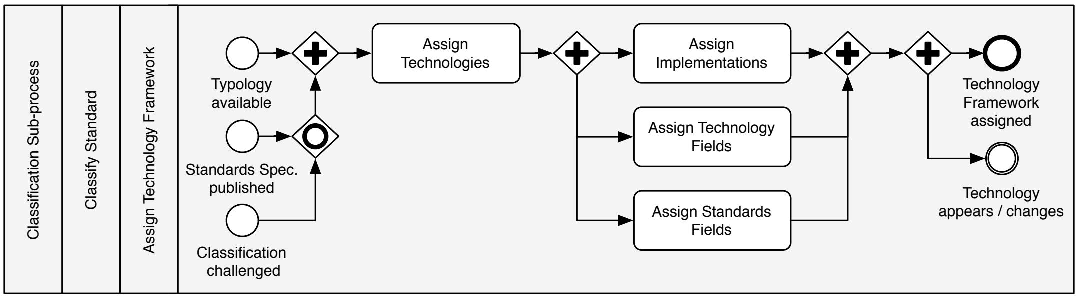


Figure 6.7.: ASSET - Procedural Model: Assign Technology Framework Sub-process

description (see Section 5.1). Secondly, a Standard instance is required to provide a link to its specification.

If a standard was classified at least once, ASSET provides capabilities to reuse existing classification information, reducing efforts of subsequent classifications. A standards profile may, therefore, be used to automatically populate values of questionnaires or assessment forms. Stakeholders, thus, are only required to provide values for which they disagree with the existing classification. Likewise, information that is kept in standards profiles of older versions of a standard could be reused when creating standards profiles for a newer version of the standard.

This sub-process terminates by reaching the *"Technology Framework assigned"* end-event. Stakeholders may, however, not always be able to classify a standard adequately. The completion of the *"Assign Technology Framework"* sub-process may, thus, trigger the *"Technology appears / changes"* end-event, if a stakeholder cannot assign all Technology, TechnologyField or StandardField entities that a standard applies to. A new iteration of the *"Create Technology Typology"* sub-process will be initiated to incorporate the dynamics of standards in disruptive innovation (see Figure 6.4).

Assign Dependencies and Relevance

Standards provide value within their respective environment. Assigning the technology framework, ASSET describes the technology that is relevant for a standard. The environment of a standard, moreover, comprises dependencies between standards. Also, a standard may only provide value for a particular role that a stakeholder enacts. The goal of the *"Assign Dependencies and Relevance"* sub-process, thus, is to extend the classification of standards to comprise these aspects of the environment. Stakeholders, therefore, perform the *"Define Standard Type"*, *"Assign Domain Roles"*, *"Assign Legal & Regulatory Framework"*, and *"Define Related Standards"* activities (see Figure 6.3.3).

ASSET does not define a sequential constraint on the former three activities as the information does not define dependencies between their respective entities. Tools, implementing ASSET may, therefore, allow stakeholders to perform the following steps in an arbitrary order or even concurrently:

- *"Define Standard Type"*: Distinguishing base standards from standards profiles, stakeholders have to identify explicit references to other standards specifications. These can typically be found in the introductory section of a standards specification and, thus, does not require profound knowledge of a standard.
- *"Assign Stakeholders"*: ASSET aims at supporting the assessment of network effects. Thus, the set of stakeholders that participate in standardization has to be assigned in the "Classify Standard" sub-process. Applying ASSET's stakeholder model, a stakeholder that performs that "Assign Stakeholders" activity may classify its organization's standards-specific role in the standardization of the given standard. An implementation may allow denomination of other stakeholders. However, they should implement means to verify this information (e.g., only assign a standard-specific role to a stakeholder entity, if its amount of denominators exceeds a given threshold). Information that is maintained by the use of the Standardization entity may be used to support a strategical decision. For example, if a stakeholder does (not) want to implement the same standard as a competitor or partner organization.
- *"Assign Domain Roles"*: ASSET captures a standard's relevance using the concept of domain-specific roles (see Section 5.5). In doing so, ASSET's capabilities to filter standards according to stakeholder perspectives are provided. Creating a standards profile, thus, requires the assignment of DomainRole instances that derive value from the standard. Stakeholders, therefore, select appropriate instances from the technology typology.
- *"Assign Legal & Regulatory Framework"*: Standards may be referenced in laws, acts, and regulations. If stakeholders know about standards that provide a basis for a disruptive innovation's legal and regulatory framework, they create and assign corresponding instances in this step. ASSET does not mandate an extensive search of standards involvement in such legal aspects, focusing on the assessment of standards. Stakeholders may, therefore, skip this step.

Defining the type of the standard, stakeholders provide the input that is necessary for the definition of related standards. Reducing the set of related standards, ASSET requires instances of the DomainRole entity to be assigned. In addition, the dependency of standards may be defined by a similar legal and regulatory framework. The *"Define Related Standards"* activity, consequently, has to succeed the above-named activities.

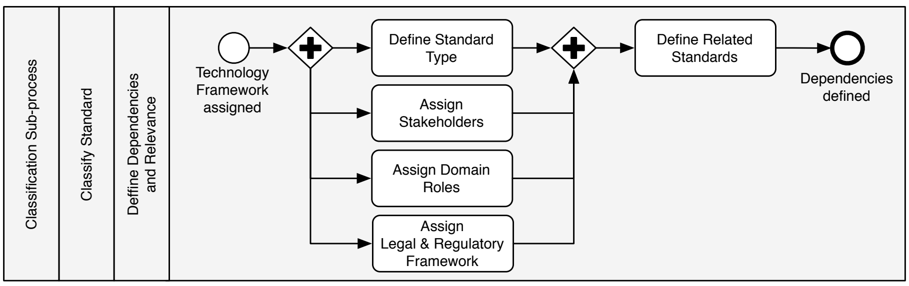


Figure 6.8.: ASSET - Procedural Model: Assign Dependencies and Relevance Sub-process

If a standard was classified to be of type StandardProfile, stakeholders are to define at least one dependency to its corresponding BaseStandard instance. Likewise, stakeholders can identify preceding Standard instances based on their temporal dependency and, thus, create according relationships. The definition of related standards that represent competitors or complements, however, requires stakeholders to know other standards that share the standard's scope or subject.

The *"Assign Dependencies and Relevance"* sub-process completes as soon as the stakeholder has defined all related standard, reaching the *"Dependencies defined"* end-event.

Value Attributes

Completing the creation of a standards profile, stakeholders, finally, have to provide values for a standard's attributes. Figure 6.9 illustrates the flow of activities that are involved in valuing attributes. ASSET does not impose a particular sequence of the activities to *"Value Descriptive Attributes"* and *"Value Applicability Attributes"*. They may, thus, be performed concurrently. Interpretative attributes are derived from other attributes. Values for interpretative attributes, thus, can only be provided, once descriptive and applicability attributes have been valued. ASSET's procedural model, therefore, defines the *"Value Interpretative Attributes"* to succeed previous activities.

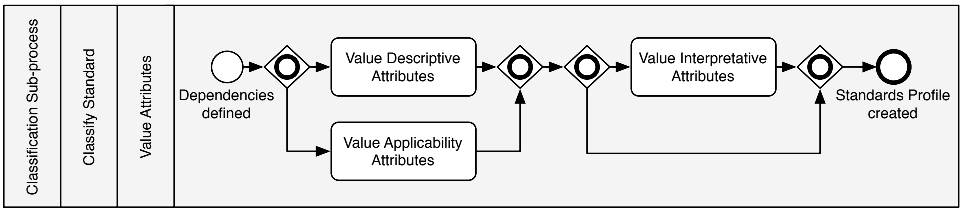


Figure 6.9.: ASSET - Procedural Model: Value Attributes Sub-process

The technology framework that a standard is assigned to defines the set of a standard's attributes. The roles that a stakeholder enacts when performing the *"Classify Standard"* sub-process, additionally, constrain the set of attributes that should be valued by the stakeholder. Not all stakeholders will, thus, perform all activities of the *"Value Attributes"* sub-process nor will all stakeholders value the same attributes. ASSET, consequently, models a conditional flow of its valuation activities, i.e., allows stakeholders to skip activities if no corresponding attribute should be valued.

Valuing attributes requires stakeholders to have knowledge of the standard's content, related standards, emerging technology, and the market for the disruptive innovation. ASSET facilitates the valuation of attributes by constraining the set of possible values based on the AttributeDomain entities or an attribute's *scaleOrder-property* (see Section 5.6). Using this kind of information, implementations of ASSET may create questionnaires with according input fields (see Section 7.2).

Once the stakeholder has valued all corresponding attributes, the sub-process completes by triggering the *"Standards Profile created"* end-event. Classifications are performed by different stakeholders, creating an individual sets of attributes.

6.3.4. Sub-process: Use Standards Profiles

The previous sections introduced the activities of ASSET's *"Classification"* sub-process, creating instances of domain- and standards-specific entities that build the standards profiles. We will now introduce how ASSET helps stakeholders to evaluate standards using the standards profiles.

Standards profiles are the results of ASSET's classification phase and represent the first type of information, i.e., organizationally independent information. The goal of ASSET's *"Evaluation Sub-process"*, therefore, is to guide stakeholders in the process of defining their context of standards assessment.

ASSET supports two different contexts of standardization to address the different needs of stakeholders: Firstly, ASSET's *"Select Standards"* sub-process provides guidance on finding a list of standards, if the context is to find standards that match a development project of a product or service. Secondly, ASSET supports stakeholders in monitoring the status quo and performing roadmapping activities as defined in the *"Status Quo & Roadmapping"* sub-process.

We will discuss both sub-processes in the remainder of this section, introducing their respective activities.

Select Standards

The goal of ASSET's *"Select Standards"* sub-process is to inform stakeholders about standards that should be considered when developing products or services. In terms of ASSET's concepts, stakeholders are guided through the process of finding and ordering standards profiles that match their context. ASSET represents context using a *contextual typology*. Figure 6.10 illustrates the sequence of activities and events of ASSET's *"Select Standards"* sub-process.

ASSET models two conditions for the *"Select Standards"* sub-process to be executed by stakeholders: Firstly, the internal *"Standards Profile created"* start-event must be triggered. In doing so, ASSET ensures that the technology typology has already been created and applied, i.e., a standards profile has been created. Instantiations of ASSET may derive related events that, for example, require a set of standards profiles to be created before the *"Select Standards"* sub-process may be started. While ASSET's contribution will fully demonstrate only if a significant set of standards profiles has been created, the determination of this trade-off is out of scope of this thesis. Conceptionally, however, there is no difference as long as an internal event signals ASSET to be ready for the execution of the *"Select Standards"* sub-process. Secondly, a stakeholder must demand an evaluation, i.e., issue the *"Evaluation triggered"* start-event to trigger process execution.

The *"Create Contextual Typology"* sub-process is the first step of selecting standards using ASSET. The contextual typology constitutes a selection of instances of domain-specific and standards-specific entities as defined by ASSET's technology typology (see Section 6.1). ASSET, thus, guides stakeholders in the process of selecting elements of the technology typology that describe their context. The following activities constitute the *"Create Contextual Typology"* sub-process:

- *"Select Roles"*: Stakeholders have to select the Role instances that describe the perspective for their purpose of selecting standards. For this purpose, they must select suitable StandardsRole and DomainRoles instances. As defined in the information model (see Section 5.5), ASSET may filter standards based on the relevance of a standard for a given DomainRole instance. Also, appropriate assessment attributes will be selected in that way (see Section 5.14). If the execution of the *"Select Standards"* sub-process is tool-supported, this step may be done automatically.
- *"Select Technology Fields"* and *"Select Technologies"*: Once the appropriate Role instances have been selected, stakeholders have to describe their product or service development project using ASSET's concepts to represent emerging technology. Firstly, stakeholders select TechnologyField instances that appear to be relevant to their context. This selection may be refined by selecting corresponding Technology instances subsequently. Stakeholders, thus, define their subject of standardization.
- *"Select Standards Fields"*: Stakeholders select the StandardsField instances, matching the problem that should be addressed by their development project. In doing so, they define possible scopes of standardization.

Performing the above-mentioned activities, stakeholders create a sub-technology typology that describes the scope and subject of standardization in their development project. Thereafter, ASSET requires stakeholders to rank the relative importance of, both, domain-specific and standards-specific instances of AttributeType entities (see *"Rank Attributes"* step). In doing so, organizational capabilities, risks, and opportunities are incorporated into the selection process. The set of attributes that weights have to be provided for can be filtered using the contextual typology (see Section 6.4.2). Moreover, instantiations

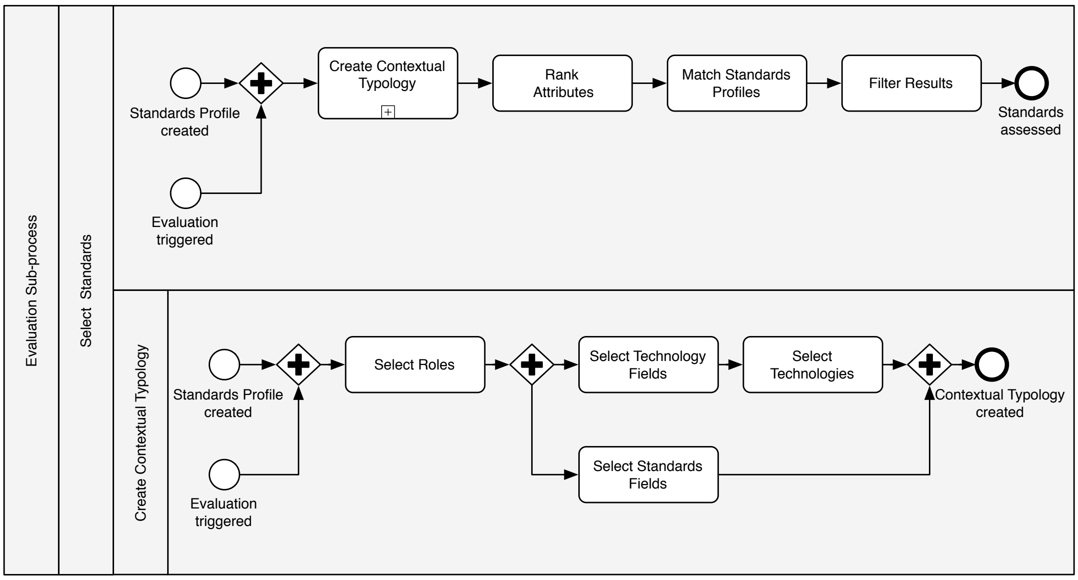


Figure 6.10.: ASSET - Procedural Model: Select Standards Sub-process

of ASSET may apply different techniques to ascertain weights. Multi-criteria decision-making approaches like Analytical Hierarchy Processing (AHP), for example, apply pair-wise comparisons. Assuming the existence of weights, ASSET is, however, agnostic to the particular technique to ascertain weights.

In providing the relative importance of relevant attributes, they, furthermore, provide the input to rank standards accordingly. ASSET's *"Match Standards Profiles"* step, may consequently generate an *ordered list of standards profiles* by matching the contextual typology to standards profiles and calculating scores of their attributes. This step should be executed automatically by implementing state of the art decision support technology. Being out of the scope of this thesis, we provide an outlook to possible technologies in Section 10.3.

Uncertainty is a major factor that influence the accuracy of standards evaluations in disruptive innovation. ASSET, thus, allows stakeholders to filter their results in the final step of the *"Select Standards"* sub-process. In doing so, stakeholders may perform what-if-analyses to explore how the calculated ranking of standards varies, if, for example, weights for assessment attributes changed. Also, ASSET supports filtering of standards based on other information that is provided by the underlying information model. Stakeholders may, for example, select only standards that are supported by stakeholders of their respective ecosystem to leverage network effects.

Status Quo & Roadmapping

In the previous section, we presented ASSET's support for selecting a standard in the development of a product or service. ASSET, thereby, supports short- to middle-term standardization decisions on the operational and tactical level. Strategical long-term decisions on standardization will, however, not always have a particular product or service in mind. ASSET, therefore, provides support to assess the status quo of standardization and to evaluate standardization activities, in general, i.e., without focusing on a particular product or service.

Figure 6.11 presents ASSET's corresponding *"Status Quo & Roadmapping"* sub-process. The sub-process defines the sequence of activities that ASSET applies for assessing the status quo and for identifying and prioritizing current gaps of standardization.

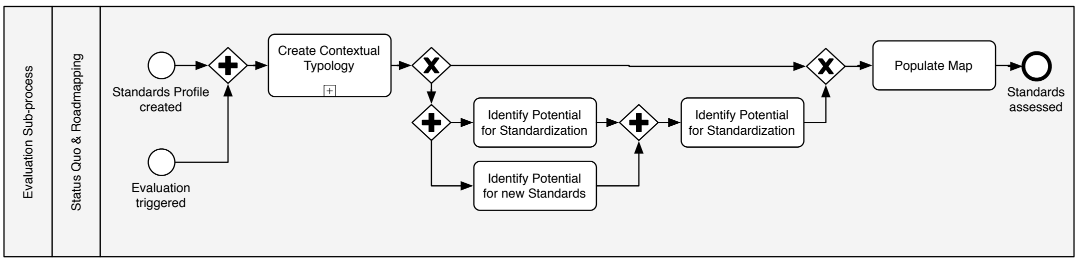


Figure 6.11.: ASSET - Procedural Model: Status Quo & Roadmapping Sub-process

Stakeholders may execute the *"Status Quo & Roadmapping"* sub-process for two purposes: They may wish to aggregate the status quo, for example, to see the portfolio of standards. Moreover, they may perform additional activities to roadmap standardization activities. The *"Status Quo & Roadmapping"* sub-process shares the same events and, thus, starting conditions like the *"Select Standards"* sub-process (see Figure 6.10).

The first step *"Aggregate Status Quo"*, thus, has to identify the set of scopes and subjects of standards that are relevant for the given purpose of status quo or roadmapping. Therefore, ASSET's "Status Quo & Roadmapping" processes, reuses the "Create Contextual Typology" sub-process.

If stakeholders wish to develop a roadmap for prioritizing future standardization activities, ASSET's *"Status Quo & Roadmapping"* sub-process suggest three additional steps:

- *"Identify Potential of Standardization"*: Firstly, stakeholders have to provide estimates for the potential of standardization for all combinations of standards and technology fields. They should, therefore, answer the set of questions "What is the value of standardizing [StandardsField] for [TechnologyField]?" The value of standards is subjective and comprises different perspectives (see Section 2.1.1). The question, therefore, is intentionally fuzzy, allowing stakeholders to apply their concept of the value of standards. ASSET, however, demands stakeholders to estimate their value-based on an ordinal scale. Using a four-point Likert scale, stakeholders are required to decide if the value of standardization is "positive", "probably positive", "probably negative", and "negative".
- *"Identify Potential for new Standards"*: In addition, stakeholders have to estimate the current value of standards for each StandardsField-TechnologyField-combination. Answering the questions "What is the potential of creating a new standard for [StandardsField] addressing [TechnologyField]?", stakeholders indirectly assess the current state of standardization. Thus, they identify potential for new standards. Again, ASSET requires the answers to be provided in ordinal scale. Using a Likert scale, for example, stakeholder estimate the potential to be "high", "probably high", "probably low", and "low".
- *"Prioritize Gaps"*: Resulting form the completion of the *"Identify Potential of Standardization"* activity, the potential for standardization was identified for each combination of StandardsField and TechnologyField instances. Likewise, the potential for new standards is known as the result of the *"Identify Potential for new Standards"* activity. Thus, gaps of standardization can be derived and prioritized. A gap, thereby, represents any combination of standards and technology fields that has—on average—positive potential of standardization and a positive potential for new standards. ASSET distinguishes three types of gaps in the standardization of disruptive innovation. ASSET assigned "high" priority to any gap that is characterized by "positive" potential of standardization and "high" potential for new standards. If the potential of standardization or new standards is any combination of "positive / probably positive" and "high / probably high", ASSET considers gaps to be "increased". ASSET assigns, the level "existing" to a gap that presents any other combination of values.

Finally, the "Populate Map" step will position all standards on a map using on assigned standards and technology fields. ASSET, therefore, applies a matrix that carries the hierarchy of StandardsField instances on one axis and the hierarchy of TechnologyField instances on the other (see Table 6.1).

	StandardsField 1	*StandardsField 2*	...
TechnologyField 1	Standard 1, Standard 2	Standard 1	...
TechnologyField 2	Standard 3	Standard 2	...
...	...	...	...

Table 6.1.: ASSET: Portfolio Aggregation Matrix

Thus, a portfolio of standards constitutes the result of the *"Populate Map"* activity. Based on this structured overview of standards, stakeholders may quickly identify standards that are broad in scope, i.e., address a multitude of StandardsField-TechnologyField-combinations. In addition, StandardsField-TechnologyField-combinations that comprise many Standard entities indicate areas of high competition among standards.

Performing the *"Status Quo & Roadmapping"* process, ASSET supports stakeholders in the creating overviews of the status quo of the disruptive innovations portfolio of standards. Also, stakeholders may identify standards fields and technology field combinations that are not yet standardized. Using this information, they may plan their future involvement in standardization activities (e.g., participating in standards development). On the contrary, stakeholders may also decide to not further look for standards or strive for standardization in areas where the potential for standardization is low. In summary, ASSET, thus, provides stakeholders support in assessing standards in disruptive innovation not only on the tactical level of product or service development projects, but also on the level of strategical decisions.

6.4. Automation Support

This thesis aims to increase the efficiency of standards assessment in disruptive innovation. In Section 1.2, we motivated that information reuse and collaboration of stakeholders are prerequisites. From the cloud standard study, we learned automation of coordination and aggregation tasks are requirements for improving the efficiency of standards assessment (see Section 4.3.3. As a plus, automated information filtering contributes to reducing decision complexity.

The previous sections introduced ASSET's stakeholder and procedural model that was built to guide the instantiation of the conceptual information model for a given domain of disruptive innovation (see Chapter 5). Artifacts from both models build the foundations for information reuse, collaboration, and information filtering. Thus, they build the basis for providing support to automate and improve the efficiency of standards assessment. In this section, we will, therefore, provide details on how the conceptual artifacts enable the automation of standards assessment.

Based on the events that are defined in ASSET's "Assessment Process", we will derive an event model that explicates the dependencies between ASSET's sub-processes in Section 6.4.1. The model may be used by implementations to automate control of collaboration across the different iterations of ASSET's assessment phases. Automating filtering and aggregation of information, as well as the valuations of assessment attributes, provides additional potentials to improve the efficiency of ASSET. We will, therefore, discuss related aspects in Section 6.4.2 and Section 6.4.3. The conceptual information model, furthermore, allows for suggesting related standards in the process of classifying standards. We will present, ASSET's support for automating this tasks in Section 6.4.4.

6.4.1. Coordinating Updates

Uncertainty and dynamics of disruptive innovation demand an iterative approach to assessing standardization. ASSET's procedural model, consequently, identifies two phases and three sub-processes that are executed iteratively. The previous sections, therefore, described sub-processes, events, and input/output artifacts of ASSET's *"Assessment Process"*. The events build the basis for coordinating the iterations of ASSET's *"Create Technology Typology"*, *"Classify Standard"*, and *"Evaluate Standards"* sup-processes.

In this section, we will use the events of ASSET procedural model to develop state models of ASSET's two main artifacts: the *technology typology* and *standards profiles*. The state models allow for defining the life-cycle of the technology typology and standards profiles. Thus, they provide a means for the automation of ASSET. Table 6.2 summarizes the events of ASSET's classification phase. Moreover, it depicts the capability of each event to change the status of the technology typology or a standards profile. A short description of the event complements each row.

As discussed in Section 6.3, the events may result from *external* and *internal* triggers. The publication of a new standards specification, for example, is an external event that ASSET must react to (e.g., create a new standards profile). The *"Typology available"* event, on the contrary, is an internal event that allows for, e.g., triggering the classification of a standard. Not all events of in the procedural model, however, change the state of ASSET assessment artifacts. As listed in the table, the *"Technology Framework defined"* and the *"Dependencies defined"* events do not affect the state of the technology typology or standards profiles.[34]

If events are marked relevant for, both, the technology typology and standards profiles in Table 6.2, these events constitute synchronization points. Here a transition of the state of the technology typology implies changes to the state of a standards profile and vice

[34] These events are issued in the process of creating a technology typology and standards profiles respectively. They indicate progress in doing so. However, they are not required to synchronize the technology typology or standards profiles.

Event	*TT**	*SP*†	*Description*
Emerging Technology appears	yes	no	External event, decision to instantiate ASSET.
Standards Spec. available	no	yes	External event, the decision to create a standards profile.
Typology available	yes	yes	Timer event, periodically marks typology available and allows the creation of standards profiles.
Standards Profile created	no	yes	Internal event, triggers aggregation of standards profile information.
Technology appears/ changes	yes	yes	External trigger and internal event, triggers an update of the technology typology.
Classification challenged	yes	yes	External and internal event, triggers an update of standards profiles.
Technology Framework assigned	no	yes	Internal event, may lead to the decision to update the technology typology.
Technology Framework defined	no	no	Internal event, intermediate step in *"Create Technology Typology"* sub-process.
Dependencies defined	no	no	Internal event, intermediate step in *"Classify standard"* sub-process.

* Event is relevant for Technology Typology

† Event is relevant for Standards Profile

Table 6.2.: ASSET: Event Model

versa. In summary, *"Typology available"*, *"Technology appears / changes"*, and *"Classification challenged"* events simultaneously change states of the technology typology and standards profiles.

We will now use this classification of events to derive state diagrams for technology typology and standards profile. Therefore, we will transform events of the procedural model to transitions in the state diagrams.

Figure 6.12 presents the life-cycle of a technology typology in ASSET. As illustrated the external *"Emerging Technology appears"* event sets the technology typology's state to "required". The typology transitions to the state "available" triggered by the *"Classification challenged"* event that is issued by the *"Create Technology Typology"* sub-process as soon as it terminates. According to the procedural model, the *"Technology available"* event is a prerequisite for the creation of standards profiles (see Figure 6.13). Event-based implementations may, thus, periodically trigger this event. Alternatively, implementations may check if a technology typology is in the state "available" to ensure consistency of standards profiles. A technology typology will leave the "available" state if a "Technology appears / changes". Then, the re-development of the technology typology is "required". The life-cycle of a technology typology comes to an end, if the "Emerging Technology dissolves", i.e., standards assessment is no longer required.

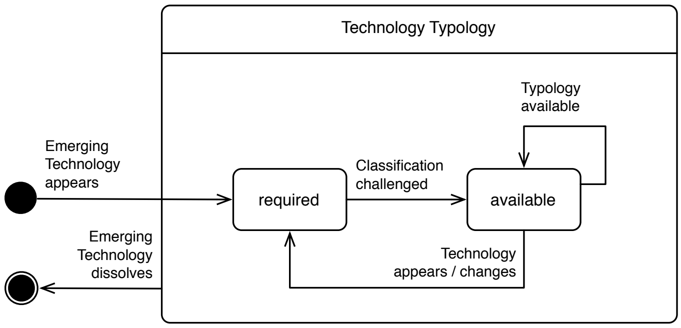


Figure 6.12.: Life-cycle: Technology Typology

The life-cycle of a standards profile is shown in Figure 6.13. A standards profile is "required" as soon as a standards specification has been published. As discussed in Section 6.6 the scouting of standards is out of scope of ASSET. The *"Standards Specification published"* event, therefore, is considered external and represents a stakeholder's decision to create a standards profile for a new standard that should be assessed.

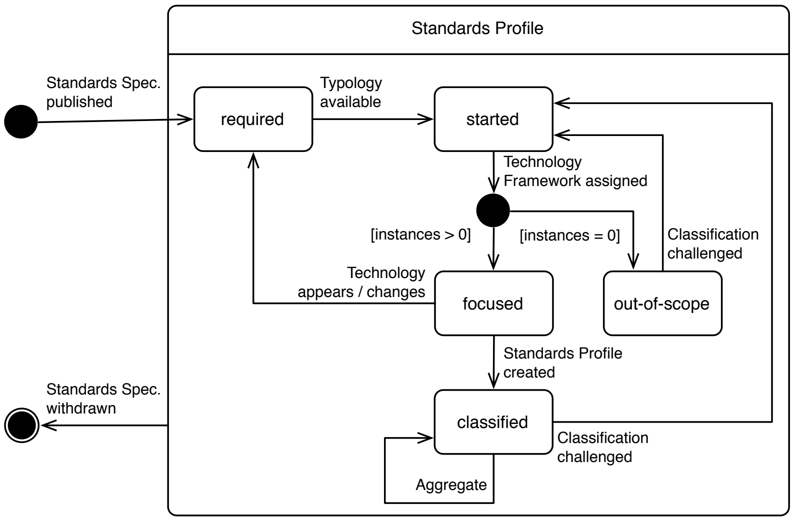


Figure 6.13.: Life-cycle: Standards Profile

As soon as the technology typology has been created, i.e., the *"Typology available"* event has been issued, the state of a standards profile transitions to "started". Next, a *"Technology Framework assigned"* event triggers the transition to the "focused" or "out-of-scope" state. If no matching instances of Technology, TechnologyField, or StandardsField entities were assigned (see "instances = 0" condition), a standards profile would transition to the "out-of-scope" state. An update of the technology typology (i.e., the *"Classification* *challenged"* may, however, trigger the transition to the "started" state.[35] The standards profile reaches the "focused" stage if the standard could be described with more than one instances of model entities that constitute the technology framework.

The execution of ASSET's *"Assign Technology Framework"* sub-process verifies, if a standard should be considered by ASSET. Also, a change of technology or a new technology could be identified in this step. The life-cycle of the standards profile, therefore, introduces the transition to the "required" state. In doing so, the state of the technology typology also transitions to "required". Thus, an update of the technology typology is required for the standards profile to eventually reach the "classified" state.

The "classified" state marks a standards profile available for evaluation purposes. A standards profile may leave the "classified" state if the classification is challenged. Therefore, the *"Classification challenged"* event triggers a transition to the "started" state. The event is triggered internally if the technology typology was updated. In doing so, the standards profile and the technology typology are kept in sync. ASSET's procedural model, however, allows stakeholders to individually start the re-classification of a standard at any time. Thus, the *"Classification challenged"* event is also considered external to ASSET. As defined by the conceptual information model, a classification of a standard does lead to the creation of instances of the AttributeInstance entity. Thus, the values of Attribute instances that are ascribed to a standard in the standards profile must be aggregated. Therefore, aggregations will be triggered periodically (see "aggregate" transition). Updates to a standards profile will be discontinued as soon as the standards specification is withdrawn (see *"Standards Spec. withdrawn"* transition).

The development of the state diagrams to coordinate changes to the technology typology and standards profiles, identified three transitions for which events have not been defined in ASSET procedural model. Table 6.3 summarizes these additional events.

Event	*TT**	*SP†*	*Description*
Emerging Technology disolves	yes	no	External event, stops ASSET.
Standards Spec. withdrawn	no	yes	External event, no more updates on a standards profile will be done.
Aggregate	no	yes	Timer event, periodically aggregate information of a standards profile.

* Event is relevant for Technology Typology

† Event is relevant for Standards Profile

Table 6.3.: ASSET: Extensions to the Event Model

[35] Alternatively, the life-cycle of standards profiles could be terminated. We, however, aim to incorporate as many standards as possible into the classification and, thus, conceptualized ASSET to trigger re-classifications of out-to-scope standards, if the typology was changed.

In summary, two additional external events are defined that allow for terminating the life-cycle of a technology typology or standards profile. In addition, the *"aggregate"* event will be used to update a standards profile, according to its potentially varying classifications.

In this section, we presented the use of the events that are defined in ASSET's procedural model. In doing so, we demonstrated how updates to the technology typology and standards profiles can be automatically coordinated. Managing the life-cycles of the technology typology and standards profiles, thus, becomes lesser of an issue and efficiency of standards assessment is improved.

We did not derive a state model from the events of the "Evaluation sub-process". ASSET assumes evaluations to not have a state, i.e., they will be created on the fly and, thus, are not persisted. Therefore, no potential for automation was identified here.

6.4.2. Filtering of Information

The combination of the information model with the procedural model allows stakeholders to assess standards from different perspectives. Thus, ASSET supports tailoring of standards assessment, according to the capabilities and knowledge of different stakeholders. In consequence, stakeholders will only be asked to provide information that they are capable of assessing. Likewise, implementations of ASSET will be capable of filtering information according to the current stakeholder's roles, hiding irrelevant information based on ASSET's stakeholder model. In this section, we discuss how ASSET contributes to automating the filtering of relevant information at first.

ASSET structures assessment information using the underlying conceptual information model. Likewise, potentials to automate information filtering can be derived from the information model. Tools may realize these potentials by exploiting the relationships that the information model defines between the *AttributeType*, *Role*, *Stakeholder*, *StandardsField*, and *TechnologyField* entity. However, these filtering potentials will only come into effect if they are applied together with ASSET's stakeholder model and the order of tasks that is defined by its procedural model. In the following, we will present the set of automation potentials for information filtering. Thereby, we will discuss the relevance of each potential in the context of ASSET's stakeholder model and its sub-processes:

- First, the "assessedBy"-relation (see Figure 5.15) allows any implementation of ASSET to hide instances of the AttributeType entity that are not assigned to the current instance of a concrete sub-class of the Role entity. Using this information, an implementation of ASSET's "Classification" sub-process may automatically hide instance of the AttributeType entity in the "Value Attributes" step (see Figure 6.3.3) that are not relevant for the current stakeholder. Relevance can be automatically determined using the set of Role instances that a stakeholder enacts. Likewise, tools may hide attributes of irrelevant AttributeType instances when ranking the importance of attribute values in ASSET's "Select Standards" sub-process. Finally, the amount of information that a standards profile presents, for example, when calculating results in ASSET's "Evaluation" sub-process, could be automatically reduced based on the "assessedBy"-relation (see Figure 6.3).

- Second, a tool may furthermore constrain the set of relevant attribute types based on the selection of relevant instances of the StandardsField and TechnologyField entities. The information model provides corresponding filtering capabilities based on the "attributeTypes"-relations between the AttributeType entity and the StandardsField and TechnologyField entities. ASSET procedural model requires any candidate implementation to always select the technology framework or create a contextual typology before attributes are valued in the "Classification" and "Evaluation" sub-processes. In doing so, ASSET guides stakeholders to model the relevant scope and subject of standardization. Any succeeding step in the procedural model may, therefore, filter attribute types using this information. Implementations of the "Classify Standard" sub-process may, for example, constrain the set of related standards. In ASSET's "Define Related Standards" step (see Figure 6.8), any related standard that is relevant should obviously address the standards and technology fields that match the current context. Likewise, implementations may dynamically calculate the set of attributes that a stakeholder has to value in ASSET's "Value Attributes" step based on the context that has been defined previously in the process. Implementations may equally apply filtering capabilities in ASSET's "Evaluation" sub-process when demanding stakeholders to rank the importance of attributes in the "Select Standards" sub-process (see Figure 6.10).

- Third, ASSET provides implementations with the potential to automate filtering of information applying the "relevantFor"-relation (see Figure 5.13). Using this information, results of ASSET's "Evaluation" sub-processes may, for example, be focused further according to the performing stakeholder's domain-specific roles. Implementations may, thus, automatically filter standards from resulting sets if they are not relevant for the current stakeholder. That is if the standard is not currently marked relevant for any of the domain-specific roles that the stakeholder currently enacts. The results that a tool presents in ASSET's "Filter Results" step (see Figure 6.10), for example, may thus be condensed even further.

- Finally, implementations could automatically filter results of the ASSET's assessments based on the classification of stakeholders (see *StakholderType* entity in Figure 5.5) or their jurisdiction (see *Jurisdiction* entity in Figure 5.5). Tools could, thereby, require the list of standard to comprise only standards that match the stakeholders properties. Moreover, they could implement filtering capabilities for ASSET's "Filter Results" step (see Figure 6.10) using this information.

In summary, the combination of ASSET's information, stakeholder, and procedural model presents a set of potentials to automate information filtering capabilities in tools. However, the set of relevant information that an implementation presents to its users may be determined by two or more of ASSET's filtering capabilities. The set of relevant attributes that an implementation requires stakeholders to provide valuations for, for example, is the result of the combination of filtering capabilities provided by "assessedBy"-relation (see above), the "attributeTypes"-relation and ASSET's procedural model. Implementations are, therefore, required combine these filtering capabilities while ensuring replicability. Furthermore, inconsistencies of the filters might appear in practice if, for example, an *AttributeType* instance is marked by the contextual typology but does not match the stakeholders set of roles. Implementations will have to implement capabilities to resolve such inconsistencies.

6.4.3. Aggregation of Standards Profiles

The classification of standards in ASSET can be understood as an ongoing questionnaire-based assessment of standards. In consequence, the relevance of standards profiles and the classification schema (i.e., the technology typology) are constantly assured. In combination with the filtering capabilities described above, implementations of ASSET, however, have to cope with partly overlapping and potentially conflicting assessment information, stemming from different perspectives. Therefore, automated aggregation capabilities are required to consolidate partial assessment into consistent, comprehensive standards profiles while handling potentials conflicting values. Moreover, strategic decisions require an overview of the current portfolio of standards. Thus, automation support is also required that aggregates information on the level of standards profiles.

We will introduce the automation potentials for the different types of aggregation of information in this section. Implementing these potentials, tools may automate the consolidation of the varying stakeholder perspectives and enable strategic analyzes of portfolios of standards.

Consolidation of Classification Data

Section 6.6 defined ASSET's sub-process to classify standards. For a standards profile to be completed, stakeholders have to assign the technology framework, define a standard's dependencies and relevance, and provide values for the relevant assessment attributes. Consolidation of varying standards profiles, thus, requires consolidation of the technology framework, a standard's dependencies and relevance, and its attributes.

Building upon the approach of the cloud standards study (see Section 4.1), the basic principle of consolidating information of standards profiles is defined by a Delphi-approach (see Section 2.2.3). Therefore, relevant results of previous classification will be presented to stakeholders that perform subsequent classifications. Stakeholders, therefore, may modify existing classifications. The periodical "aggregate" transitions presented in the Section 6.4.1, thereby, allows implementations of ASSET to simulate distinct rounds of a Delphi-approach. Applying the Delphi-approach, the values that are included in a standards profile, therefore, will consolidate over time.

ASSET, however, provides additional potential for automation based on the AttributeInstance and Attribute entities. Conceptionally, the goal of ASSET's *"Value Attributes"* sub-process is to create instances of the AttributeInstance entity that correspond the relevant AttributeType instances. The values of these instances can, thereafter, be automatically aggregated to instances of the Attribute entity that are assigned in the standards profile (see Section 5.6). A standards profiles, thus, only comprises the values of Attribute instances that are associated with the standard. Since the attributes may not only comprise ordinal or nominal values, aggregation is facilitated by the aggregation rules defined in Section 5.6. The amount of attribute values of the same instance of the AttributeType entity that is currently assigned to a standard is, thereby, constrained by the *attributeCardinality*-property (see Section5.6). An implementation of ASSET may, thus, automatically perform aggregation of attribute values based on these rules. Similar to the presentation of a standard's currently assigned technology framework, stakeholders could be shown the current values of attributes when classifying standards. In doing so, consolidation of assessments could additionally be supported by the consensus building capabilities of a Delphi-approach.

Valuation of Attribute Instances

The information models introduced InterpretativeAT entities as a special type of attributes. Instances of InterpretativeAT entities define an endpoint of service that is capable of calculating the values of attributes (see *iService*-property in Figure 5.14). As defined in the information model, attributes of type InterpretativeAT may be used to refer to other attributes to derive higher-level attributes. ASSET's procedural model ensures calculation of attribute only after descriptive and applicability attributes have been assigned. In doing so, ASSET provides a means to automate the valuation of assessment attributes.

This conceptualization assumes a uniform interface for all iService-endpoints. Applying Representational State Transfer (REST) as the architecture style, each iService instance could, for example, provide a Hypertext Transfer Protocol (HTTP) interface for a HTTP get-method expecting the related attribute types as parameters. Varying and more complex interfaces for iService-implementations could be supported by requesting the iService-attribute to point to a Web Service Definition Language (WSDL)-endpoint. While doing so would provide greater flexibility in terms of supported interfaces of iService-implementations, this challenge is not conceptual but technological. We, thus, simply defined an iService-implementation to be available at a certain Uniform Resource Identifier (URI).

The concept of InterpretativeAT may, furthermore, be used to define metrics that capture the strength of network effects in standardization. An instance of an InterpretativeAT could, for example, be defined to predict the market success of a standard based on the amount and types of stakeholders. Since the metrics to assess network effects are diverse, ASSET applies the service-based approach, providing the flexibility to include different metrics. Integrating comprehensive metrics for the management of networks effects, however, is out of the scope of this thesis (see e.g., [44, 156] for detailed discussions).

Evaluation of Standards Profiles

Aggregating the portfolio of standards is the basic principle of ASSET's support of strategical decisions. It is based on ASSET's conceptualization of capturing a standard's scope and subject, applying instances of StandardsField and TechnologyField entities. ASSET's steps to assess the status quo and perform a roadmapping of future activities, thus, make intense use of aggregating information that is maintained in the information model. Obviously, these activities demonstrate potential to reduce assessment efforts by automation.

The aggregations that are required to support the *"Aggregate Status Quo"* activity, conceptionally represent queries against the information model based on the current selection of standards and technology fields. The corresponding hierarchies of instances provide the necessary structure that allows automation of the aggregation of standards profiles.

As described above, filtering of information can be automated, by applying the contextual typology that defines the relevant scope for the aggregation (see Section 6.3.4). Implementations could likewise use the contextual typology in defining the queries that are required to automate the assessment of the potential of standardization, in general, and new standards, in particular. Similarly, analyzing gaps can be automated. The rules for the prioritization as defined in Section 6.11 provide another input to automate the creation of maps that are required for roadmapping activities.

6.4.4. Identification of Related Standards

Finding related standards requires a profound knowledge of the standardization environment and a uniform classification scheme. While ASSET provides the classification scheme, it is also capable of deriving suggestions of related standards, based on its information model. In the process of classifying a standard, stakeholders, thus, may benefit from a list of suggestions for related standards.

Generally, support to automate the identification of related standards could be provided on the content- and market-related dimensions or the temporal dimension of dependencies of standards (see Section 5.4). The identification of content-related dependencies, however, would require standards specifications to be machine readable, for example, to parse explicit references to another standard or even understand the content to identify implicit content-relations.

Thus, ASSET provides potential to automate the management of dependencies of standards. In consequence, assessment efforts will decrease. Changes to the set of competing standards could, for example, be automatically added to standards profiles of all affected standards. While not all dependencies are bi-directional (e.g., a standard complementing another will not always be a complement to the other), implementations may trigger revisions of a standard's set of related standards based on this information.

6.5. Conclusion

In this chapter, we presented ASSET, our method to support the assessment of standards in disruptive innovation. The procedural model was exclusively build using constructs that are defined in the conceptual information model. Thus, ASSET comprises a procedural model that is independent of a particular application domain. In consequence, ASSET may guide standards assessment in different domains of disruptive innovation.

ASSET's procedural model defines the activities that stakeholders have to perform to instantiate the conceptual information model, i.e., create the technology typology and classify standards. Based on the domain-specific technology typology and the standards profiles, the method supports the evaluation of standards for their use in different given contexts. ASSET, thus, structures the activities that are necessary to assess standards for a given domain of disruptive innovation, reflecting the data constraints that defined by the conceptual information model. In doing so, ASSET procedural model coordinates individual contributions of different stakeholders. In doing so, ASSET's procedural model addresses the challenge of coordinating iterative execution of assessment steps (see Section 4.3.2). Moreover, the combination of the ASSET's procedural model and the conceptual information models allowed for identifying potentials for task automation.

ID	*Requirement*	*Realization*
IR-5	Support stakeholders and roles	Stakeholder model constrains StandardsRole instances. DomainRole instances can be added anytime.
PR-1	Support updates of the classification scheme	Procedural model defines events and steps to update typology (Delphi-approach).
PR-2	Support updates of classifications	Procedural model defines events and steps to update standards profiles, existing profiles build the basis for re-classification (Delphi-approach).
PR-3	Coordinate updates	Event model and state model ensure synchronization of typology and standards profiles across iterations.
PR-4	Support contextualization	Stakeholders select typology elements to describe the context in the evaluation subprocess.
AR-4	Support ranking of standards	Procedural model includes subjective rankings of attributes, prioritization of standards, thus, can be automated.

Table 6.4.: ASSET: Realization of Method Requirements

Specifically, ASSET realizes the process requirements (see Section 4.2) as summarized in Table 6.4. ASSET's procedural model supports iterative changes to the technology typology, implementing a Delphi-approach (PR-1). In doing so, it enables discussions among stakeholders of standards assessment. Also, ASSET coordinates updates to existing classifications of standards, i.e., standards profiles (PR-2). ASSET supports coordination of updates to the technology typology and standards profiles using process events (PR-3). A state model ensures synchronization of updates. The dynamics of standards in disruptive innovation are, thus, accommodated through the flexibility of the typology and features to coordination the evolution of ASSET's main artifacts. Finally, ASSET supports contextualization of evaluation sub-processes by demanding users to represent their product or service development project using a subset of the elements that constitute the technology typology (PR-4).

In addition process requirements ASSET contributes to fulfilling additional method requirements: ASSET's stakeholder model defines and classifies relevant stakeholders, defining instances of the conceptual information model's StandardsRole entity (IR-5). In addition, ASSET's procedural model incorporates steps that guide stakeholders in defining the subjective importance of assessment attributes, enabling the automation of the ranking of standards (AR-4).

While ASSET provides features to enable frequent assessments of standards in disruptive innovation, there remain open issues in standards assessment:

- A detailed analysis of the particular benefits of using standards in a given development project can, for example, only be identified by the engineers of the product or service in proof of concepts implementations. Similarly, detailed cost-benefit analyses, being used in product planning and strategic decisions, are out of scope. The final decision for or against the implementation of a standard, thus, may require additional assessment efforts that are not currently supported by ASSET.
- In addition, inconsistencies may arise in the domain-specific information model. For example, a standard may be defined to have relationships with instances of TechnologyField, Technology, and Implementation entities. In such situations, there could arise inconsistency in terms of the amount of standards that are classified by a TechnologyField instance and the sum of standards that address corresponding Technology instances. ASSET, currently, does not support the identification of such inconsistencies. Long-term studies with a software implementation of ASSET, however, could be used to verify the severity of this issue.
- The initial creation of a technology typology as well as the creation of standards profiles requires efforts in-spite of ASSET's support and automation capabilities. The success of ASSET's application, therefore, depends on a critical mass of stakeholders that maintain an up-to-date technology typology and current standards profiles (see [156]). The usability of a corresponding standards assessment platform, thereby, might decide on ASSET's feasibility in practice.

In the next part of this thesis, we will discuss instantiations of ASSET to cloud computing and Smart Grid to validate ASSET's contributions. We will, however, start with presenting our Proof-of-Concept (PoC) implementation of a standards assessment tool to test the realizability of the automation potentials that we identified in this chapter.

Part III.

Instantiation and Validation

7. Proof-of-Concept: A Cloud Standards Assessment Platform

In this chapter, we will present a PoC of the constructs and procedures proposed in ASSET. Thus, we aim at demonstrating the realizability of ASSET as a software system to support the assessment of standards in disruptive innovation. Moreover, our PoC allows for validating the realizability of identified automation potentials to reduce standards assessment efforts. We will, again, apply cloud computing as the domain for assessing standards in disruptive innovation.

In Section 7.1, we will discuss preliminary considerations, detail the goals and scope of our PoC, and introduce a generic architecture for a software platform to assess standards in disruptive innovation. Next, we will present details of the Cloud Standards Assessment Platform (CSAP), our PoC implementation of ASSET. In Section 7.2, we will outline CSAP components that implement ASSET's procedural model. We will discuss the implementations of automation potentials in Section 7.3. Section 7.4 concludes this chapter with a summary and discussion of results.[36]

7.1. Overview

In Section 4.3, we derived requirements for a method to support the assessment of standards in disruptive innovation. Based on the development of our method to fulfill these requirements (see Section 6.3), we identified potential to automate the assessment process and, thereby, reduce assessment efforts in Section 6.4. A tool to support the assessment of standards in disruptive innovation, however, has to fulfill additional requirements. We will briefly discuss such requirements in the following sub-section. Thereafter, we will introduce a platform architecture that addresses the requirements that stem from, both, ASSET and the system specific aspects. We will conclude this section, be summarizing the approach and the technologies that we applied to implement our PoC.

7.1.1. Preliminaries

We designed ASSET to be applicable to different domains of disruptive innovation. In consequence, a platform must provide support for its configuration to support the assessment in different domains of disruptive innovation. Thereby, *reuse* of components as well as of domain- and standards-specific entities contributes to reducing configuration efforts.

[36] This chapter uses material that has been published in [35].

ASSET does not define particular methods to moderate group decisions, but allows to incorporate existing group decision making approaches like voting-based techniques or Delphi studies (see Section 2.2.3). Therefore, ASSET demands a software-based platform to be able to *integrate* with related software implementations.

Moreover, an implementation of a platform to support the assessment of standards in disruptive innovation has to provide *automated access* to domain- and standards-specific entities for supporting *extendability* of existing assessment activities according to the needs of different use cases.

ASSET is build on the foundations of the information model for standards assessment (see Chapter 5). Therefore, a model-based implementation approach should be applied to realize benefits in development. An architecture and implementation of ASSET should, moreover, separate assessment logic from data management to reflect both ASSET's procedural model and the corresponding information model.

While ASSET represents "any actor that participates in standardization of disruptive innovation" (Section 5.5, page 88) using stakeholders, it does not provide a concept for incorporating multiple users of a single stakeholder. A software system to implement ASSET, thus, is required to provide user management functionality, mapping users of the software system to stakeholders of ASSET.

7.1.2. Architecture

We will present an architecture for building a standards assessments platform for disruptive innovation in this section. The architecture incorporates modules and components to address the requirements of ASSET as well as system-specific aspects as presented in the previous section. Service-orientation is the guiding principle of the platform architecture. Moreover, the architecture is based on three layers that separate data management from assessment logic and the service front-end. In doing so, the platform architecture builds the foundations for the development of service-based Web applications, addressing the need for accessibility of assessment information.

As presented in Figure 7.1, the *standards assessment platform architecture* comprises six modules: *"Platform Persistency"*, *"Technology Typology Manager"*, *"Standards Manager"*, *"Evaluation Manager"*, *"User Manager"*, and *"Extensibility Interface"*. While the components of the *"Platform Persistency"*, obviously, provide the foundation of the assessment platform, components of the *"Extensibility Interface"* make these entities available to the outside world and provide means to extend the functionality of an implementation of the standards assessment platform. The different manager modules provide the functionalities to maintain ASSET's entities (see Chapter 5), provide ASSET's assessment logic as defined in its procedural model (see Section 6.3), and automate the generation of assessment information (see Section 6.4).

Applying REST as the basic architectural style that is maintained by the platform is accessible through standardized interfaces (e.g., standards profiles or domain- and standards-specific entities). The controller components of the *"Technology Typology Manager"*, *"Standards Manager"*, *"Evaluation Manager"*, and *"User Manager"* provide respective functionality, while the corresponding adapter components expose the corresponding RESTful interfaces. Components such as the *"Technology Builder"*, *"Classifier"*, *"Selector"*, or *"Roadmapper"*, thus, implement the flow of interactions between entities as defined by ASSET's procedural model. The proposed platform architecture, therefore, balances a trade-off between strict REST principles such as Hypermedia as the Engine of Application State (HATEOAS), aiming to achieve communication between entities in an unplanned way, and static application logic as coded into service interfaces following the Service-oriented Architecture (SOA) paradigm.

In addition, the platform architecture makes use of five types of components:

- *Controller components* provide Create, Read, Update, and Delete (CRUD) functionality for respective entities as defined in ASSET's information model. The *"TechnologyField Controller"*, for example, provides CRUD functionality to manage the instances of the *TechnologyField* entity that the technology framework of the disruptive innovation comprises. For the sake of clarity, Figure 7.1 only de-

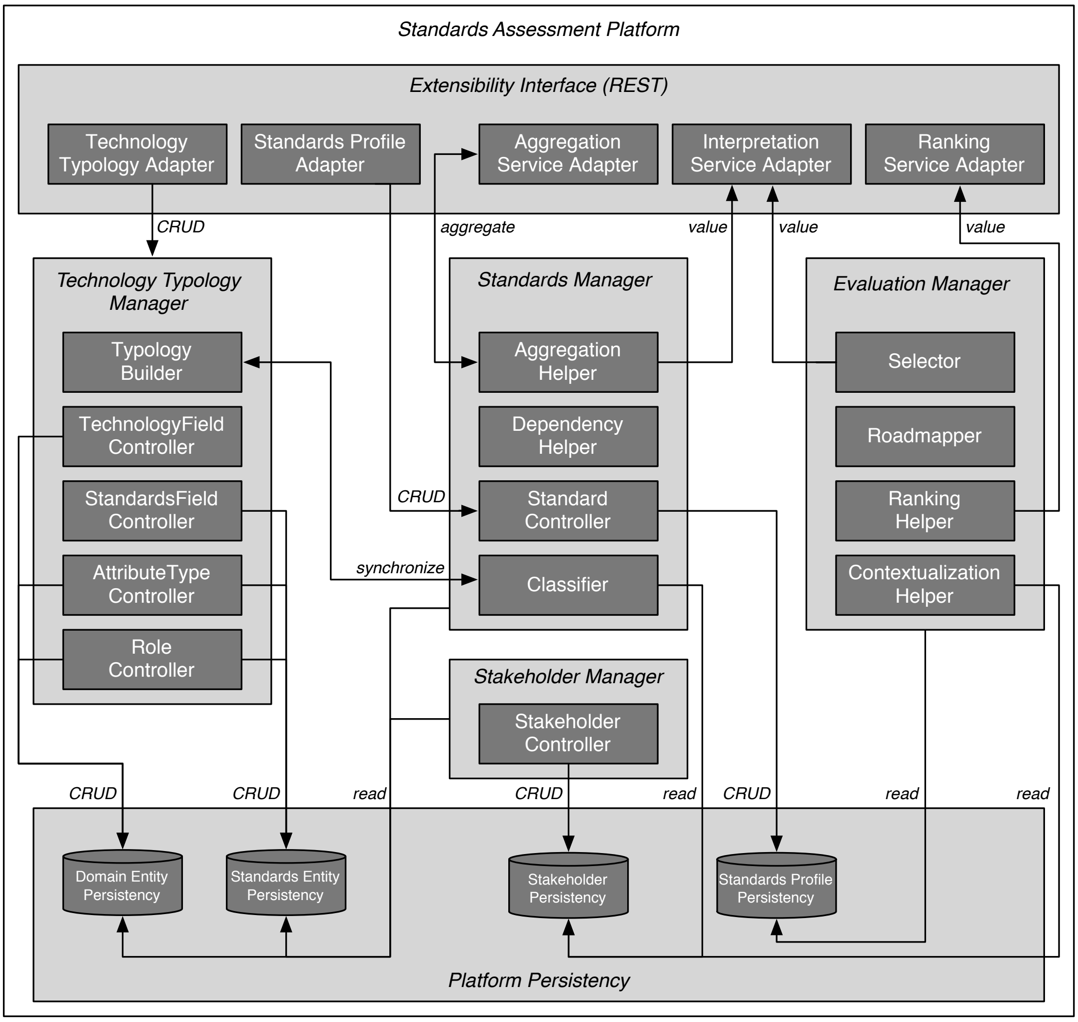


Figure 7.1.: Architecture of a Standards Assessment Platform

picts a subset of controller components that allows for demonstrating interactions of components. The “Standard Controller”, for example, makes use of additional controller components to manage instances of the Attribute and AttributeInstance that are not depicted.

- Similarly, *adapter components* define interfaces to proxy CRUD functionality, i.e., provide access to the assessment information, or extend the functionality of the assessment platform. The *“Technology Typology Adapter”*, for example, proxies CRUD functionality that allows external applications to access and manage all entities of the technology typology. In contrast, the *“Aggregation Service Adapter”* provides an interface to trigger aggregation of cloud standards profiles or to prepare calls to external services that perform aggregation tasks.

- Next, *persistency components* provide storage capabilities for the entities of the conceptual information model. The *“Standards Profile Persistency”*, for example, stores information on the assessment of standards such as instances of *Attribute* and *AttributeInstance* entities.

- The purpose of *helper components* is twofold: They provide reusable assessment logic such as required for the aggregation of standards profiles. In addition, helper components provide implementations for service endpoints that are published by adapters or trigger invocation of remote services. The *“Aggregation Helper”*, for example, comprises logic to aggregate values of instances of the AttributeInstance entity, but also invokes remote aggregation or interpretation services, if necessary. In addition, the “Aggregation Helper” provides an endpoint that allows external applications to trigger aggregation of values that are shown in standards profiles.

- Finally, all components that do not fall into one of the above-mentioned categories provide assessment logic as defined in ASSET’s procedural model. We will provide respective details, when discussing the implementation of our PoC prototype in Section 7.2.

Next to defining a standards assessment platform’s modules and components, Figure 7.1 depicts interactions of the required components across different modules. Components may have additional interactions with components of the same module, details of theses interactions are, however, specific to the implementation of the platform architecture. Thus, they are not defined on the architectural level. Components may invoke functionality of other components either by method calls or service invocations. While service-based interactions allow for loose coupling of components, method calls introduce less complexity and might be most suitable for internal communication, depending on the choice of technology. Implementations of ASSET that follow the presented platform architecture may, thus, choose the appropriate style of interactions based on their choice of technology and respective requirements. We will now briefly outline the types of interactions between different components of the architecture.

CRUD operations on persistency components are triggered by controller components. In addition, the *“Technology Typology Adapter”* and the *“Standards Profile Adapter”* that proxy CRUD functionality to the *“Extensibility Interface”* may trigger CRUD operations. However, adapters may not directly access persistency components.

With the exception of the *“synchronize”* interactions, there are no interactions of components between any two manager modules. In doing so, manager modules are self-contained reducing complexity and increasing component reuse. The *“synchronize”* interaction of the *“Typology Builder”* and the *“Classifier”*, however, is required to update standards profiles, if the technology typology changes. The sames applies if a classification of a standard leads to an update of the technology typology. Consequently, the *“synchronize”* interaction is defined to be *bi-directional*. The *“synchronize”* interaction, thus, provides the functionality that ASSET requires to coordinate respective updates, using the *“Technology appears / changes”* and *“Classification challenged”* events.

Non-controller components of manager modules may call adapters, incorporating external assessment logic. The *“Aggregation Helper”* may retrieve the value of a standard’s assessment attribute, using the “value” interaction. Only the *“Aggregation Service Adapter”* may invoke the *“Valuation Helper”* component using the bi-directional *“aggregate”* interaction. In doing so, the architecture allows aggregation of standards profiles to be triggered externally.

7.1.3. Implementation

We implemented the PoC as a Web application, using the *Play framework* for Web application development.[37] Play is an open source Web application development framework implementing the *Model-View-Controller (MVC)* paradigm. Thus, we were able to separate the handling of assessment data from assessment and presentation logic. Figure 7.2 outlines the implemented model, view and selected controller components.

Play supports application development using Java[38] and Scala[39] as programming languages. While we implemented controller and model classes in Java, views make use of Scala for dynamic content generation. We applied JavaScript and jQuery[40] to implement adaptive views, using Asynchronous JavaScript and XML (AJAX) to dynamically reload contents. Figure 7.2 summarizes the components of the platform architecture that we implemented for our prototypical Web application.

ASSET’s’ conceptual information model guided the implementation of the *model classes*. We applied Play’s integration of *Ebean*[41], providing object-relational mapping functionality. Using Entity-beans as model abstractions, we implemented the information model

[37] `https://www.playframework.com/`
[38] `https://www.java.com/`
[39] `http://www.scala-lang.org/`
[40] `http://jquery.com/`
[41] `http://www.avaje.org/`

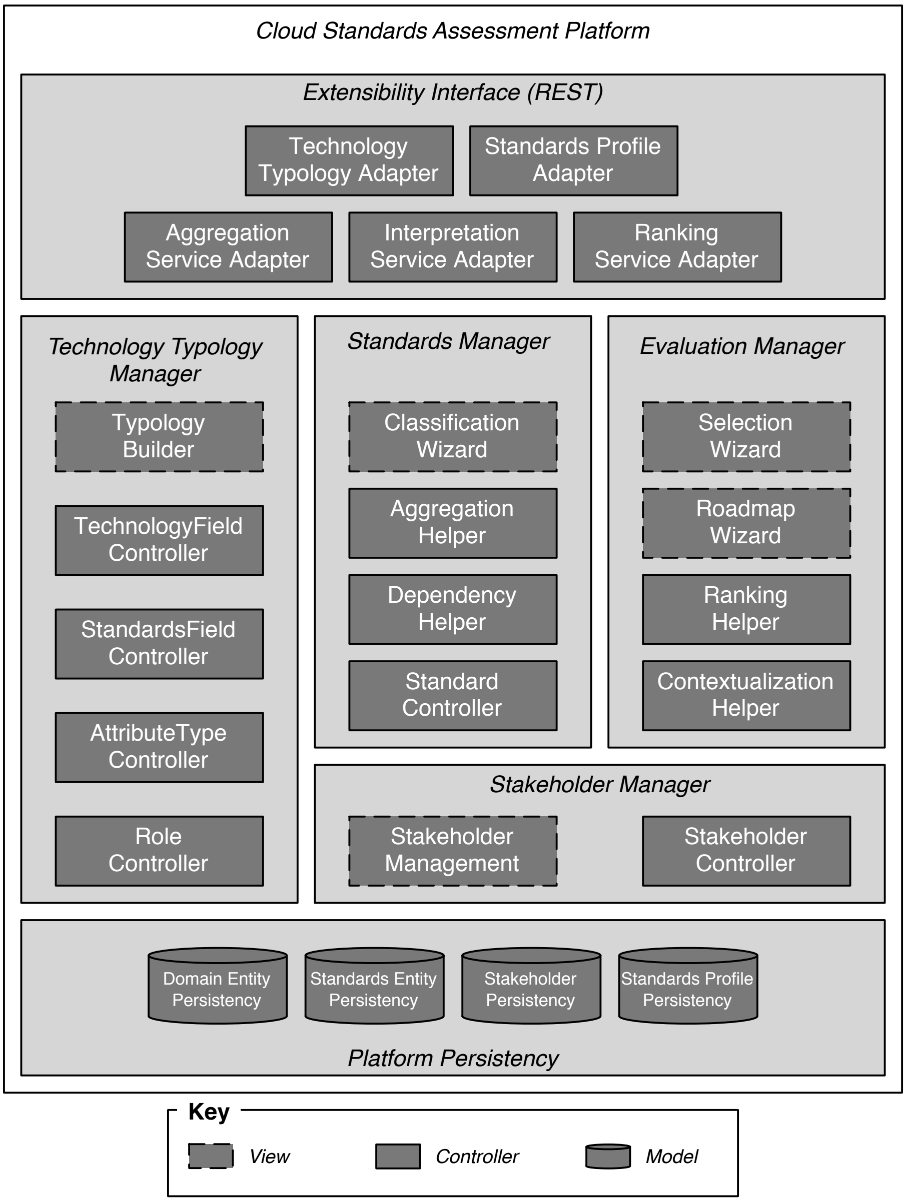


Figure 7.2.: Implementation of the Platform Architecture

with the help of annotations from *Java Persistence API (JPA)*[42]. Our prototypical implementation supports H2[43] and mySQL[44] database engines.

Transferring our architecture for standards assessment (see Section 7.1.2) into Play's MVC-approach, we implemented *controller classes* for all entity controller, helper, and adapter components. Entity controller components proxy data manipulation request to corresponding Ebean functionality. We implemented helper and adapter components with

[42] http://www.oracle.com/technetwork/java/javaee/tech/persistence-jsp-140049.html
[43] http://www.h2database.com/
[44] http://www.mysql.com/

the help of Play's REST capabilities, i.e., defined routes and implemented methods in controller classes to serve HTTP requests.

The *Bootstrap framework*[45] and more specifically *Ace*[46] template facilitated the development of our *view classes*. In doing so, we were able the design and implement the Graphical User Interface (GUI), using predefined Cascading Style Sheets (CSS) and templated Hypertext Markup Language (HTML)-files. CSAP, additionally, received a responsive design, being able to adapt to different sizes of displays.

7.2. Assessment Functionality

We implemented ASSET's procedural model using wizards, supporting classifications (see *"Classification Wizard"*) evaluations of standards (see *"Selection Wizard"* and *"Roadmap Wizard"*). Additional view classes provide GUIs for managing the technology typology (see *"Typology Management"*), stakeholder and user management (see *"Stakeholder Management"*), and support for anonymous user.

In the remainder of this section, we will present the implementation CSAP's wizards.[47] In doing so, we aim to demonstrate our realization of procedural constraints and information dependencies. A documentation of CSAP's other components is given in Appendix C.1.

7.2.1. Classification Wizard

As introduced in Section 7.1.3, CSAP implements ASSET's processes to classify and evaluate standards using wizards. In this section, we will outline our prototype's views that implement ASSET's "Classify Standard" sub-process (see Figure 6.6).

Figure 7.3 presents the "Classification Wizard". Selecting the standard to be classified is facilitated by re-using the browse functionality as depicted in Figure C.1b. If users wish to create a new standards profile, they must add the standard to the database, at first. For this purpose, they are required to provide the basic information. In addition, they have to choose which type of standard they are going to classify (i.e., BaseStandard or StandardProfile). Once a standard has been added to the database, CSAP will demand users to create an initial classification. The first step of the "Classification Wizard" presents basic information as a brief summary. Users may use this information to access the standards specification or double-check the version of the standard that they are going to classify. In accordance with ASSET's procedural model, user cannot change basic information once a standard has been classified.[48]

[45] `http://getbootstrap.com/`

[46] `https://wrapbootstrap.com/theme/ace-responsive-admin-template-WB0B30DGR`

[47] The screenshots that will be shown in the following sections contain data from reproducing the results of the cloud standards study. We will discuss conceptional aspects of reproducing respective results in Section 8.1.

[48] Adminstrative users may fix spelling mistakes or broken links.

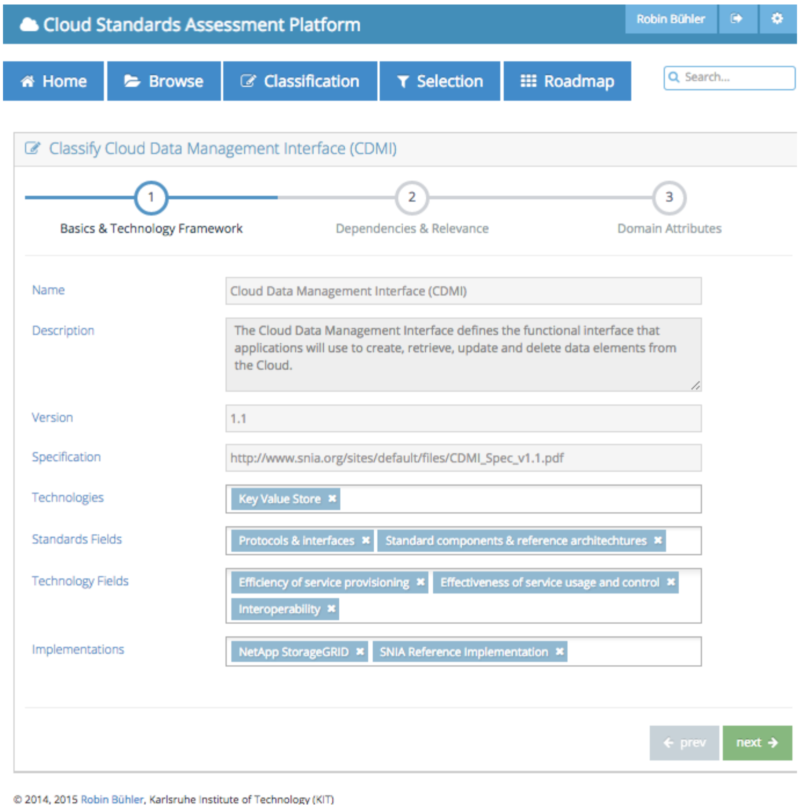


Figure 7.3.: CSAP - Classification Wizard: Assign Technology Framework (Step 1)

Users are required to select relevant technologies, technology fields, standards fields, and known implementations of the standard to complete the first classification step. Using select boxes as input elements, CSAP allows users to quickly select the relevant instances from the technology typology. The wizard populates initial values, based on the information that the standards profile currently comprises. Thus, CSAP only requires users to remove or add attribute values, if they challenge an existing classification. If a standard is classified for the first time, no values will be shown, obviously.

Figure 7.4 presents CSAP's elements to perform ASSET's "Assign Dependencies and Relevance" sub-process. Users have to select the set of domain-specific roles that they perceive the standard to be relevant for (see Figure 5.13). Next, they may add or remove stakeholders of the standard. In doing so, CSAP supports ASSET's goal to capture the dynamics of disruptive innovation.

Users may, furthermore, acknowledge the currently defined type of the standard or object against the current classification by selecting another type. Finally, CSAP provides users with the possibility to name related standards. According to ASSET's information model, the relation between two standards may be described as competing, complementing, endorsing, or preceding. Additionally, user may define a base standard for standard profiles.

CSAP will list current assignments of domain-specific roles, stakeholders, type of standard, and relations to other standards as initial values for corresponding input fields. The

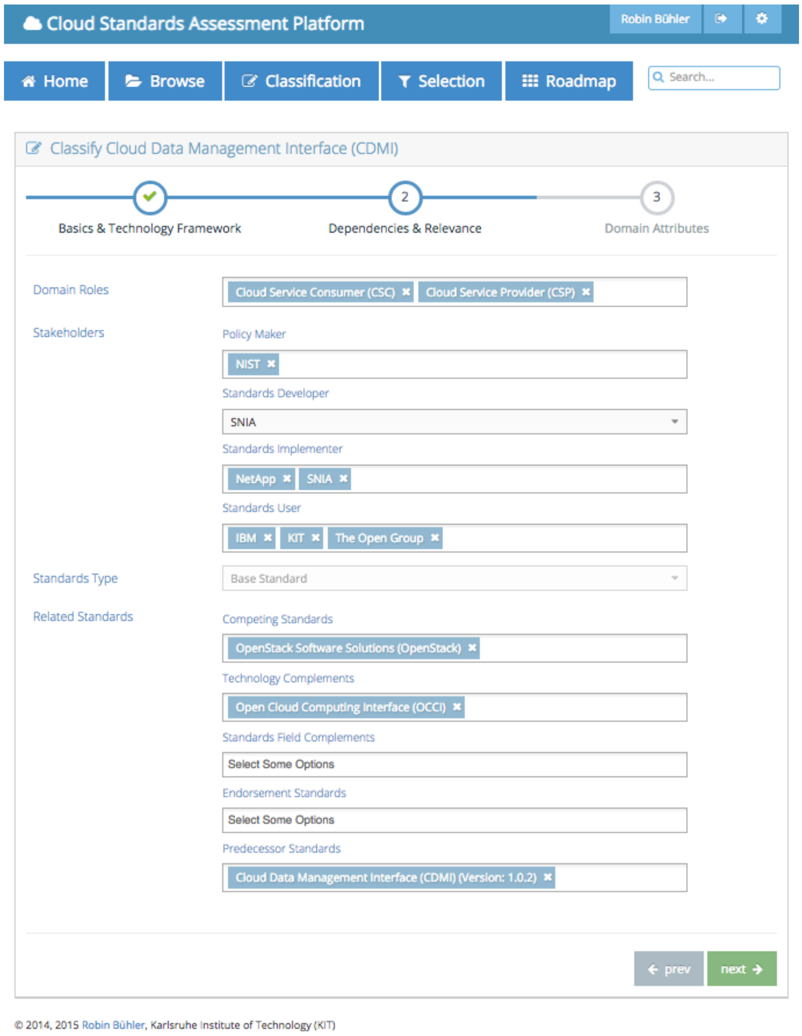


Figure 7.4.: CSAP - Classification Wizard: Assign Dependencies & Relevance (Step 2)

set of alternative values will always be derived from the current state of the technology typology, the set of known stakeholders, and the set of currently managed standards profiles. In doing so, CSAP only demand users to choose between suitable alternatives and, thereby, contributes to reducing assessment efforts.

In addition, the contents of the second step of the “Classification Wizard” will dynamically adapt according to the classification that a user has provided in the previous step. The sets of possibly related standards, for example, will change according to the selection of standards fields, technology fields, and technology in the previous step (for details see Section 7.3.4).

In the final step of the “Classification Wizard” each user will be required to provide values for descriptive and applicability attributes. User will not provide values for interpretative attributes as these values will be automatically derived (see Section 7.3.3). CSAP determines the set of relevant attributes based on the standard’s technology framework and the set of attributes that the current user is capable of assessing (see Section 7.3.2 for details).

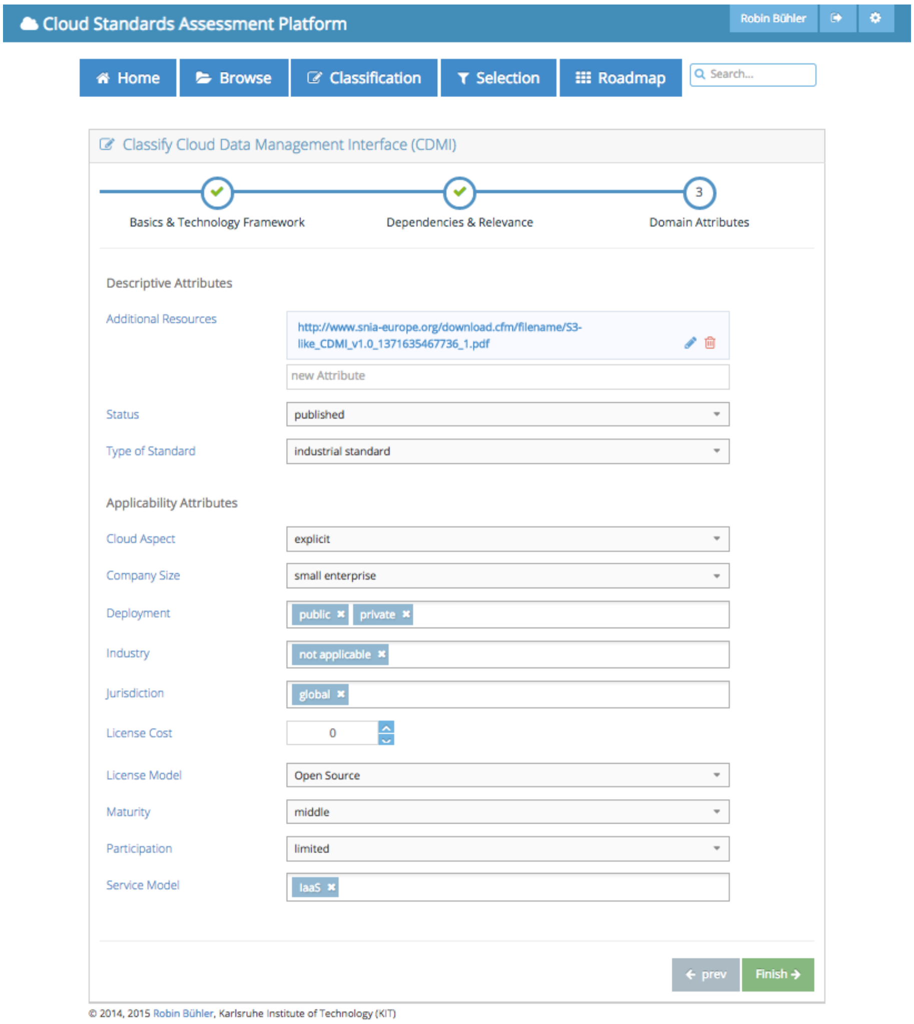


Figure 7.5.: CSAP - Classification Wizard: Value Attributes (Step 3)

The type of GUI element that CSAP renders for each attribute depends on the value domain and the attribute cardinality of its attribute type. CSAP supports valuations of attributes with cardinal value domains by providing spinners (see, e.g., license cost in Figure 7.5). The user may select any value between the defined upper and lower bound of its attribute type. Step lengths will vary according to the range of possible values. If the attribute's domain was set to either ordinal or nominal and its cardinality permits only one attribute per standard (i.e., attribute cardinality is set to one), single select boxes will be shown (see, e.g., "Status" in Figure 7.5). If the cardinality is greater than one or indefinite, multiple select boxes will be used (see, e.g., "Deployment" in Figure 7.5). Finally, the "Classification Wizard" will provide input fields and labels for attributes if their value domain equals CSAP's single value type. The wizard will, however, disregard attribute cardinalities at this point. Determination of the attributes that will be assigned to the standards profile will only be done after the user has completed ASSET's "Classify Standard" sub-process (see details in Section 7.3.3). In consequence, CSAP will present all values that have been submitted in previous classifications. User may change existing values, remove values, or add new values to complete their assessment.

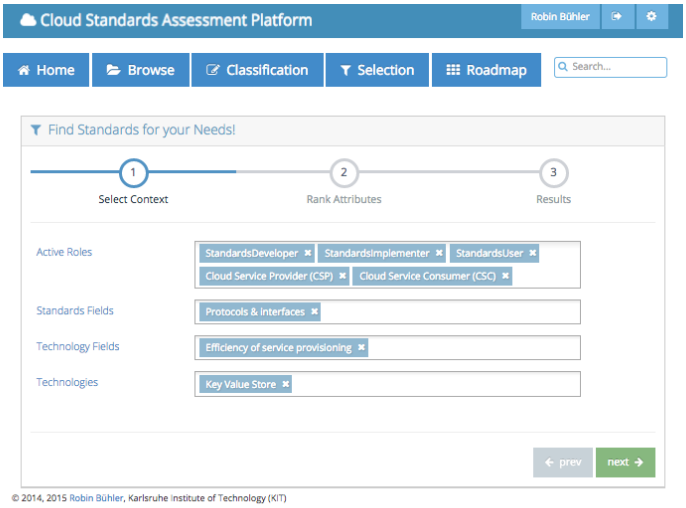


Figure 7.6.: CSAP - Selection Wizard: Create Contextual Typology (Step 1)

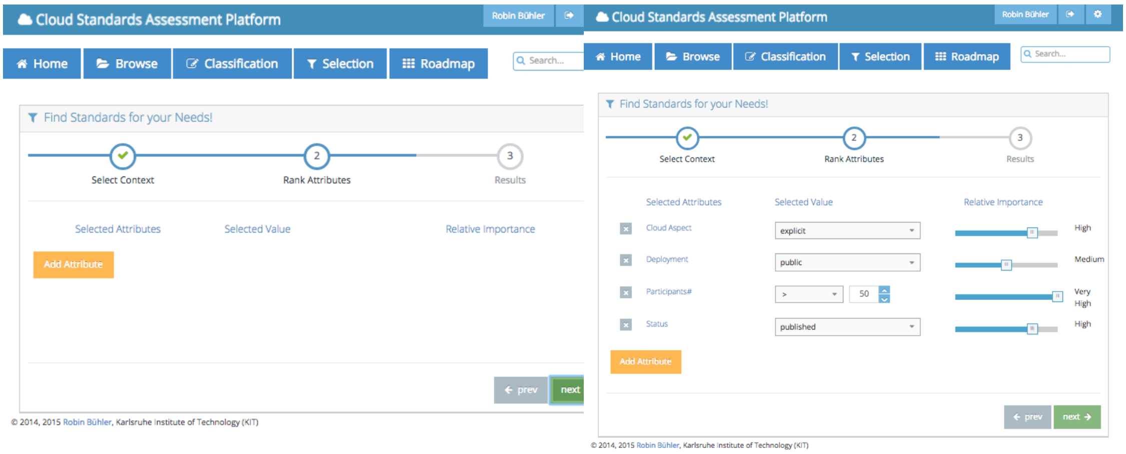
7.2.2. Selection Wizard

CSAP's "Selection Wizard" provides the functionality to rank the set of standards according the user's standardization preferences. Proceeding through three steps, users may create a contextual typology (see Figure 7.6) and rank relevant attributes (see Figures 7.7 and 7.8). Based on these inputs, CSAP will calculate an ordered list of suitable standards. Users may filter the result set, applying a threshold to the minimum score that a standard must achieve (see Figure 7.9). The "Selection Wizard", thus, implements ASSET's "Select Standards" sub-process (see Figure 6.10).

Users create the contextual typology by choosing standards fields, technology fields, and technologies that best describe their situation. They may narrow their context by describing their perspective of the assessment using ASSET's role concept. CSAP will automatically populate the initial selection of roles, using the user's current role assignments. The user may change the initial selection. If a user, for example, is seeking assessment support in the context of implementing or using a standard, he may narrow the set of selected roles to "Standards Implementer" and "Standards User".

CSAP will filter domain attributes to its relevant subset using the contextual typology. The "Rank Attributes" screen will initially be empty (see Figure 7.7a). Users may select a set of attribute types using the modal dialog that CSAP renders once the "Add Attributes"-button has been clicked. The modal dialog, depicted in Figure 7.8, consists of all attribute types that match the given contextual typology. Therefore, CSAP evaluates relationships that ASSET's conceptual information model defines between attribute types, standards fields, technology fields and roles (see Figure 5.14). Applying a simple scoring method (see Section 2.2), CSAP asks users to rank the relative importance of attribute values (see Figure 7.7b).

The final step of CSAP's "Selection Wizard" presents the results of the matchmaking (see Figure 7.9). Users may browse matching standards profiles. CSAP reuses elements from the standards profile views to present an accordion of basic information, the standard's



(a) Initial Ranking Screen (b) Ranking of Relevant Attributes

Figure 7.7.: CSAP - Selection Wizard: Rank Attributes (Step 2)

complete technology framework, and information on the standard's dependencies and relevance (see Figure 7.9a). In addition, user's may comprehend their influence on the calculated ranking of standards by analyzing individual scores (see Figure 7.9b).

CSAP filters the result set to only show standards that achieved the maximum score, initially. User's may, however, extend their results by lowering the threshold for the results to be shown. For this purpose, CSAP provides a slider element at the top of the result screen. Additionally, CSAP support going back and forth between all steps of the "Selection Wizard" component.

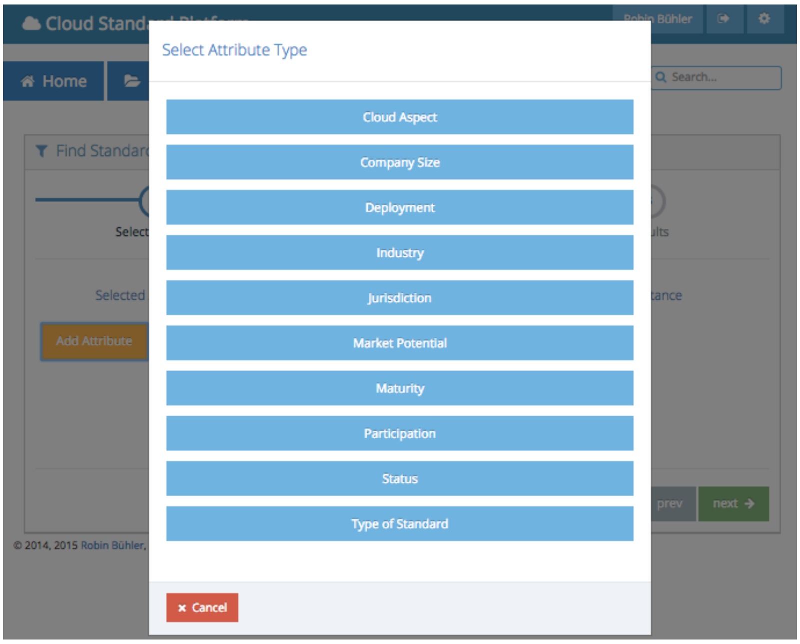
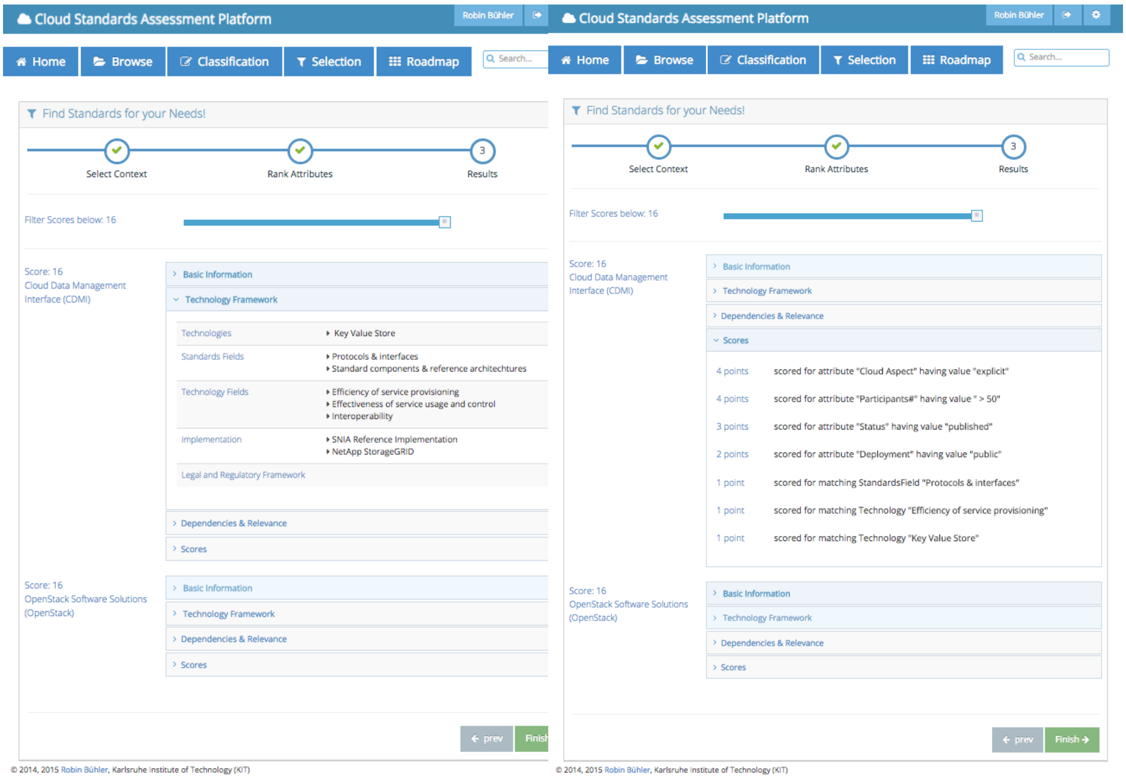


Figure 7.8.: CSAP - Selection Wizard: Selection of Attribute Types (Step 2)



(a) Technology Framework (b) Scores

Figure 7.9.: CSAP - Selection Wizard: Filter Results (Step 3)

7.2.3. Roadmap Wizard

CSAP's last wizard provides the functionality to capture the status quo of standardization or roadmap standardization activities. Comprising four steps, the "Roadmap Wizard" guides users through ASSET's corresponding sub-process (see Figure 6.11).

At first, CSAP requires users to select relevant standards fields and technology fields. Based on these initial inputs, CSAP will build the relevant segments of ASSET's portfolio aggregation matrix (see Table 6.1). Subsequently, users are required to estimate the potential of standardization (see Figure 7.11a) and the potential of new standards (see Figure 7.11b) for each segment. CSAP will provide initial values for both types of potentials based on calculating the average of previously performed assessments (see Section 7.3.3). If users do not want to change these initial values, they may proceed to the final step. CSAP will then present the status quo of standardization as seen by the community of users. If users, however, change values, CSAP will calculate their individual standardization roadmap. Both, status quo and roadmapping features apply ASSET's idea of deriving standardization gaps from two types of potentials (see Section 6.3.4). CSAP's corresponding views (see Figure 7.12) implement ASSET's concept of the portfolio aggregation matrix and apply the cloud standards study's concept of valuing potentials using the Likert-scale.

The final step of the "Roadmap Wizard" presents CSAP's representation a cloud standards map (see Figure 4.4). As depicted in Figure 7.12a, CSAP presents standardization gaps using a color scheme. In addition, user's may delve into details of a respective segment by clicking on a cell of the matrix. CSAP will present the list of related standards as a modal dialog (see Figure 7.12b). Results will always be calculated against the current state of CSAP's portfolio of standards profiles. Thus, it will evolve with maturing standards profiles.

Methodically CSAP's "Roadmap Wizard" implements a Delphi-based approach for consensus building in group decisions (see Section 2.2.2). It, therefore, demonstrates how the conceptual information model and ASSET's procedural model build the basis to incorporate state-of-art decision support methods into the assessment of standards in disruptive innovation, while reducing assessment efforts by automation.

7.3. Automation

In the previous section, we introduced CSAP's view components that implement ASSET's core functionality to assess cloud standards. Users primarily use views to classify and evaluate standards. The previous discussion, thus, did not cover details on the implementation of ASSET's potential to automate standards assessment as identified in Section 6.4. In this section, we will, therefore, provide details CSAP's realization of automation for standards assessment.

7.3.1. Coordinating Updates

ASSET defines an event model to coordinate standards assessment in disruptive innovation (see Section 6.4.1). More specifically, ASSET applies the "Technology appears

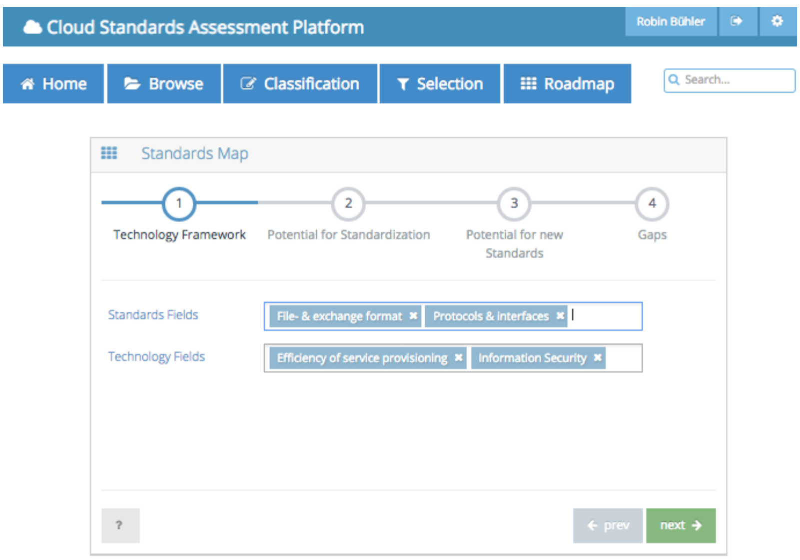
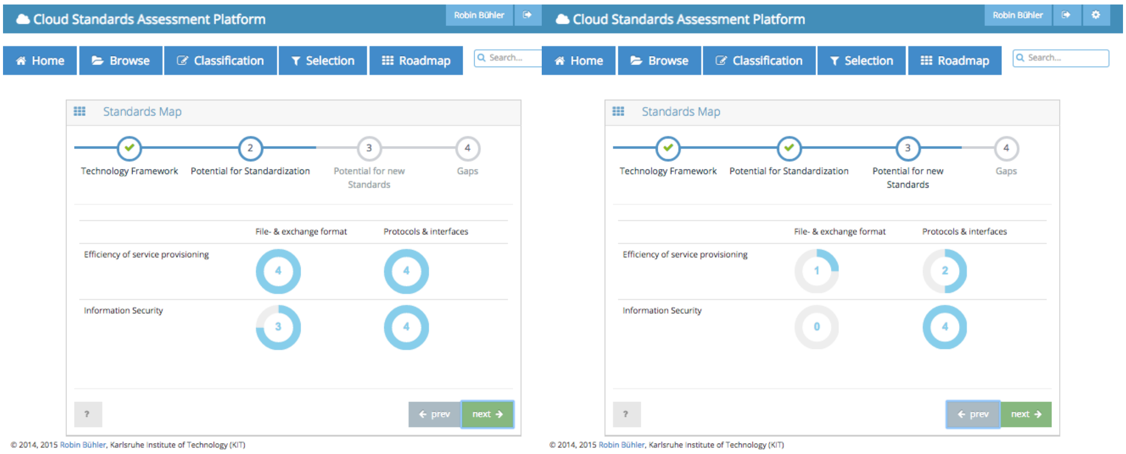


Figure 7.10.: CSAP - Roadmap Wizard: Select Technology Framework (Step 1)

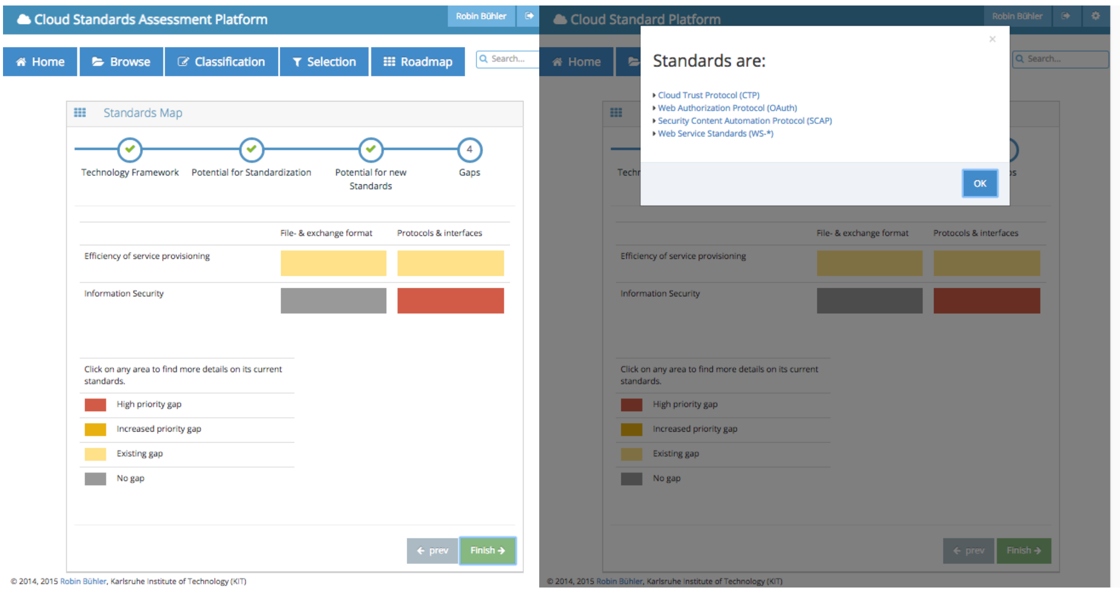


(a) potential of standardization (Step 2) (b) Potential for new Standards (Step 3)

Figure 7.11.: CSAP - Roadmap Wizard: Identify Potentials

/ changes", "Typology available", and "Classification challenged" events to synchronize updates of its two main artifacts, i.e., the technology typology and standards profiles. We did, however, not implement an event engine or an event bus for CSAP, but applied a simplification. In the following, we will briefly discuss CSAP's implementation of coordinating updates of the technology typology and standards profiles:

- We assume the technology typology to always be in the state "available". Saving changes in the "Typology Builder", thus, will maintain the available state of the technology typology. Conceptionally, the save operation instantly triggers the "Technology appears / changes" event and the "Classification challenged" event.



(a) Overview (b) Details

Figure 7.12.: CSAP - Roadmap Wizard: Aggregated Results (Step 4)

The technology typology, thus, does not transition to the "required" state but remains "available". In consequence, CSAP is not required to maintain the state of the technology typology. Furthermore, our prototype is not required to periodically trigger "Typology available events" to allow standards profiles to be created or updated (see Figure 6.13). CSAP will immediately trigger updates to standards profiles. Therefore, we implemented the "Classification Wizard" to always work with the current state of the technology typology (i.e., it will not present delete instances and instantly include added ones).

- Based on the continuous availability of the technology typology and CSAP's instant adaptation of standards profiles, the "Classification challenged" event in the life-cycle of a standards profile (see Figure 6.13) will only be triggered by external events in our implementation, i.e., users that start a re-classification of a standard, using the "Classification Wizard". In order to further simplify our implementation of CSAP, we allow users to create standards profiles without assigning a technology framework at first. Conceptionally, each new standards profile thus directly transitions to the "classified" state. In consequence, a standards profile will always be "classified" as long as the standard is not "withdrawn". The life-cycle of a standards profile, thus, has only two transitions: "aggregate" and "Classification challenged".

Figure 7.13 presents CSAP's implementation of automation support for the coordination of updates, based on the simplifications described above. As depicted, CSAP treats ASSET's "Technology changes / appears" and the "Classification challenged" events as external triggers. These events represent the activation of "Typology Builder" or "Classification Wizard" by a user of CSAP. For updating a standards profile the respective component performs calls to the "Standard Controller", who in turns invokes the "Aggregation Helper" to interpret attributes and aggregate attribute values. As described in Section 7.1.3 the "Aggregation Helper" component allows for integrating external logic to automatically value interpretative attributes and aggregate values that are assigned to a standard (see Section 7.3.3 for details). This sequence of method calls is equally applied, if CSAP processes results from a completion of the "Classify Standard" sub-process, i.e., when the "Classification Wizard" triggers the update function of the "Standard Controller" component.

Implementing the described sequence of method calls, CSAP is capable of keeping standards profiles updated, if the technology typology changes. If, for example, instances of a technology framework entity have been removed, corresponding relations to standards will be deleted automatically. Likewise, name changes will instantly propagate. If new technology, technology field or standards field have been added to the technology typology, changes will propagate over the long term. That is, stakeholders have to assign the added instances to the standard's relevant technology framework.

As depicted, method calls are currently implemented synchronously. For demonstration purposes, we did not see benefits of using asynchronous calls in coordinating updates. If the performance of service calls to interpretation or aggregation services, however, becomes an issue, CSAP could be adapted to using asynchronous calls.

In summary, CSAP gives a first demonstration of ASSET contribution to automating the coordination of updates. The chosen simplifications, however, come at the costs of potential conflicts, if, for example, more than one user concurrently change the technology typology. Our implementation does not prevent such situations. Thus, lost-updates because of dirty data reads may occur. Implementing ASSET's event model as presented in Section 6.4.1, however, allows future implementations of ASSET to address such shortcomings. As presented in Section C.1.2, CSAP applies the concept of administrative users. For the current prototype, we assume that only few users are provided with administrative privileges to prevent such situations. Using technology such as an event bus or an event engine in the future would enable the use of a more sophisticated coordination mechanisms that, for example, trigger a set of expert users to revise the technology typology, if changes are required.

7.3.2. Filtering of Information

We presented ASSET's potentials for automating filtering of information in standards assessment in Section 6.4.2. We will now describe our implementation these potentials in CSAP.

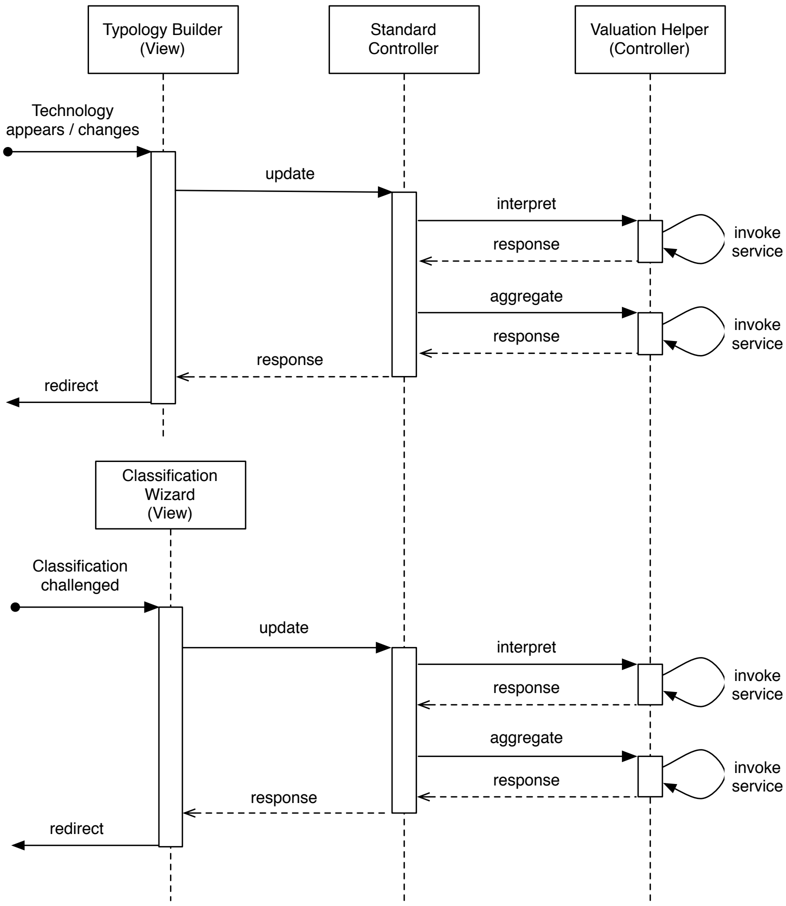


Figure 7.13.: CSAP: Coordinating Updates (Sequence Diagram)

Basically, two types of filters can be applied to determine relevant sets of standards or attribute types with ASSET:

- *Technology Framework Filter:* ASSET makes use of technologies, technology fields, and standards fields to classify the scope and the subject of a standard. Since ASSET's information model requires each technology to be assigned to at least one technology field, the amount of standards that apply to technology will generally be smaller than the amount of standards that apply to a technology field. Thus, using technologies to filter standards is more restrictive than using technology fields. Conceptionally, however, the two filters are comparable. While we discuss the automation of filtering on using technology fields and standards fields, our implementation applies the same filters using technologies and standards fields, if user select technologies instead of technology fields.

  Attributes types are relevant for a set of technology fields or standards fields. Using the corresponding "attributeTypes"-associations, tools that implement ASSET may automate filtering attribute types using technology fields and standards fields.

- *Role Filter:* ASSET's conceptualization of stakeholder and roles in standardization provides a second dimension of filtering assessment information. Using ASSET's stakeholder model, standards and assessment attributes are marked relevant for different sets of roles. Thus, CSAP's data queries may dynamically resolve the "relevantFor"-association to filter standards and attribute types that are relevant to the given roles.

CSAP-components apply different combinations of both filtering capabilities to automatically filter relevant information subsets. Figure 7.14 provides a summary of the possible alternatives.

The outer circle defines represents the set of all standards or attribute types that are currently known to CSAP or other implementations of ASSET. Standards or attribute types

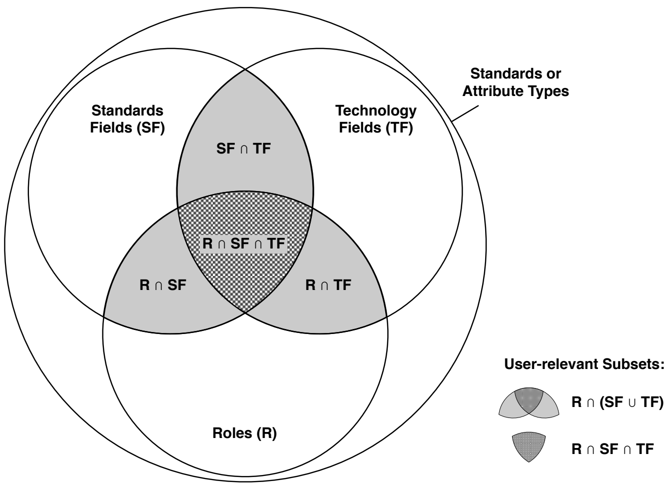


Figure 7.14.: CSAP - Information Filtering: User-relevant Standards or Attribute Types

that are relevant to given selection of standards fields (SF), technology fields (TF), or roles (R) form potentially overlapping subsets.

The intersection of SF and TF (i.e., $SF \cap TF$) defines the subset of standards or attribute types that is relevant to a combination of scopes and subjects of standards. Consequently, a union of SF and TF (i.e., $SF \cup TF$) provides all standards or attribute types that are relevant to any of the given standards or technology fields. Combining the technology framework filter and with a the role filter allows for constraining subsets of standards and attribute types further. $R \cap SF$ and $R \cap TF$ constitute the set of user-relevant standards or attribute types that address a particular scope or subject of standardization. $R \cap SF \cap TF$, consequently builds the subset of standards or attribute types that addresses a user's relevant scopes and subjects. The union of R and the Union Technology Framework filter (i.e., $R \cap (SF \cup TF)$) defines the set of standards or attribute types that are user-relevant and match scopes or subjects of standards. The union of R, SF, and TF, however, does not provide a useful constraint to filter information as it will return all standards or attribute types.

Obviously, $R \cap SF \cap TF$ is the most restrictive combination of technology framework and role filters, reducing the relevant information to a minimum. Strictly applying $R \cap SF \cap TF$ for all wizards of CSAP, however, could lead to loss of information or missed opportunities to gather additional assessment information. We will briefly define the relevant information subset for each of CSAP's wizards in the following:

- *"Classification Wizard":* The goal of ASSET's "Classify Standard" sub-process is collecting classification information for a particular standard. Therefore, the technology framework filter and the role filter are only applied to reduce the amount of attributes that are shown in the third step (see Figure 7.7b). Assessment attributes may be applicable for only one technology or standards fields (see Section 8.1.3). Therefore, stakeholders should value all attributes in the "Classification Wizard" that a user is capable to assess. The relevant subset of attributes is thus defined by $R \cap (SF \cup TF)$.
- *"Selection Wizard":* ASSET's "Select Standards" sub-process guides users in ranking standards according to user preferences in a given context. Thus, filters will be applied to constrain the sets of standards and attribute types. At first, CSAP will calculate the set of attribute types that are relevant for the selected contextual typology. The role filter will additionally remove attributes that are not relevant to any of the current user's roles. CSAP, thus, determines the set of attribute types that users may select in their rankings using $R \cap (SF \cup TF)$. Once a user has ranked relevant attributes, standards will be filtered that do not address all selected standards and technology fields (i.e., $R \cap (SF \cap TF)$). As presented in Section 7.2.2, we apply a scoring-based technique to rank standards that match the applied technology framework filter. The role filter will, however, always be applied to remove standards from the result that do not match the users domain-specific role.
- *"Roadmap Wizard":* Our implementation of ASSET's "Status Quo & Roadmapping" sub-process only applies filters when presenting the results. The set of standards that is presented for each combination of standards and technology field obvi-

ously requires the usage of the intersection technology framework filter. Applying the role filter, standards that are shown to the user will, furthermore, be filtered according to the current user's roles. Thus, CSAP applies $R \cap (SF \cap TF)$ to automatically filter standards for the "Roadmap Wizard".

ASSET's procedural model ensures that all wizards will be able to apply automated filtering capabilities. For this purpose, ASSET's sub-processes include steps to define or select a contextual typology before filters will be applied (see Figure 6.6 and Figure 6.10). In order to dynamically execute the related queries, CSAP requires the user to logon. Each user will always be assigned to one stakeholder (see Section C.1.2). Since stakeholders are required to denominate their roles in standardization, CSAP is capable of automatically filtering relevant information.[49] Using the Ebean framework simplifies the definition of the required database queries. Listing 7.1 presents the source code that CSAP applies to filter attribute types. As depicted, the corresponding Ebean query uses standards fields, technology fields, and roles as parameters. The query logic directly reflects the combination of $\cap$ (i.e., AND) and $\cup$ (i.e., OR) operators.[50]

```
public static List<AttributeType>
    getAttributeTypesRandSForTF(
     List<StandardsField> sfs,
     List<TechnologyField> tfs,
     List<Role> roles){
  return find
      .where()
      .and(
        //Match roles
        Expr.in("roles", roles)
        ,
        Expr.or(
          //Match technology fields
          Expr.in("technologyFields", tfs),
          //Match standards fields
          Expr.in("standardsFields", sfs)
        )
      )
      .findList();
}
```

Listing 7.1: Automated Filtering: Implementation of the $R \cap (SF \cup TF)$ Query

[49] Conceptually, the sum of roles that are enacted by a stakeholder will also depend on the organizations that the stakeholder is a member of. Future implementations may traverse the hierarchy of stakeholders that is defined by the "memberOf"-association to support inheritance of roles for stakeholders.

[50] Queries that apply intersection-based technology framework filtering are build correspondingly, i.e., using AND operators only.

7.3.3. Aggregation of Standards Profiles

The application of ASSET leads to the existence of a variety of standard classifications, providing potentially conflicting values. A tool to automate standards assessment, thus, has to consolidate respective data. Consolidation involves decisions on which instances of the technology framework will be assigned to a standard, which stakeholders to list, which roles a standard is actually relevant for, or which other standards are effectively related. Moreover, values of domain-specific attributes have to be consolidated. For the set of interpretative attributes, the values have to be determined before consolidation may occur. Finally, automation has to address the evaluation of standards profiles to support ASSET's "Evaluation" sub-processes.

When implementing the required automation, additional design decisions have to be made. In the following sub-section, we will discuss CSAP's implementation of automation for the aggregation of standards profiles.

Consolidation of Classification Data

ASSET does not specify how conflicts or inconsistency in classification data should be resolved. Moreover, its information model does not explicitly define means to maintain varying classifications of a standard's technology framework, stakeholders, or related standards. As defined in Section 5.2, the technology framework classifies a standard according to its scope (i.e., standards field) and subject (i.e., a technology or technology field). Moreover, it links a standard to its implementations and potential usages in defining the innovation's legal and regulatory framework. Finally, the information model is capable of maintaining information on a standard's dependencies to other standards as well as its relevance for stakeholders. However, a standard can only be assigned to one instance of each entity at once. Raw data of individual classifications cannot be stored directly.

Thus, an implementation of ASSET is required to either consolidate information instantly or implement other means of storing classification data. While the instant adaptation of a standards profile reduces storage requirements, it does not allow for tracing the evolution of a standards profile. In addition, instant adaptation prevents the application of threshold or majority vote approaches to consolidate classification data (e.g., assign only technology fields that have at least been assigned in 30 percent of all classifications).

We implemented CSAP using an implementation-specific *Questionnaire* entity. CSAP will create an instance of this entity for each completion of the "Classify Standard" sub-process. Figure 7.15 depicts the *Questionnaire* entity and its relationships to ASSET model entities. As depicted, each Questionnaire instance documents its date and stakeholder (using the User entity, see Section C.1.2). The Questionnaire entity shares the Standard entity's relationships. Thus, a questionnaire may relate to zero or more standards fields, technology fields, technologies, implementations, legal and regulatory frameworks, relationship types (i.e., other standards), standardizations (i.e., stakeholders), or domain roles. A questionnaire will keep track of the values of domain-specific attributes having

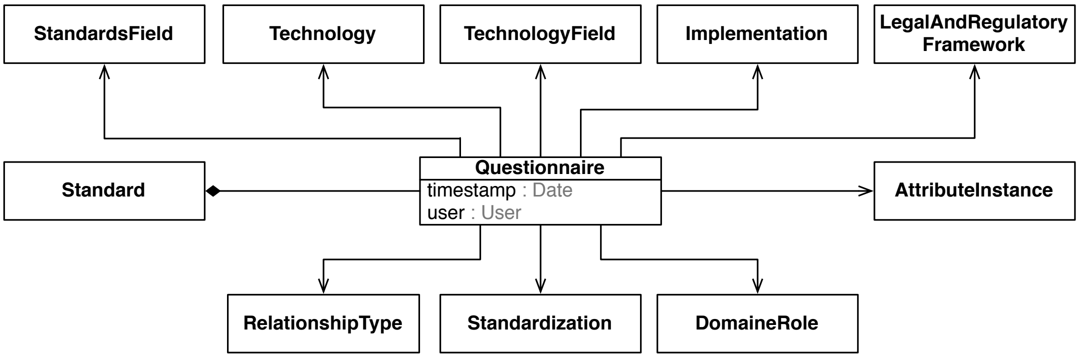


Figure 7.15.: CSAP - Model Extension: Questionnaire Entity

a one-to-many association to the AttributeInstance entity. Figure 7.15 presents the corresponding entities and their associations. The uniform cardinalities have been omitted in favor of clarity. Obviously, questionnaires will always be related to exactly one standard, which in turn should be classified in many questionnaires. Since there is no value of maintaining a Questionnaire instance without its corresponding Standard instance, Figure 7.15 depicts a composition between the Questionnaire and the Standard entity.

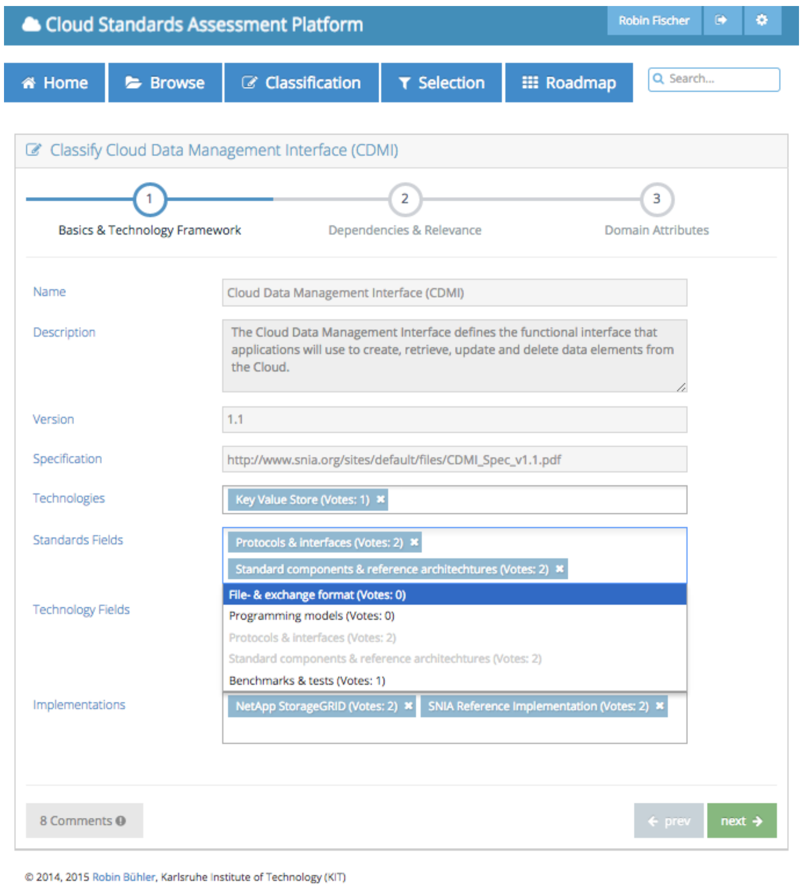


Figure 7.16.: CSAP - Classification Wizard: Votes Count (Admin-only)

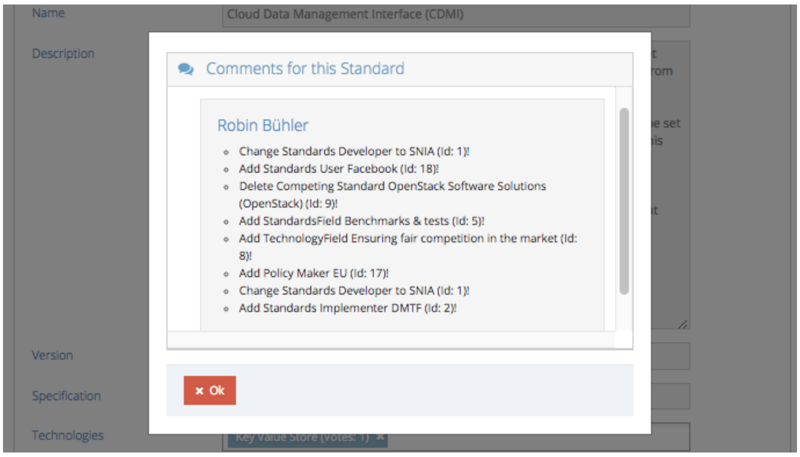


Figure 7.17.: CSAP - Classification Wizard: Comments (Admin-only)

Using the Questionnaire entity, CSAP implements basic consolidation functionality to aggregate a standard's relevant technology framework, stakeholders, and related standards. Applying the separation of administrative and regular users, CSAP assumes that administrative users will eventually decide on the classification of a standard. Our prototypical, thus, updates a standard's dependencies to other model entities, if an administrative user completes the "Classify Standard" sub-process. Supporting administrative users, aggregates of classification information are calculated from questionnaires and shown to administrative users. CSAP, for example, counts the number of times that an instance of a model entity has been assigned to a standard in questionnaires. The resulting value will be shown to administrative users as votes in the "Classification Wizard" as presented in Figure 7.16.

In addition, the CSAP automatically derives comments to guide administrative users in adapting the standards profile. The "Classification Wizard" will show the "Comments" button if varying classification data exists. The exemplary situation, depicted in Figure 7.16, for example, comprises eight comments that suggest adaptations of the technology framework and dependencies or relevance of a standard (see Figure 7.17 for examples).

The combination of votes and comments guides administrative users in selecting relevant instances of the technology typology that will be shown in the standards profile.

Valuation of Attribute Instances

ASSET introduces the InterpretativeAT entity, enabling automation of the valuation of assessment attributes (see Section 5.6). Using InterpretativeAT instances, external services can be integrated that provide automated valuation logic. Such services could, for example, analyze network effects to determine the value of standards.

CSAP's "Extensibility Interface" allows CSAP to invoke external services. External services, in turn, may retrieve required data through CSAP's public Application Program-

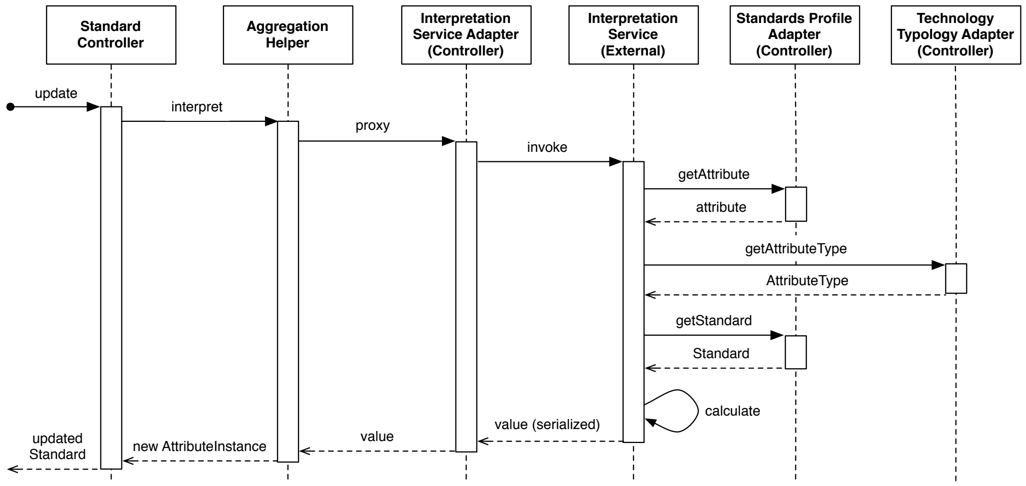


Figure 7.18.: CSAP: Exemplary Interplay of Adapter Components (Interpretation Services)

ming Interface (API).[51] Figure 7.18 presents an exemplary sequence of the interplay of the different adapter components to automate valuation of attributes.

An update of a standard will always trigger the interpret-method of the "Aggregation Helper" component. The "Aggregation Helper", in turn, will determine the interpretation service for each interpretative attribute that is assigned to the standard.The "Interpretation Service Adapter" acts as a proxy that prepares the service invocation hand handles responses. The amount and type of interactions that an "Interpretation Service" performs with the "Standards Profile Adapter" or the "Technology Typology Adapter" depends on the data that the external service requires to for its calculation. Adapter components will serve HTTP request with JavaScript Object Notation (JSON)-representations of, for example, a standard, its attributes, or its attribute type.[52] Once an interpretation service return a value, the "Interpretation Service Adapter" will deserialize the response value before the "Aggregation Helper" creates a new instance of the AttributeInstance entity to persist the value. The "Standard Controller" component will continue its update logic before persisting the updated Standard instance.

We implemented the following interpretation services to demonstrate realizability of automation:

- *Participants Counter:* The service will return the amount of unique stakeholders that participate in the standardization of a given standard. The return value represent the value of the InterpretativeAT "NumberOfParticipants" (see Section 8.1.3). Once triggered, the service will request the standards profile using the "Standards Profile Adapter" to calculate the count of distinct stakeholders that enact one of ASSET's standards-specific roles. Appendix C.8.1 presents the corresponding code snippet.

- *Market Potential Analyzer:* We define market potential as a function of the number of stakeholders and the count of implementations that are known for a given

[51] Appendix C.3 provides a summary.
[52] Appendix C.4 provides corresponding examples.

standard. The corresponding InterpretativeAT “Market Potential”, thus, defines a dependency to the above named InterpretativeAT “NumberOfParticipants”. The service has to return the values “high”, “middle”, or “low” as defined by its AttributeType’s list of allowed values. The service implementation, thus, has to access the standards profile and the definition of the attribute’s attributeType. Detailed interpretation logic is given in the code snippet of Appendix C.8.2.

Aggregation of Attribute Values

ASSET mandates the aggregation of an attribute’s value based on an aggregation logic that has to be defined for each attribute type (see Section 5.6). We designed CSAP to integrate external aggregation logic using aggregation services via the “Aggregation Service Adapter” (see Figure 7.2).

Figure 7.19 depicts an exemplary sequence of the interplay of CSAP’s corresponding components. As presented in Section 7.3.1, we implemented CSAP to aggregate attribute values, every time a user completed the “Classification Wizard”. In response, the “Standard Controller” component will trigger the aggregation function of CSAP’s “Aggregation Helper” component that transforms the method call into an invocation of an aggregation service as defined by the current attribute’s attribute type. As with interpretation services, an adapter is responsible the (de-)serialize objects and invoke services (see “Aggregation Service Adapter”). Using CSAP’s “Standards Profile Adapter”, external aggregation services may retrieve the properties of an attribute as well as its corresponding attribute instances. Additional data may be requested as available through CSAP’s public API. External aggregation services may, thus, parse the set of attribute instances and perform required calculations to aggregate attribute values.

Following this approach, we implemented a set of automated aggregation services to automate the aggregation of a standard’s attribute values. We will briefly summarize the service functionality in the following:

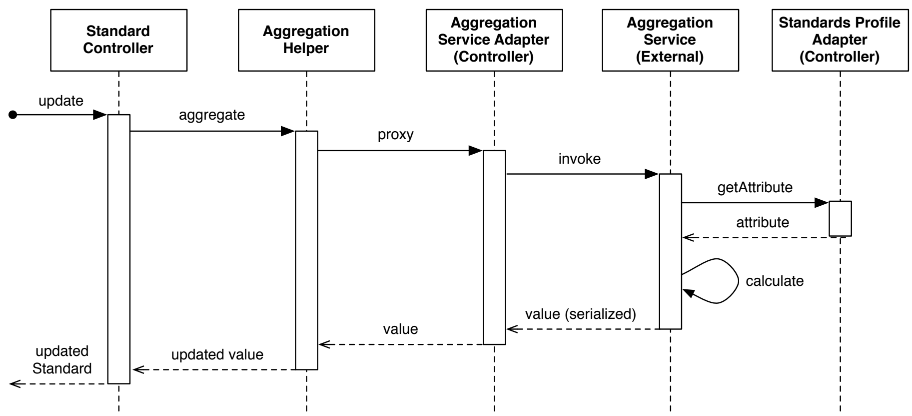


Figure 7.19.: CSAP: Exemplary Interplay of Adapter Components (Aggregation Services)

- *Latest Value:* This simple service will return the most recent value of an attribute. The service is applicable to all kind of attribute types. Thus, it has to request the attribute's set of attribute instances. Appendix C.7.4 provides details of the implementation.

- *Minimum and Maximum Value Service:* The two services will determine the minimum and maximum value of an attribute respectively. Obviously, this service may only be applied to attribute types, having a cardinal or ordinal value domain. Next to the attribute's set of attribute instances, the service requires access to definition of the respective attribute type for two reasons: At first, the service has the verify the attributes value domain (i.e., cardinal, ordinal, or nominal). Next, it has to parse the scale order for the values (i.e., "HigherIsBetter" or "LowerIsBetter") and the set of allowed values, if the domain is ordinal. Appendix C.7.2 provides details of the implementation.

- *Majority Vote Service:* This service will determine an attribute's value by calculating the value with the most denominations of all attribute values. The services is applicable to all types of attributes. It requires access to the attribute's set of attribute instances, counting the votes for each unique value. Appendix C.7.3 provides details of the implementation.

- *Threshold Service:* This service provides aggregation capabilities for attribute types that support more than on value per attribute. It is applicable to all value domains. A standard, for example, may be applicable to more than industry. This service ranks attribute values by the count of respective votes. Thereafter, it checks, if the rank of the value is smaller than the attributes cardinality. Next, it verifies, if the amount of votes exceeds the defined threshold. If both conditions hold, the attribute's value will be returned. If not, the service will return "null" to indicate, that the attribute should not be included into the standards profile. Appendix C.7.1 provides details of the implementation.

Evaluation of Standards Profiles

So far, services automate the valuation and aggregation of classification data to create standards profiles. ASSET's "Evaluation" sub-process, however, requires aggregation of standards profiles. The "Select Standards" sub-process, for example, involves ranking of standards profiles, according to the stakeholder's preferences. Likewise, the "Status Quo & Roadmapping" sub-process needs to determine the set of standards that are relevant for a given combination of standards and technology field, for example.

We will briefly present CSAP's approach to implementing automation in these respects in the following:

- *"Match Standards Profile":* CSAP automates the matchmaking of standards profiles and the contextual typology. Therefore, CSAP automatically retrieve the set of relevant standards, using the "Contextualization Helper" (see Listing C.5.2 in Appendix C.5). Thereafter, standards will be ranked according to stakeholder's preference of attribute values, using a basic scoring model that is provided by CSAP's "Ranking Helper" (see Listing C.7 in Appendix C.5): Thereby, standards will be awarded a score between 1 and 5 points reflecting the preferences of "very little", "little", "medium", "high", and "very high", if a standard's attribute matches the attribute values as selected by the stakeholder. If the selected attribute values fall into the cardinal value domain, higher-level attribute values will also be awarded scores. In addition, standards score one additional point for each technology, technology field, or standards field that matches the contextual typology. The resulting set of ranked standards will be returned sorted by descending scores.

- *"Aggregate Status Quo" and "Prioritize Gaps":* Automating these steps, CSAP reduces efforts in supporting strategic decisions by automating the population of ASSET's Portfolio Aggregation Matrix. Required aggregation logic is, again, provided by the "Contextualization Helper" (see Listing C.6). Moreover, CSAP implements a simple extension to ASSET's information model (see Figure 7.20). Introducing the StandardizationPotential and the StandardPotential entities, CSAP allows for persisting potentials for standardization and new standards. ASSET uses this kind of information to determine gaps for standardization. Each type of potential maintains references to the corresponding instances of the StandardsField and TechnologField entity. Moreover, stakeholder and a timestamp information will be maintained. As presented in Section 7.2.3, CSAP will uses averages of potentials to determine the status quo of standardization or individual roadmaps. Listing C.6 in Appendix C.5 presents the corresponding application logic.

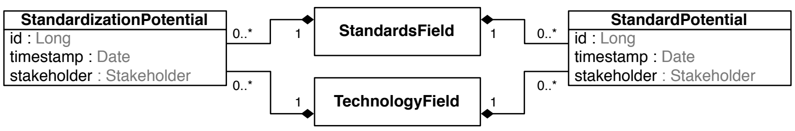


Figure 7.20.: CSAP - Model Extension: Standardization and Standards Potential

7.3.4. Identification of Related Standards

ASSET conceptualizes dependencies of standards using content-based, market-based, and temporal dimensions (see Section 5.4). Analyzing the technology framework of standards, thus, allows for automating the identification of market-related dependencies (see Section 6.4.4). The resulting set, however, only presents a set of potentially related standards. Human interpretation is required to select appropriate relationship types (i.e., CompetitionRT, ComplementRT, PredecessorRT, and EndorsementRT).

CSAP automates the identification of related standards using queries that return sets of standards that share combinations of technologies, technology fields or standards fields. The "Dependency Helper" component implements respective queries, using the Ebean framework and the conceptualization presented in Section 5.4. Appendix C.5.4 provides the corresponding code snippets. The resulting set of standards is, however, not always distinct, i.e., two standards may be candidates to form at least two types of dependencies.

We resolved conflicts as described in the following:

- *Technology Complement Standards vs. Competing Standards:* Our definition of the technology compliment ComplementaryRT entity requires any two standards to share the same instance of the StandardsField entity. Thus, a conflict arises in distinguishing technology complements and competing standards. As conceptualized in Section 5.4, the latter are characterized to share the same standards field and the same technology. In consequence, any technology complement may also be a candidate for a competing standard. As for our prototype, we resolved the conflict as follows: CSAP lists standards that share instances of the StandardsField and Technology entity as candidates for technology complements and competitors. If two standards are assigned complements, they will no longer be considered candidates for a competing relationship. The same applies vice-versa.
- *Endorsement Standards vs. Competing Standards:* The sets of technologies or technology fields and standards fields must be identical for any two standards that form an endorsement relationship. However, the standards developer must be different. Again, there might be conflicts between identified endorsement standards and competing standards. Following ASSET's conceptualization, competing standards also qualify as endorsement standards. CSAP will only include standards to the set of potentially competing standards as long as they are not defined to have an endorsement relationship. Again, the same applies vice versa.

CSAP will automatically create bi-directional dependencies if appropriate. In doing so, CSAP contributes to reducing maintenance efforts of standards assessment. Since competition and complement characteristics are mutual, relationships between competing and complementary standards will always be bi-directional. Profile, endorsement, and predecessor dependencies, on the contrary, are uni-directional. Thus, CSAP will not automatically create respective counterparts.

7.4. Results and Discussion

The goal of this chapter was to demonstrate the realizability of ASSET as a software tool. Therefore, we presented a service-oriented architecture that guided the implementing of CSAP, our research prototype of an extensible standards assessment software platform. We outlined CSAP's realization of ASSET's assessment processes and discussed CSAP's implementation of ASSET's automation potentials.

Table 7.1 concludes CSAP's support automating requirements assessment tasks. We demonstrated how ASSET's concept of aggregation services and CSAP's service-oriented architecture allows for incorporating external aggregation logic, automating consolidation of assessment attributes (AR-1). Moreover, we demonstrated how CSAP's classification wizard incorporates votes that reflect the relevance of a standard's technology framework or relevance. CSAP demonstrates automation capabilities in identifying related standards. Interpretation services, furthermore, enable automated valuation of assessment attributes. Thus, CSAP reduces efforts in standards assessment by automating identification of dependencies and valuation of attributes (AR-2). Finally, CSAP realizes automation in support portfolio analyses. CSAP's "Ranking Helper", thereby, provides support to automate the creation and contextualization of maps that summarize the status quo or individual a roadmap for standardization (AR-3). Likewise, CSAP's "Ranking Helper" automates

ID	*Requirement*	*Conclusion*
IR-4	Support measures for network effects	Interpretation services use ASSET's information model to automate the calculation of measures.
IR-5	Support stakeholders and roles	Automated filtering of information according to ASSET's stakeholder model.
PR-1	Support updates of the classification scheme	"Typology Builder" enables modifications of technology typology.
PR-2	Support updates of classifications	Current standards profiles provide initial classification values. Delphi-based approach.
PR-3	Coordinate updates	Changes to technology typology are automatically propagated to standards profiles. Manual assessment of the quality of the technology typology.
PR-4	Support contextualization	Wizards and parameterized queries enable automated filtering of standards and attributes.
AR-1	Consolidate values from multiple classifications	Aggregation services automate consolidation of classifications into standards profiles.
AR-2	Support determination of dependencies and attributes	Interpretation service provides automated attribute valuations. Automated decision support for the classification of dependencies.
AR-3	Aggregate standards	Automated contextualization of maps. Community approach for documenting status quo.
AR-4	Rank standards	Automated scoring method provides basic ranking capabilities.

Table 7.1.: CSAP: Realization of Method Requirements

prioritization of standards and identification of gaps in standardization, applying simple scoring methods (AR-4). In contrast to more elaborated scoring techniques (e.g., AHP), our simplistic approach frees user from establishing a distinct order of attributes by, for example, answering a fast increasing set of pairwise comparisons of an attribute types relevance. Of course, CSAP's approach comes at the cost of inferior rigor. Considering the high levels of uncertainty in disruptive innovation, we traded precision for reduced efforts in our prototypical implementation, aiming to demonstrate the feasibility of realizing ASSET's automation support. Using CSAP's API, future extensions may address this topic and exploit ASSET's capabilities more scientifically.

In addition to realizing the identified automation requirements, we succeed in automating additional functionality as follows:

- We implemented a "Participants Counter" service to demonstrate CSAP's support for assessing networks effects (IR-4). Future research may apply more elaborated services, based on CSAP's service-oriented design.

- As demonstrated CSAP's components automatically filter the set of standards and attribute types, using ASSET's stakeholder model (IR-5).

- CSAP's "Typology Builder" supports updates of ASSET's technology typology as required by the dynamics of disruptive innovation (PR-1). We, however, identified that updates are typically addressing only small parts of a technology typology. ASSET's sequence of "Define Technologies" and "Define Technology Fields" or "Define Standards Field" steps, thus, must not strictly be enforced (see Figure 6.4). Applying ASSET's procedure for managing attribute types, would, for example, require users to skip all previous steps, if sequential constraints were strictly applied. Doing so, however, introduces a significant overhead, if, for example, users only want to change the cardinality of an attribute type. The "Typology Builder", thus, provides individual views for managing technologies, technology fields, standards fields, roles, and attribute types.

- CSAP, thus, allows users to provide individual and frequent classifications of standards (PR-2). Thereby, CSAP implements a Delphi-based approach by showing consolidated values, if users classify a standard. In doing so, CSAP aims to support the consolidation of standard classifications over time. However, CSAP does not yet support automated triggering of changes to technology typology based on analyzing standards profiles (i.e., "Technology appears / changes" event may not be triggered when classifying standards). Thus, users of CSAP have to change the technology typology (e.g., if they cannot find a suitable technology or technology field) before (re-)starting the classification of a standard. We will discuss an extension in this regards in the final chapter of this thesis.

- CSAP applied simplifications to ASSET's event model. Thus, changes to the technology typology will be propagated instantly (e.g., by triggering aggregation of standards profiles). In doing so, CSAP supports automation of coordinating updates of the technology typology and standards profiles (PR-3).

- Providing the “Selection Wizard”, CSAP implements ASSET’s “Select Standards” sub-process. More specifically, CSAP’s “Contextualization Helper”’ automates the “Match Standards Profiles” by using sets of technologies, technology fields, and standards fields as parameters for queries to contextualize standards profiles (PR-4).

In summary, we may, generally, confirm the realizability of ASSET in our PoC implementation. More specifically, CSAP demonstrates ASSET’s support to automate assessment tasks. Thus, we provided first evidence that an implementation of ASSET reduces assessment efforts by task automation (see Section 4.3.3). However, additional field experiments would be required to measure actual efficiency improvements.

8. Case Studies in Cloud Standards Assessment

So far, we have demonstrated feasibility of our method for Assessing Standards of Emerging Technology (ASSET) in a Proof-of-Concept (PoC) implementation. Our Cloud Standards Assessment Platform (CSAP) prototype, thereby, showed realizability of tasks automation in standards assessment.

Expanding on the validation of ASSET, we will revisit results of the cloud standards study in this chapter. Therefore, we will conduct a series of case studies that allow for validating ASSET's support for enabling information reuse and collaboration among stakeholders (see Hypothesis 1). Moreover, we will use the case studies to validate correctness and relevance of our conceptual information model. Thus, we validate that the structure of our domain-specific models is consistent with the real world (correctness) and that the models are capable of representing all relevant elements and relationships from the real world (relevance) [18]. For a discussion on approaches to assess the quality of conceptual models, for example, see [131, 148]. In the case studies, we will furthermore apply CSAP to validate ASSET's support for coordinating iterative execution of assessment steps and efficiency improvements (Hypothesis 2).

In Section 8.1 we start our discussion of case studies with a view to representing the cloud taxonomy and cloud standard profiles with ASSET. After conceptionally transforming the cloud taxonomy into a cloud technology typology, we apply CSAP to demonstrate the feasibility of representing cloud standards profiles with ASSET. In Section 8.2, we will discuss aspects of changing an existing cloud technology typology. Moreover, we will discuss how ASSET captures the different types of standards. We discuss the representation of dependencies of standards using examples from cloud computing in Section 8.3. In Section 8.4, we demonstrate how relations of technologies, implementations, and standards are classified with ASSET. Therefore, we turn to the example of standards for virtualization technology.

8.1. Creating a Cloud Technology Typology

According to the procedural model any application of ASSET to a new domain of disruptive innovation starts with performing the *"Create Technology Typology"* step (see Figure 6.3). More precisely, ASSET's procedural model demands identification of the instances of ASSET's model entities that will are required for standards assessment. Thus, the task of creating a cloud technology typology is to identify technologies, technology fields, standards fields, roles, and attribute types that enable assessment of cloud standards.

In this section following, we will transfer the taxonomy of cloud standards that we have applied in the cloud standards study (see Section 4.2.1) into instances of Technology, TechnologyField, and StandardsField entities, modeling the technology framework of cloud computing (see Section 8.1.1). Thereafter, we will provide details on instances of the Role (see Section 8.1.2) and AttributesType entities (see Section 8.1.3) that must be created to represent the cloud standards study with ASSET.

In this case study, we aim at validating the correctness and relevance of our conceptual information model. Therefore, we compare the original cloud taxonomy with the cloud technology typology that results from ASSET "Create Technology Typology" step. In addition, we will use CSAP to build cloud standards profiles with ASSET. Comparing the resulting provide cloud standards profiles with those developed in the study, we perform an additional validation of the information models correctness and relevance.

8.1.1. Technology Framework

ASSET's procedural model prescribes a sub-process to define the technology framework for the disruptive innovation under consideration (see Figure 6.5). Pursuing a bottom-up approach, stakeholders have to identify the technologies that make up the technology framework. After that, technology and standards fields are to be named that allow ASSET to classify standards, according to scope and subject.

Technologies

The taxonomy of cloud standards, as applied in the study, did not contain a classification of standards, according to technologies. In consequence, neither challenges nor fields of standardization refer to particular technologies that allow for creating instances of the Technology entity from the study.

Performing the *"Define Technologies"* step of ASSET's *"Define Technology Framework"* sub-process, thus, does not reveal instances of the Technology entity. According to ASSET's information model, there is no requirement to define instances of the Technology entity, i.e., most associations from the Technology entity to other entities bear a minimum cardinality of zero. The only exception is the association between the Technology entity and the Implementation entity (see Figure 5.3). Instances of the Technology and Implementation entity require at least one counterpart. In consequence, implementations may only be integrated into the assessment if a corresponding instance of the Technology entity is available. Therefore, tools to implement ASSET must ensure that implementations will be assigned to at least one technology. If no suitable technology can be found in the technology typology, a new instance of technology must be created to incorporate implementations.

Standards Fields

The cloud standards study applied a taxonomy that consisted of three fields of standardization, i.e., technology, management, and legal aspects. 14 sub-fields were used to provide more detailed classification support (see Section 4.2.1). As discussed in Section 5.1, incorporation of standards that refer to management aspects (e.g., business models or management processes), would require the development of a business typology, which is out of the scope of this thesis (see Figure B.2). Moreover, the study classified legal and regulatory aspects as potential fields of standardization. Self-obligations or corporate policies as considered in the study, however, constitute different types laws or regulations that make up a legal and regulatory framework. Thus, they do not provide scopes of standards as targeted by ASSET. Applying ASSET's information model, self-obligations and corporate policies define sub-types of the LegalAndRegulatoryFramework entity. A categorization of laws or regulations, however, is out of scope of this thesis. Transferring fields of standardization from the study into ASSET, we, thus, omit fields of standardization that fall under the management and legal category.

In summary, we derived five instances of the StandardsField entity from the cloud standards study. All StandardsField instances are top-level elements. Table 8.1 summarizes the StandardsField instances that we created to transfer the taxonomy of the initial study into ASSET.

StandardsField Instance	*Sub-Field (StandardsField Instance)*
File and exchange formats	–
Programming models	–
Protocols and interfaces	–
Standard components and reference architectures	–
Benchmarks and tests	–

Table 8.1.: Case Study - Cloud Standards Typology: StandardsField Instances

As shown in Table 8.1, all but the "Programming models" StandardsField instance could be further subdivided. For example, "File and exchange formats" could also be modeled by defining a "Formats" StandardsField instance, having the two sub-field StandardsField instances "File format" and "Exchange format".[53] Performing the first iteration of ASSET's "Create Technology Typology" sub-process we chose to transfer the study's results in a strict manner as the relevance of fields for standardization has been ensured in surveys and expert workshops. A community for cloud standards assessment could, however, use our initial set of standards fields as a starting point for further iterations of the "Define Technology Framework" activity. In doing so, they may trigger changes in the technology typology (e.g., diversification of standards fields).

[53] Similar arguments can be made for "Protocols and interfaces", "Standards components and reference architectures", and "Benchmarks and tests".

Technology Fields

The study's taxonomy comprised nine challenges that were decomposed into 19 sub-challenges for cloud computing. The study, thus, did not incorporate technology fields but used more abstract challenges in cloud computing. Being a conceptual construct, ASSET's TechnologyField entity allows for "aggregating the subject of standardization" (see Page 80). Conceptually, challenges, as applied in the cloud standards study, may, thus, be modeled as instances of the TechnologyField entity.

Depending on the scope of the assessment and the maturity of the disruptive innovation under consideration, these instances of the TechnologyField entity will evolve into more technical constructs over time. Technology fields will, thus, turn more concrete as the community of stakeholders gains knowledge over the emerging technology (similar to the evolution of StandardsField instances).

The results of our cloud standards study did not indicate potential to address the challenge of "ensuring fair competition in the market" with standards that fall under the technology

TechnologyField Instance	*Sub-Field (TechnologyField Instance)*
Efficiency of service provisioning	Development tools and components Creation of scalable architectures Resource management and flexibility Availability of services
Effectiveness of service usage	Contracts (incl. questions of liability) Control of services by users Governance or escalation mechanisms
Transparency of service delivery and billing	Billing (incl. license management) Quality assurance and monitoring of SLA Type and location of data processing
Information security	Identity and rights management Confidentiality and integrity Access control Logging Attack prevention Verification and certification
Data privacy	–
Interoperability	Migrating into or out of the cloud Ability to integrate on-premise IT Cloud federation
Portability	Service portability Data portability
Compliance with regulatory requirements	–

Table 8.2.: Case Study - Cloud Standards Typology: TechnologyField Instances

category of standards fields (see Figure 4.3). Transferring the taxonomy of the initial study into a cloud technology typology, we, thus, disregard this challenge.

As depicted in Table 8.2, we were able to identify 29 instances of the TechnologyField entity to represent the challenges named in the study. Modeling the two levels of challenges, eight instances represent a parent TechnologyField entity. The remaining 21 instances are sub-fields. Conceptually they, thus, build relations to their parent TechnologyField instances. The TechnologyFields "Data privacy" and "Compliance with regulatory requirements" do not define sub-fields.

The taxonomy applied in the study was designed hierarchically. Therefore, we did not identify instances of TechnologyFields that build structural relations to more than one parent TechnologyField instance, analyzing the taxonomy of the study. Generally, TechnologyFields, however, may build structural relationships. For example, the field of virtualization technologies, as presented in Section 8.4, constitutes a sub-field to "efficiency of service provisioning" and "portability".

8.1.2. Stakeholders and Roles

Generally, ASSET conceptualizes stakeholders of a particular standard as dynamic entities. Thus, these are not part of the technology typology (see Figure 5.16), but will only be assigned in the "Classify Standard" sub-process (see Figure 6.8). Consequently, instances of the Standardization entity will only be created as standards are classified by stakeholders.

Classifying the type of a stakeholder's participation in standardization, ASSET's stakeholder model defines four types of standards-specific roles. Moreover, an unlimited amount of domain-specific roles can be used to characterize the standard's relevance for a particular user group of the disruptive innovation. The different types of roles, thus, allows for capturing different perspectives of standards assessment (e.g., for filtering irrelevant information). ASSET's "Create Technology Typology" sub-process, therefore, mandates defining relevant instances of the Role entity.

In the remainder of this section, we will discuss how ASSET allows for defining the stakeholders of cloud standardization that we have identified in the cloud standards study.

Standards-specific Roles

The standards-specific roles, defined by ASSET's stakeholder model, leads to the creation four instances of the StandardsRole. The set of instances of the Role entity (or its subtypes), shown in Table 8.3, thus, will always comprise four instances of the StandardsRole entity. ASSET, thus, considers standards-specific roles statically.

Our cloud standards study only implicitly incorporated standards-specific perspectives. The standards profile, for example, listed the set of standards developers using the "Initiator"-attribute (see Section 4.2.2). Also, all stakeholders that are involved in standardization were named by the “Participants”-attribute. However, we did not make a distinction between the different Roles (e.g., standards implementer, standards user, or policy maker). Moreover, only stakeholders that we perceived to bear the potential to significantly influence standardization were listed by name. Other stakeholders were only counted, building the basis for estimations of a standard’s potential for market success.

Domain-specific Roles

ASSET’s concept of domain-specific roles provides the capability to incorporate assessment perspectives that stem from life-cycle models (see Section 2.3.2) or use cases for emerging technology. In contrast to standards-specific roles, the amount of DomainRole instances is domain-specific and may change as the field of disruptive innovation matures. Thus, instances of the DomainRole entity must be identified when applying ASSET to a domain of disruptive innovation.

The standards profile that was applied in the study comprised a “User Group”-attribute, characterizing the relevance of a standard for potential users such as service providers, service intermediaries, and service consumers (see Section 4.2.2). Applying ASSET’s stakeholder model, user groups constitute domain-specific stakeholder roles. Therefore, we identify three instances of the DomainRole entity. In accordance with our life-cycle model four cloud service management, we, however, decided to reduce the set of domain-specific roles to only service provider and service consumer.

Table 8.3 summarizes the instances of the Role entity and denominates respective types that we may derive from applying ASSET to the domain of cloud computing.

Role Instance	*Entity Type*
Standards Developer	StandardsRole
Standards Implementer	StandardsRole
Standards User	StandardsRole
Policy Maker	StandardsRole
Service Provider	DomainRole
Service Consumer	DomainRole

Table 8.3.: Case Study - Cloud Standards Typology: Cloud-specific Role Instances

8.1.3. Assessment Attributes

The goal of the final step of ASSET’s “Create Technology Typology” sub-process is to define the set of attributes that a cloud standards profile should comprise (see Figure 6.4). In the following, we will discuss instances of the AttributeType entity that can be identified from the collection of attributes of our cloud standards study (see Figure 4.2).

In summary, we were able to identify ten AttributeType instances that allow for transferring the 15 attributes from the cloud standards study. Five attributes used in the cloud standards study, thus, do not require attribute types in ASSET. Table 8.4 provides an overview of how attributes can be modeled with AttributeType entities.

ASSET differentiates three types of attributes, introducing the DescriptiveAT, ApplicabilityAT, and InterpretativeAT entities. The first step of transferring attributes from the cloud standards study, thus, is to select the appropriate entity for modeling the attributes with ASSET. Using ASSET, two instances of the DescriptiveAT entity allow for transferring the "Status" and "Type" attributes. Moreover, seven instances of the ApplicablityAT entity are required to model "Cloud Aspect", "Service Model", "Industry", "Deployment", "Company Size", "Maturity", and "Participation". As discussed in Section 5.14, the separation of descriptive and applicability AttributeTypes allows for structuring the set of attributes, reflecting their standards- and domain-specific viewpoints. We define "Market Potential" to be modeled by an instance of ASSET's InterpretativeAT entity. Thus, values for assessing the market potential of a standard can be automated, if a service to calculate values was available.

Information that the study classified using the "Initiator", "Participants", and "Jurisdiction" attributes, will be classified using the Standardization entity of ASSET's information model. Likewise, no attribute type is required to store the "Link" to a standards specification as the Standard entity maintains this information. Finally, ASSET will track the "User Group" for which a standard is relevant, using instances and associations of the DomainRole entity.

An outlook on the relevance of AttributeType instances to standards fields, technology fields, and roles is presented in Appendix C.2.2. As the cloud standards study did not provide filtering capabilities, the respective assignments lack verification in, for example, questionnaires or expert workshops. Therefore, we do not fully elaborate on this aspect, but only included potential assignments into the appendix of this work.

We will summarize the additional properties of required AttributeType instances in the following. We will start with a look at instances of the DescriptiveAT entity. Next, we will present the resulting set of ApplicabilityAT instances. Finally, we demonstrate how ASSET supports defining attributes, using the InterpretativeAT entity.

DescriptiveAT Instances

We model the "Status" of a standard as a descriptive attribute. A standard will always have exactly one status at a time. Thus, we set the cardinality of the DescriptiveAT instance to one, allowing each standard for having exactly one "Status"attribute assigned. Moreover, we defined the attribute's domain to apply an ordinal scale, having a "higherIsbetter" scale order. ASSET requires defining a set of allowed values to model an attribute type's value domain. We define "work-in-progress", "draft", and "published" as possible values. However, we could have applied a more sophisticated approach, using internationally harmonized stage codes (see [101]). The "higherIsbetter" scale order will inform comparisons of two attributes' values, based on their position in the list of

Cloud Standards Study		*ASSET*	
Category	*Attribute*	*AttributeType*	*Entity Type*
Basics	Status	DescriptiveAT	Status
Basics	Type	DescriptiveAT	Type of Standard
Basics	Cloud Aspect	ApplicabilityAT	Cloud Aspect
Basics	Initiator	*- via Standardization Entity -*	
Basics	Participants	*- via Standardization Entity -*	
Basics	Link	*- via Standard Entity -*	
Field of Application	Service Model	ApplicabilityAT	Service Model
Field of Application	User Group	*- via DomainRole Entity -*	
Field of Application	Industry	ApplicabilityAT	Industry
Field of Application	Deployment	ApplicabilityAT	Deployment
Field of Application	Jurisdiction	*- via Standardization Entity -*	
Field of Application	Company Size	ApplicabilityAT	Company Size
Assessment	Maturity	ApplicabilityAT	Maturity
Assessment	Market Potential	InterpretativeAT	Market Potential
Assessment	Participation	ApplicabilityAT	Participation

Table 8.4.: Case Study - Cloud Standards Typology: Mapping of Assessment Attributes

allowedValues (see Section 5.14). We specify an endpoint to a service that will be used to aggregate different valuations for a standard's "Status" attribute.[54] The service provides an implementation of a majority vote approach.

Furthermore, we created a "Type of Standard" attribute type to classify a standard's different levels of commitment. Transferring the approach from our study, we defined the set of allowed values to comprise "best practice", "reference implementation", "specification", "industry standard", "standards", and "EU-norm". We selected a cardinality of one, as a standard should not fall into more than one of these categories at once. Moreover, we defined the attribute domain to apply a nominal scale, as we could not identify a ranking of different types of standards. Again, attribute values will be consolidated, using the majority vote service. x

Table 8.5 summarizes the properties of the DescriptiveAT instances to model "Status" and "Type" with ASSET.

[54]Details on the implementation of aggregation and interpretation services are discussed in Section 7.3.3, Appendix C.7 provides source code examples.

Name	*C*	*D*	*SO*	*aService*
Status	1	Ordinal	0	as/majorityVote/:aId
Type of Standard	1	Nominal	-	as/majorityVote/:aId

C (Cardinality): -1 (infinite), 1, 2, 3...
D (Attribute Domain): *c*-cardinal, *o*-ordinal, *n*-nominal, *sv*-singleValue
SO (Scale Order): *0*-higherIsBetter, *1*-lowerIsBetter, *2*-existenceIsBetter

Table 8.5.: Case Study - Cloud Standards Typology: DescriptiveAT Instances

ApplicabilityAT Instances

Using ASSET, most attributes that were used in the cloud standards study are modeled as instances of the ApplicabilityAT entity. Table 8.6 summarizes the identified seven instances of the ApplicabilityAT entity, providing an overview of their respective properties.

The majority of AttributeTypes, thereby, applies a nominal scale, i.e., provides an order to allowed values. Obviously, allowed values that assess the maturity or opportunities to participate in standards development provide an order (e.g., high maturity is better than medium maturity). Likewise, an open participation approach for standardization can be seen to be more desirable than a closed approach. Thus, “Maturity” and “Participation” attribute types are modeled using the ordinal scale. We were able to directly transfer the varying set of allowed values. Thus, we do not repeat respective values in this section (see Figure 4.2 for details).

While a standard should definitively only be assigned to one maturity level at a time, standards might support different types of deployment, multiple industries or service model at once. We, thus, modeled cardinalities of the corresponding DescriptiveAT instances to be indefinite. Theoretically, this would allow an unlimited amount of service models to be assigned to a standard. Since the set of possible attribute values is, however, constraint

Name	*C*	*D*	*SO*	*aService*
Cloud Aspect	1	Nominal	-	as/majorityVote/:aId
Company Size	1	Nominal	-	as/majorityVote/:aId
Deployment	-1	Nominal	-	as/threshold/:aId, T=5
Industry	-1	Nominal	-	as/threshold/:aId, T=0.15
Maturity	1	Ordinal	0	as/majorityVote/:aId
Participation	1	Ordinal	1	as/majorityVote/:aId
Service Model	-1	Nominal	-	as/threshold/:aId, T=0.30

C (Cardinality): -1 (infinite), 1, 2, 3...
D (Attribute Domain): *c*-cardinal, *o*-ordinal, *n*-nominal, *sv*-singleValue
SO (Scale Order): *0*-higherIsBetter, *1*-lowerIsBetter, *2*-existenceIsBetter
T (Threshold): [0;1]-percentage, n (actual count)

Table 8.6.: Case Study - Cloud Standards Typology: ApplicabilityAT Instances

by the number of allowed values, a standards profile will contain at most one attribute per value. Applying a threshold-based aggregation service, we, furthermore, exclude values that stakeholders name in less than 30 percent of all classifications (see “Service Model”). Likewise, a given value of the deployment attribute will only be shown in the standards profile if it was classified at least five times (see threshold value of the “Deployment” AttributeType). Thus, the set of attribute values that standards profiles comprise results from calculating the combination of these constraints.

InterpretativeAT Instances

Transferring the “Market Potential” attribute, we identify potential for automating valuation of attributes. Thus, we model “Market Potential” as an instance of the InterpretativeAT entity. There should always only be one value that estimates a standard’s market potential. Thus, we model the cardinality to be one. Obviously, the scale of the value domain is ordinal, applying a “higherIsbetter”- approach. A majority vote service will be used to perform value aggregation. For calculating a standard’s market potential, we specify a reference to a service endpoint that provides the required logic (see Appendix C.8.2 for an example).

Name	*C*	*D*	*SO*	*aService*	*iService*
Market Potential	1	Ordinal	0	as/majorityVote/:aId	is/marketPotentialAnalyzer/:aId

C (Cardinality): -1 (infinite), 1, 2, 3...
D (Attribute Domain): *c*-cardinal, *o*-ordinal, *n*-nominal, *sv*-singleValue
SO (Scale Order): *0*-higherIsBetter, *1*-lowerIsBetter, *2*-existenceIsBetter

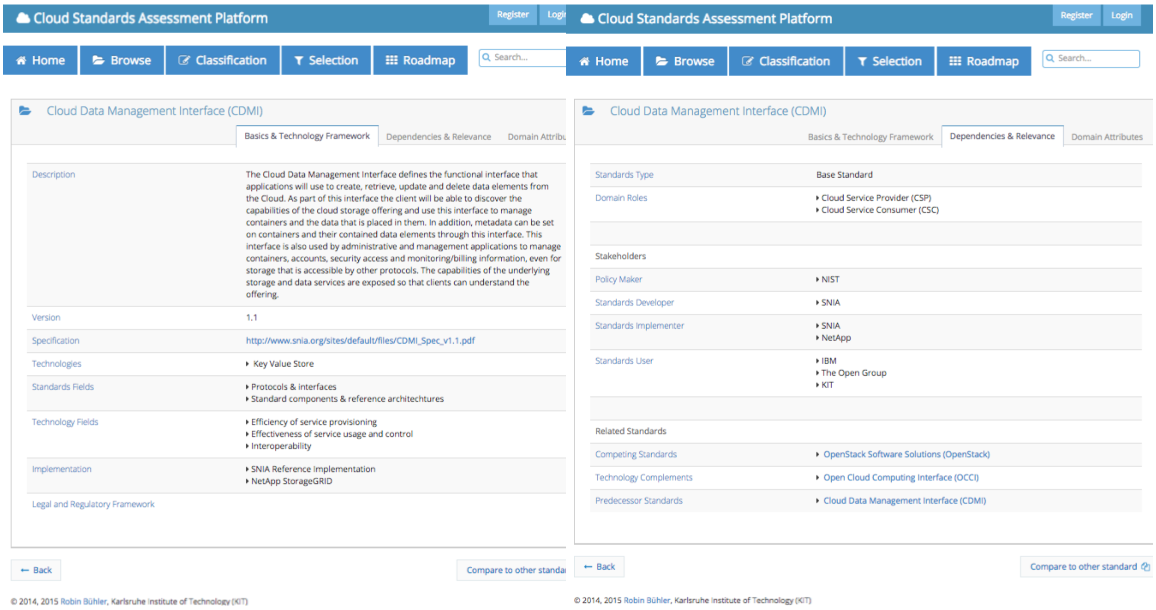
Table 8.7.: Case Study - Cloud Standards Typology: InterpretativeAT Instances

8.1.4. Codification in CSAP

The cloud standards typology developed in the previous chapter and the cloud standards profiles created in our cloud standards study (see Section 4.2.2) provide inputs for validating our PoC implementation. Thus, we created a codified version of the cloud technology typology. Appendix C.1.3 comprises screenshots that document the codification of the above develop cloud technology typology.

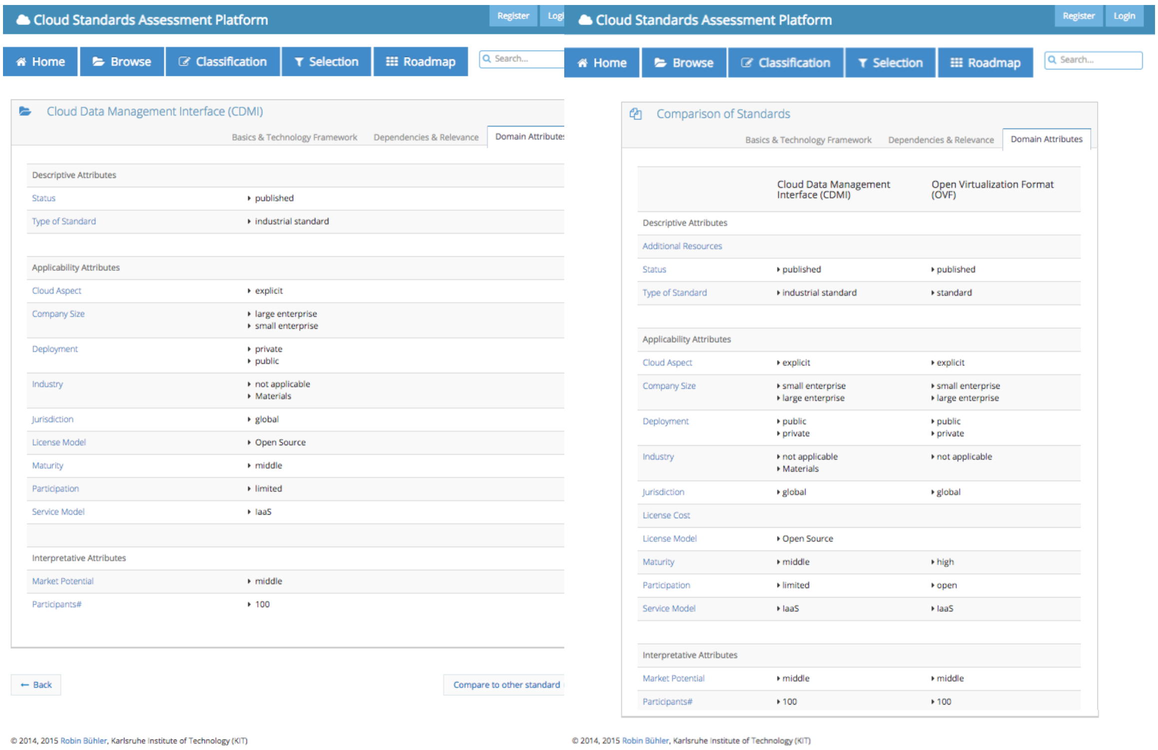
Moreover, we successfully codified online versions of the 20 cloud standards profiles, creating required instances of technology framework, relationships, stakeholders, and attributes entities for each standard. Therefore, we successfully codified more than 280 attributes, providing the initial values of the cloud standards profiles. Figures 8.1 and Figure 8.2 present CSAP’s representation of standards profiles.

We conclude relevance of CSAP and the conceptual information model, combining the validations of the conceptual information model performed in the previous sections with the successful codification of the cloud technology typology and cloud standards profiles.



(a) Basics and Technology Framework (b) Dependencies and Relevance

Figure 8.1.: CSAP - Standards Profile: CDMI



(a) Domain-specific Attributes (b) Comparison of Standards Profiles

Figure 8.2.: CSAP - Standards Profile: CDMI (Contintued)

As we evaluated the appropriateness of standards profiles in the cloud standards study using expert interviews and workshop, we may thus also conclude correctness of CSAP and the conceptual information model. Conclusions on relevance and correctness, however, must be reassured if changes are applied to the technology typology.

8.2. Changing the Cloud Technology Typology

In this section, we will discuss how ASSET's information model implicitly integrates typing of standards as discussed by state-of-the-art approaches (see Section 2.1.3). Moreover, we will discuss how CSAP handles changes to the cloud technology.

Implicit Types of Standards

Standards can be classified according to subject-matter (i.e., differences in entities or requirements), development method (i.e., differences in actors, organizations, or processes), and use (i.e., differences in function, business sector, business model, availability, or obligation). An overview the state-of-the-art in classify types of standards has been given in Section 2.1.3. Conceptually, these types of standards are, in fact, not characteristics of the Standard entity, but are determined by the set of relationships it builds to other instances of other entities of ASSET's information model. Thus, ASSET only recognizes BaseStandard and StandardProfile entities for typing standards. In the following, we will, however, provide an outlook on how other types of standards can automatically be derived, using instances of the InterpretativeAT entity and respective interpretation services.

- Describing the scope of a standard, instances of the StandardsField entity allow for distinguishing basic, requiring, and measurement standards. Moreover, the separation of implementation and concept level standards is reflected a standard's subject. Concept level standards, thereby, relate to TechnologyField instances. The subject of implementation level standards are instances of the Technology entity. Using ASSET, standards can, thus, be classified according to their *subject-matter*.
- Classifying standards according to their *development method* distinguishes de facto from de jure standards. If a standard was created by a non-accredited standards consortium, it is, for example, typically framed as a de facto standard. A standard may also be named de facto standard if the corresponding products gained the majority or at least a significant share of the market. The information model, therefore, can be used to classify de facto or de jure standards indirectly. Therefore, respective types can be inferred based on the accreditation of the stakeholders that created the standard. De jure standards, for example, have to be created by an Standards Development Organization (SDO). Moreover, ASSET supports classification according to the timing of the standardization process, using the Standards entity's relationships to the Technology and TechnologyFields entities. A standard could be considered to be anticipatory if it refers to an instance of the TechnologyField entity that is not yet related to a technology or has a dependency technology that has not yet been implemented.

- The properties that are used to classify standards according to their *use*, define a variety of attributes that are not mutually exclusive. For example, a standard could be public and licensed at the same time. Moreover, classifications according to the business sector or business model will only evolve over time. ASSET, therefore, models these characteristics of standards using AttributeType entities (see Section 5.14 for details).

In summary, the conceptual information model is capable of representing the varying types of standards that are discussed in state-of-the-art research. Thus, we may conclude additional evidence that validates the relevance of information that is maintained by ASSET.

Extending the Cloud Technology Typology

Standards specifications document standards. ASSET's information model, thus, defines each Standard instance to comprise a link to its specification. There may, however, be additional documents that provide further explanations for a standard. Alike, there may be guidelines that provide hints on how to implement a given standard. Including information of this kind into standards profiles, we defined the *"Additional Resource"* DescriptiveAT instance. Listing only the most relevant additional resources, we set the cardinality of the AttributeType to two. The aggregation of attribute values will be performed using a threshold. We set the threshold value to two. Applying the combination of the threshold-based approach and the cardinality of two, ensures that only the two most named additional resources will be assigned to a standards profiles. Moreover, each value has to be named at least twice.

The value that a standard contributes to engineering a cloud services depends on the life-cycle phase of the development project (see cloud service management life-cycle in Section 2.3.2). Similar to approaches to assess standards in software engineering (see Section 3.1), we, thus, included a "Phase" attribute. Creating an instance of the ApplicabilityAT entity, we allow for characterizing standards by an unlimited amount of "Phase" attributes. We define a nominal scale and restrict the set of allowed values to "specification", "design", "implementation", "deployment", and "operation". There may, however, not be more than five "Phase" attributes assigned to a standard at once. We define the aggregation of "Phase" attributes to follow a threshold-based approach. Thereby, we require a particular attribute value to be denominated by at least five percent of all classifications. Only then, will it be shown in a standards profile.

Cost of standardization may provide barriers to standardization in Small and Medium-sized Enterprises (SME) [67]. Supporting the need to assess the cost of using or implementing a standard, we added "License model" to set of instances of the ApplicabilityAT entity. Only one attribute of this type may be assigned to a standard at once (i.e., the cardinality is set to one). Moreover, the set of possible values allows for incorporating "one-time", "annual", "monthly fees", and "open-source" approaches. Different values of the license model AttributeType will be aggregated using the majority vote service.

Name	*C*	*D*	*SO*	*aService*	*iService*
Additional Resources (D)	2	sv	-	as/threshold/:aId, 2	-
License Model (A)	1	n	-	as/majorityVote/:aId	-
Phase (A)	-1	n	-	as/threshold/:aId, 0.05	-
Participants (I)	1	c $[1\text{-}\infty]$	-	as/latest/:aId	is/participantsCounter/:aId

D: DescriptiveAT, **A**: ApplicabilityAT, **I**: InterpretativeAT
C (Cardinality): -1 (infinite), 1, 2, 3...
D (Attribute Domain): *c*-cardinal, *o*-ordinal, *n*-nominal, *sv*-singleValue
SO (Scale Order): *0*-higherIsBetter, *1*-lowerIsBetter, *2*-existenceIsBetter

Table 8.8.: Case Study - Changing the Cloud Technology Typology: Additional Attribute Type Instances

Network effects are drivers of a standard's adoption and, thus, are a key driver of the use that standards implementers and users may gain (see Section 2.1.1). Measurements for network effects are, thus, required for comparing standards. Demonstrating ASSET's support for calculating respective measures, we introduce the *"Participants#"* InterpretativeAT instance. The "Participants#" attribute refers to the amount of stakeholders that participate in standardizing a given standard. Values can automatically be calculated, invoking the service that is defined by the iService attribute, t We apply an aggregation service to ensure that a standards profile only shows the most recent valuation.

Figure C.7 in Appendix C.1.3 presents screenshots of CSAP's representation of the *"Participants#"* attribute. Moreover, Listing C.8.1 summarizes required interpretation logic. Validating CSAP's support for synchronizing changes of the technology typology and standards profiles, we successfully performed a set of tests (e.g., create attribute types, delete attributes, update attribute type).

In this section, we presented assessment attributes that allow for incorporating additional information into cloud standards profiles. Therefore, we defined and added additional AttributeType instances to the cloud technology typology. As demonstrated, ASSET's information model provides the flexibility that is required to incorporate the required adaptations.

8.3. Classifying Dependencies of Cloud Standards

Using the set of cloud standards profiles that we developed as a result of the cloud standards study [20], we will demonstrate how ASSET supports the classification of dependencies of standards in this section. In the following, we will discuss examples for each type of the dependencies that ASSET classifies by using the "profiles-composition" and the sub-types of ASSET's RelationshipType entity. Therefore, instantiations of CompetitionRT, ComplementRT, PredecessorRT, or EndorsementRT entities have to be created.

ASSET requires denomination of references to corresponding Standard instances and selection of the appropriate sub-types (i.e., technology or standards field complement) to be defined for each valid instance of the RelationshipRT entity.

Profile Dependency (profiles-composition): As motivated in Section 5.3, standards profiles can be frequently observed in standardization. The Common Information Model (CIM) System Virtualization Profile (DSP1042) [5] is only one example of the profile family that tailors the base standard CIM Infrastructure Specification (DSP0004) [2] to the application area of cloud computing. In the notation of ASSET's conceptual information model, the CIM System Virtualization Profile (CIMSVP) (DSP1042) adapts the CIM Infrastructure Specification (DSP0004) to be applicable to the TechnologyField of virtualization. Using ASSET, the respective dependency can be represented by creating a BaseStandard instance for CIM and StandardProfile instance for CIMSVP. The "profiles-composition" will then be used to define the dependency of both Standard instances.

Competition Dependency (CompetitionRT): Virtualization technology shows signs of competing standards as there exist two proposals that, for example, define an Application Programming Interface (API) for managing virtualized resources. The respective standards, Open Cloud Computing Interface (OCCI) and Cloud Infrastructure Management Interface (CIMI), target the same subjects and compete for market dominance. Another example of competition standards is given by the ongoing conquest for design dominance between Representational State Transfer (REST) and SOAP/Web Service Definition Language (WSDL) in the area of interface standards for service composition. For the results of an extensive study see [199].

Complement Dependency (ComplementRT): Next to competing for market dominance, standards may complement one another. Cloud computing gives justification to the existence of such behavior by the example of OCCI and the Cloud Data Management Interface (CDMI). Open Grid Forum (OGF) develops OCCI, while CDMI's sponsor is the Storage Network Industry Association (SNIA). Both, OCCI and CDMI provide a specification for an API. OCCI, as mentioned, for the management of virtualized computing resources and CDMI for the managing data on virtualized storage devices. Thus, OCCI and CDMI constitute technology complements (see Figure 5.10). As the standardization community has identified the potential of using OCCI and CDMI combined, they conduct so-called plug-fest events that promote both standards while testing their interoperability. CDMI, Hypertext Transfer Protocol (HTTP), and Open Authentication Protocol (OAuth), for example, constitute a StandardsField complement. CDMI does not define a mechanism for authenticating and authorizing data manipulation request but relies on basic HTTP security such as Transport Layer Security (TLS). OAuth on the other hand is a generic standard for Web identity management that comprises a model, a protocol, and an interface to authentication and authorize data request. OAuth, in turn, is built on HTTP but builds an own protocol on top of basic HTTP actions. In summary, CDMI, HTTP, and OAuth are StandardsField complements as they relate to different

StandardsFields instances and the same Technology instance, i.e., cloud data stores. Note, TLS and OAuth, in turn, may also be considered considered competitors even though they are both complements of HTTP.

Predecessor Dependency (PredecessorRT): A given implementation of a technology may, for example, perfectly implement one version of a standard, but not another version of the same standard. Legal and regulatory frameworks, likewise, may refer to older versions of a standard, due to mismatching update cycles. Modeling temporal dependencies of standards, thus, is important for classifying and evaluating standards. Extended analyses may, for example, examine drifts in the scope of a standard along its maturation.

Uncertainty leads to a multitude of concurrent standardizations initiatives in the early phases of disruptive innovation (see Figure 2.4). While our cloud standards study clearly identified the multitude of standards and standardization initiatives, the progression of cloud computing and cloud standards has not yet reached the phase of consolidation. While creating this work, only Open Virtualization Format (OVF) provided an example of a predecessor dependency, when SNIA published an updated standards specification (i.e., version 1.1 superseded its predecessor version 1.0.2).

The related field of Business Process Management (BPM) standards provides a more elaborate example of varying paths of standards progression and structural dependencies of consolidation activities (for details see [199, 126]. WS-Business Process Execution Language (BPEL), for example, demonstrates how a standard may depend on varying preceding versions. Along its path of evolution, the predecessors of BPEL changed names and the organizations that drove its development. Yet, preceding versions continued to exist. For example, Microsoft's BizTalk Server 2013 still applies XLANG for orchestration purposes.[55]

Endorsement Dependency (EndorsementRT): We could not observe an endorsement dependency of standards in cloud computing while conducting this work. Examples of endorsement dependencies of standards, however, are to be frequently found in standardization. International standards issued by International Organization for Standardization (ISO), International Electrotechnical Commission (IEC), Comité Européen de Normalisation (CEN), Comité Européen de Normalisation Électrotechnique (CENELEC), for example, require national endorsement. Likewise, any European standard that is issued by one of the three European SDO—i. e., CEN, CENELEC, or European Telecommunications Standards Institute (ETSI)—requires replication of the standards specification by a national standardization organization for each member state of the European Union (EU). Thus, Deutsches Institut für Normung (DIN), for example, publishes standards to implement international or European standards on the national level, using an explicit reference to the international or European standard:

[55] See `http://msdn.microsoft.com/en-us/library/microsoft.xlangs.core(v=bts.80).aspx`.

> "This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by [deadline], and conflicting national standards shall be withdrawn at the latest by [deadline]" [55, p. 2], [56, p. 5]

An example of another motivation of endorsement standards can be found in the BPM community. The Business Process Model & Notation (BPMN) standard constitutes a specific example of an endorsement standard in Information and Communication Technology (ICT). After years of updated versions of the BPMN standard that have been published by the Object Management Group (OMG) alliance, BPMN was submitted to ISO, seeking formal accreditation. ISO published version 2.0 of BPMN as ISO/IEC 19510 in 2013 [105].

Using the 20 cloud standards profiles that we codified with CSAP, we were able to successfully validate our approach to automatically identify standards dependencies (for implementation details see 7.3.4). Figure 8.3 presents an excerpt of the Graphical User Interface (GUI) for classifying dependencies of the OCCI standard. Options of the select boxes are propagated automatically. No candidates standard has, for example, been found for that could be an endorsement relationship to OCCI. Likewise, the only known standard that might compete with OCCI is OpenStack (i.e., the options list does not contain additional standards).

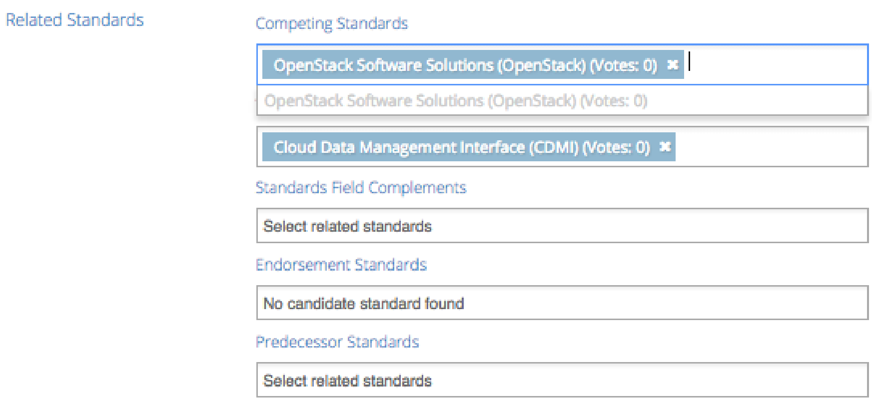


Figure 8.3.: CSAP: Automated Identification of Related Standards (Excerpt)

In summary, successfully validated ASSET's and CSAP's capabilities to incorporate different dependencies of standards into standards assessments. Due to the comparatively early phase of cloud standardization, we could not present cloud standards for each type of dependency that ASSET is capable of representing. Thus, we applied standards from related fields to validate ASSET's support for classifying standards dependencies.

8.4. Collaborative Assessment of Cloud Virtualization Standards

In this section, we will perform a partial extension of the cloud standards typology to support a more detailed classification of standards in the field of virtualization technology. Moreover, we will demonstrate how ASSET provides support to structure the set of stakeholders that influence standardization of virtualization technology. Finally, we will report on a simulated collaborative effort, where stakeholders submitted conflicting classification information.

In Section 2.3, we defined virtualization to be a set of technologies that drives flexibility, scalability, and distribution of cloud resources. Virtualization technology existed prior to the emergence of cloud computing. Thus, the technology field constitutes are a rather stable environment in cloud computing. We may, therefore, identify concrete technologies, implementations, and standards. The following assessment of cloud virtualization standards builds on an overview of standards and technologies for virtualization as presented in [124].

Cloud Virtualization Typology

Figure 8.4 visualizes the extract of a cloud technology typology for virtualization technology. As depicted, we model virtualization technology to be a technology field that describes the emerging technology of cloud computing. Virtualization, thereby, is a subfield to the "efficiency of service provisioning" and "portability".

Moreover, we identify "Machine Image Formats" to be a standards fields that details "File and Exchange Formats" (see Section 8.1.1). We, furthermore, model "Hypervisor" and "Machine Image" as Technology instances. Both technologies fall into the field of virtualization technology. Creating four instances of the Implementation entity, concludes the modeling of the technology framework for virtualization: VMWare ESXi, a hypervisor, and three types of machine images, i.e., Virtual Machine Disk (VMDK), Amazon Machine Image (AMI), and OVF. The latter constitutes a reference implementation of the identically named OVF standard.

As depicted, only the reference implementation of OVF is compliant to the OVF standards specification. The "Machine Image" Technology entity, however, defines the subject of the OVF standard. Thus, OVF defines a standard that is also relevant for VMDK and AMI, if, for example, developers of these products look for standards. Hypervisor's that use VMDK and AMI as machine images, provide mechanism to export OVF compliant machine image formats at different levels of compatibility [124, 122]. However, the VMDK or AMI formats are not compliant to OVF.

Stakeholder Dependencies

The example of virtualization technology, furthermore, allows for identifying concrete stakeholders. Classifying their relations with ASSET, allows for validating ASSET's support in this respect. We will briefly discuss stakeholders of OVF to illustrate the interplay of the Stakeholder entity, its relationships and ASSET's generic stakeholder model for assessing standards in disruptive innovation.

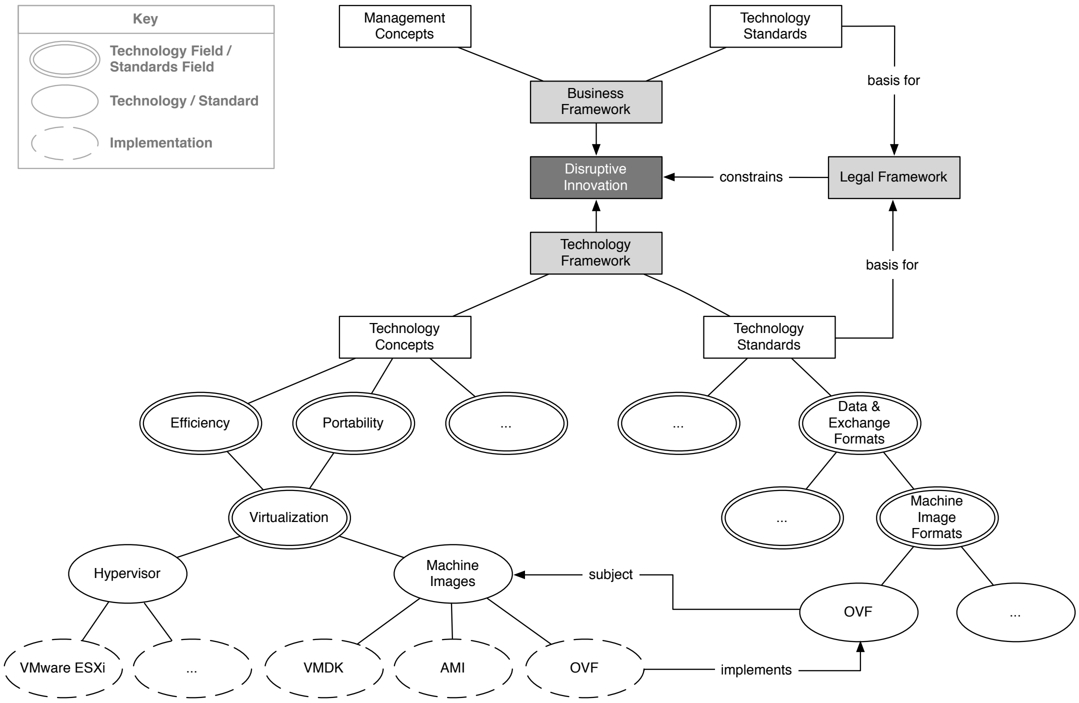


Figure 8.4.: Cloud Technology Typology - Virtualization Technology

Among other, Distributed Management Task Force (DMTF), Open Data Center Alliance (ODCA), OpenStack Foundation, International Business Machines Corporation (IBM), VMware Inc. (VMware), Citrix Systems (Citrix), and Microsoft Corporation (Microsoft) are stakeholders that influence standardization of OVF.

We classify IBM, VMware, Citrix, and Microsoft to be private organizations, having a national jurisdiction as they are headquartered in the United States (US). Arguments could, however, be made that IBM, VMware, Citrix, and Microsoft are multinational organizations that should be modeled with an international jurisdiction. While corresponding legal considerations are out of the scope of this thesis, national subsidiaries of the parent company could be modeled, defining the parent company to have an international jurisdiction.

Applying ASSET's classification of stakeholders ODCA, DMTF, and OpenStack Foundation are examples of alliances. IBM, VMware, Citrix are members of DMTF.[56] VMware, Citrix, and Microsoft are member organizations of ODCA.[57] Finally, IBM and VMware are members the OpenStack Foundation.[58] Conceptionally, the respective instances of the Stakeholder entity, thus, build dependencies to DMTF, ODCA, or OpenStack Founda-

[56] Based on the membership list published at `http://www.dmtf.org/about/list` on June 16th, 2014. The System Management Forum (SMF) listed Microsoft as a member, but Microsoft was not listed in one of the main membership categories.

[57] Based on the membership list published at `http://www.opendatacenteralliance.org/dashboard/index.php/members-list` on June 16th, 2014.

[58] Based on the membership list published at `http://www.openstack.org/foundation/companies/` on June 16th, 2014.

tion. Using ASSET's information model, three instances of the "memberOf-association" are required to store the relations.

Assigning Stakeholders to Standards

The example of OVF allows for demonstrating ASSET's capabilities to represent a standard's stakeholders.

StandardsRole: DMTF is the publisher of OVF. Thus, we model DMTF to enact the standards developer role. Therefore, we have to an instance of the Standardization entity, comprising references to the OVF Standard instance, the DMTF Stakeholder instance, and the standards developer StandardsRole instance.

VMware and Citrix, for example, are influencing OVF, both, as standards developer and standards implementer. While ASSET allows a standard to be associated with many standards developers, the relation of VMware and Citrix are transitive, i.e., are defined trough the participation of VMware and Citrix in DMTF. Thus, no further instances of the Standardization entity should be created to classify VMware and Citrix as standards developer of OVF. Documenting VMware and Citrix as implementers of OVF, in turn, can be achieved by creating two instances of the Standardization entity. Each instance references the standards implementer instance of the StandardsRole entity and respective Stakeholder instances. Microsoft seems to only implement OVF without influencing its development in development. Thus, only, one instance of a Standardization entity must be created to classify Microsoft's influence on OVF.

DomainRole: We revisit the example of the OVF standard a last time to clarify the interplay of ASSET's stakeholder and roles entities. OVF defines a standard for the description of virtual machine images. In doing so, OVF is of particular importance for providers and consumers of cloud services (see Section 2.3.1). Modeling providers and consumers of cloud services as two DomainRole entities, OVF could be marked relevant for both. For example, defining Microsoft to be a provider of cloud services, would, in turn, mark OVF to be relevant for Microsoft.

The arguments for the classification of stakeholder involvement in standardizing OVF are derived from the varying memberships in alliances or SDOs of the named organizations. They were intentionally made bold to illustrate the use of ASSET's Stakeholder and Roles entities. A more thorough analysis of respective involvements in working groups would be required to justify our classification.

Experiment: Conflicting Classifications

We applied the conceptualizations above to update the technology typology that is maintained by CSAP. Illustrating the interplay of the “Classification Wizard”, attribute types, and aggregation services, we define the following sample scenario.

- User “A” creates a new standards profile for OVF, reproducing the information that described OVF in the cloud standards study (see [20]). For the context of our experiment, we assume the value “public” to define the “Deployment” attribute. OVF’s maturity is set to high. No additional resources have been assigned to the standard.
- Subsequently, “A” adds the value “http://a.com” as an additional resource and adds the value “private” to the “Deployment” attribute. Moreover, “A” changes the maturity to “high”.
- A user “B”, classifies OVF pointing to the additional resource “http://a.com”, having a maturity of “high”, and defines OVF to apply to “public” and “private” deployments.
- Then, user “C”, classifies OVF pointing to the additional resource “http://b.com”, having a maturity of “low”, and defines OVF to apply to “private” deployments only.

Figure 8.5 summarizes the resulting classification of OVF. As can be seen, an additional resource `''http://a.com''` has been added while the standards profile does not comprise `''http://b.com''`. Since the “Additional Resource” AttributeType instance was defined to apply a threshold-based aggregation service (threshold value is 2, see Table C.2), a single denomination of `''http://b.com''` is not sufficient for incorporating the respective value into the standards profile. Likewise, for a standards profile to comprise the deployment model “private” at least five denominations are required (threshold value is set to 5, see Table C.2). In the simple example, maturity is the only attribute type that has a cardinality of one. Thus, only one value may describe the maturity of a standard at once. Since majority vote is applied to automate aggregation of values (see Table C.2), the maturity of OVF is “high”. If, however, aggregation was defined to use the latest value, the standards profile would characterize the maturity to be “low”.

As illustrated, CSAP supports the collaborative assessment of standards by automating aggregation of assessment information. The simple example, however, only provides a first indicator of ASSET’s feasibility to enable collaboration of stakeholders and coordinating varying contributions. More comprehensive field studies will be required to further validate this claim.

8.5. Results and Discussion

In this chapter, we performed a selection of case studies that applied ASSET and CSAP to assessing cloud standards. In the first case study, we applied ASSET’s “Create Technol-

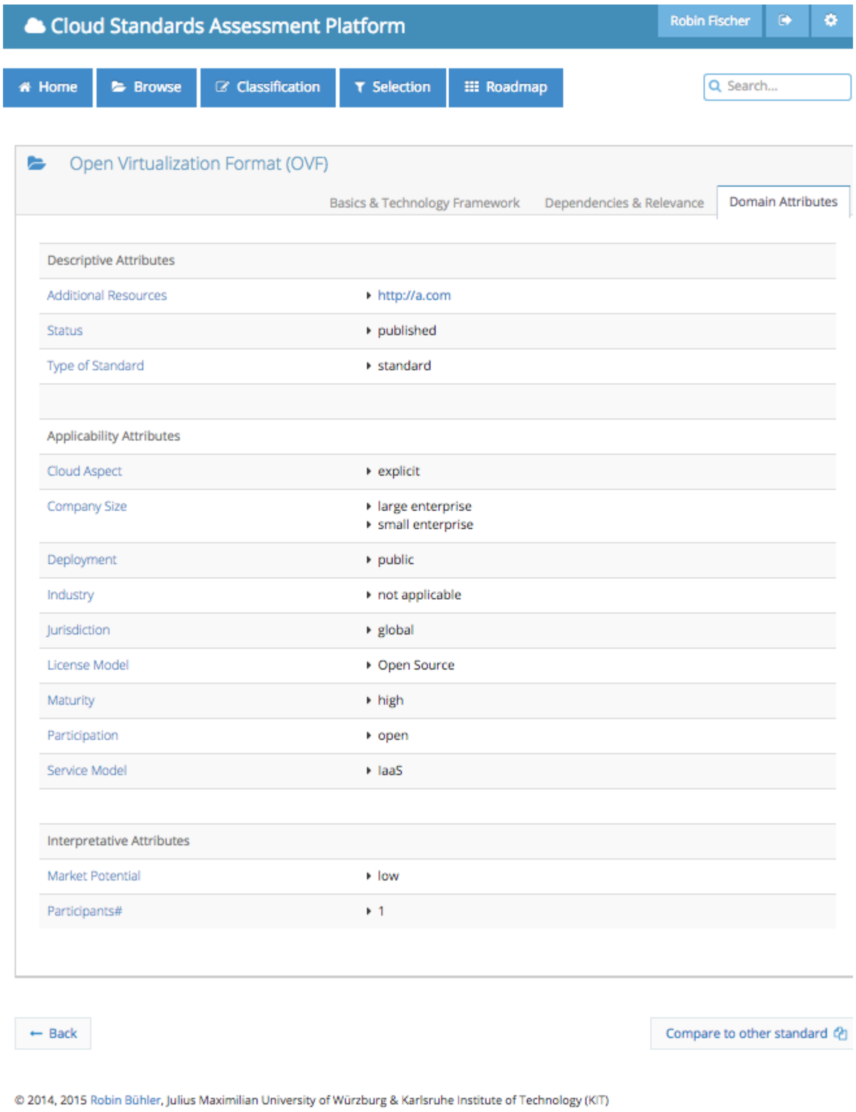


Figure 8.5.: CSAP: Classification Results (Experiment)

ogy Typology" sub-process to identify instances of ASSET's information model that are required to re-build the results from the cloud standards study. Using the study's results as the benchmark, we concluded relevance and correctness of ASSET's conceptual information model. We successfully tested extensions to the cloud technology typology in a second case study. In the third case study, we validated the conceptual information model against dependencies of (cloud) standards that are observable in the real world. Again, we demonstrated CSAP's capabilities to manage respective dependencies using task automation. Finally, we turned to assessing standard for cloud virtualization technologies. Using a small experiment, we validated ASSET's and CSAP's support for collaborating standards assessment.

Table 8.9 outlines the conclusions that we draw from validating ASSET fulfillment of information requirements:

- We identified five instances of the StandardsField entity and 21 instances of the TechnologyField entity. The latter are categorized into eight sub-fields. Moreover, we used four instances of the StandardsRole entity and two DomainRole instances to instantiate ASSET's stakeholder model. Thus, we conclude ASSET's support for classifying the scope, subject, and different types (IR-1).

- We discussed examples of dependencies of cloud standards to validate ASSET's support in classifying dependencies of standards. As demonstrated, ASSET allows for representing existing dependencies of cloud standards. Thus, we validated ASSET capabilities to support the classification of dependencies of standards (IR-2).

- Transferring the set of attributes from the study's cloud standards profiles, we instantiated ten AttributeType entities. Thus, we did not directly transfer five attributes. The information that these attributes kept, however, is maintained by the Standardization, Standard, and DomainRole entities. Our detailed characterization of each AttributeType instances demonstrated the capabilities of ASSET to incorporate varied aspects into the assessment of cloud standards. The combination of the cardinality, attribute domain, scale order, and aggregation services allows to restrict the amount of attributes of the same type that will be assigned to a standard. Thus, we conclude ASSET's flexibility to include a variety of domain-specific assessment attributes (IR-3).

Also, the use of aService and iService attributes supports the inclusion of additional assessment logic. We demonstrated how interpretative attribute types can be used to derive

ID	*Requirement*	*Conclusion*
IR-1	Support classification of scope, subject, and type	The model entities allow for building a classification scheme, reflecting all aspects of the cloud standards study.
IR-2	Support classification of standards dependencies	RelationshipType entity, sub-types, and relations are sufficient to capture dependencies of cloud standards.
IR-3	Support domain-specific classification attributes	ASSET's entities to represent assessment attributes are sufficient to represent all attributes of the cloud standards study. Extensions are possible.
AR-1	Consolidate values from multiple classifications	aService-property of AttributeType entity allows configuration of consolidation approach. Logic must be provided by services.

Table 8.9.: Validation of Method Requirements

assessment attributes on the basis of other attributes and information that ASSET's information model maintains. Particularly, we validated CSAP's support to consolidate different valuations of assessment attributes in a small experiment (AR-1).

In summary, we successfully performed qualitative validations of our approach to assessing standards in cloud computing. Quantitative evaluations are, however, required to underpin the first results that have been achieved in this thesis. Using field studies or more comprehensive experiments, evaluations should comprise measurements to track efforts for classifying, selecting, and road-mapping of standards for individual users. In doing so, we may quantify ASSET's contributions in increasing efficiency. Moreover, users should be requested to rate the quality of results that are provided by CSAP. Questions like "The standards shown were relevant to my problem", "Standards profiles contain to much information", or "I could easily comprehend the ranking of standards" could be used for this purpose. The respective feedbacks, thus, could be used to evaluate the quality of ASSET's assessment process. Finally, a comprehensive evaluation should, furthermore, assess the quality of information that is contained in standards profiles.

9. Application To Smart Grid

Revisiting the research agenda (see Section 1.2), the goal of this thesis is to provide a method that can be applied to assess standards of emerging technology in disruptive innovation. The previous chapters elaborated on the suitability of Assessing Standards of Emerging Technology (ASSET) for cloud computing, by discussing and evaluating its instantiation and a proof-of-concept implementation.

In this first chapter of the final part, we analyze the generalizability of ASSET by discussing its application to another field of disruptive innovation. Complementing the comprehensive application of ASSET to cloud computing, we will provide an outline of ASSET's instantiation to Smart Grid. The goal of this chapter is to demonstrate ASSET's capabilities to represents the state of standards assessment as documented in existing standards roadmaps for Smart Grid. We will focus on discussing core aspects of creating a technology typology and classifying standards. A detailed analysis of standards for Smart Grids reaches beyond the scope of this thesis.

In this chapter, we will provide an introduction to the concept of Smart Grid and present a summary of the state of standards assessment in Smart Grid in Section 9.1. In Section 9.2, we will outline the instantiation of the technology framework, stakeholders and roles, and assessment attributes. Moreover, we will discuss additional aspects of classifying Smart Grids standards in Section 9.3. Guided by ASSET's procedural model, the presentation of our approach to instantiate ASSET to Smart Grid is, thus, comparable to the application of ASSET to cloud computing (see Chapter 8). Section 9.4 summarizes the learnings for ASSET's generalizability to other domains of disruptive innovation.

9.1. Preface

In this section, we will present a brief introduction to Smart Grid concepts. Furthermore, we will briefly outline the state of standards assessment for Smart Grid, introducing relevant works and initiatives of Standards Development Organization (SDO). Thereby, furthermore, we will elaborate on the concept of Standards Information Form (SIF) that we identify as the state-of-the-art for classifying Smart Grid standards. Thus, they provide the starting point for instantiating ASSET's domain-specific technology framework, stakeholders and roles, and assessment attributes.

Overview

Smart Grid subsumes the modernization of electric power grids, for example, to increase reliability, resiliency, sustainability, and energy efficiency [8, 189]. By the use of two-way communication, new control capabilities are foreseen that support bidirectional flows of energy. Increasingly distributed generation of power, widespread of metering devices, use of digital information, and the uptake of electro mobility are only few examples for technology progression in the field of Smart Grids.

As with cloud computing, studies predict a massive market potential for the emerging technology [63]. However, there is uncertainty in the technological concepts, business models, participating stakeholders, and regulations and laws. Similar to cloud computing, there is a call for standards to counter uncertainty by, for example, catalyzing innovation, shaping markets, and harmonizing technology progression (see, e.g., [189]). Open questions, for example, regarding architecture, cybersecurity, interoperability, as well as testing and certification, however, pose challenges to mainstream implementations of Smart Grid technologies [8]. We, thus, consider Smart Grid a disruptive innovation, providing a second domain to validate ASSET's concepts for standards assessment.

In contrast to cloud computing, safety is an inherent aspect to Smart Grids as malfunctions, for example, might cause severe damages. While applications of cloud computing might become safety relevant, the general use of computing or storage is not directly related to safety. Thus, assessment of Smart Grid standards is even of greater importance, demonstrated by comparatively greater efforts for assessing standards in Smart Grid that we will outline in the following.

State of Standards Assessment

The state of standards in the field Smart Grid (also called e-Energy) is under constant review. Mandated by "The Energy Independence and Security Act of 2007 (EISA)", National Institute of Standards and Technology (NIST) started to assess the state of standards for Smart Grid in 2008 and reported first results in [6]. Since, the progression of technology for Smart Grid lead to two additional studies for standards assessment (see [7, 8]). In addition to the United States (US) view on standards for Smart Grids, Deutsche Kommission Elektrotechnik Elektronik Informationstechnik (DKE) coordinated significant efforts to assess standards from a German perspective. Corresponding results were initially documented in [188] as well as in the subsequent revised and updated Version 2 [189].[59]

While the different works provide a variety of classifications for the assessment of standards, we will demonstrate ASSET's capabilities to reproduce and maintain the information that Smart Grid Interoperability Panel (SGIP)[60] uses to classify standards in their the Catalogue of Standards (CoS). In total, the CoS list a total of 59 standards in the "Framework and Roadmap for Smart Grid Interoperability Standards, Release 3.0" [8]. The summary CoS presented in [8] only provides information on the standard's name, its fields of application, brief and unstructured comments, and its relevancy for domains of

[59] A extensive summary of other national efforts is given in [189].

[60] Initiated by NIST, the SGIP is a public-private-partnership to accelerate the implementation of interoperable Smart Grid devices and systems. As of June 2014, SGIP had 194 members, representing over 20 industry segments and a variety of domains in the power industry. See `http://www.sgip.org/SGIP-Vision` for details.

SGIP's architectural domains. The online version, being realized using Wiki technology allows for downloading a Standards Information Form (SIF). There is no automation to find or compare standards, using two or more SIFs. SIF are represented using spreadsheets. Each SIF provides a detailed classification of Smart Grid standards, using a total of twelve categories and different 131 attributes. Outlining all 131 attributes is beyond the scope of this chapter. However, we listed the questions that correspond to the each attribute in Appendix D.

In combinations with SIFs, SGIP structures standardization challenges in Smart Grids using Priority Action Plans (PAPs). A PAP, thereby, addresses situations where a new standard or an extension to an existing standard is needed. Moreover, PAPs may indicate an overlap between standards. As of August 2014, there have been 25 PAPs (see [8, p. 225-239]).

9.2. Smart Grid Technology Typology

In the following, we present our results of instantiating ASSET's technology typology for Smart Grid. Therefore, we derive entities to model the technology framework, stakeholder and roles, and assessment attributes from analyzing SIFs. In the following, we will refer to attributes using identifiers as presented in Appendix D.

Technology Framework

As presented in Section 5.2, ASSET comprises the Technology, TechnologyField, StandardField, Implementation, and the LegalAndRegulatoryFramework entities to classify the technology framework of a disruptive innovation. Analyzing the SIF template, we identify the following instances of ASSET's entities to represent the technology framework of Smart Grid.

Technologies: Guided by ASSET's sub-process to define the technology framework (see Figure 6.5) we started with screening SIF for attributes that refer to technologies. Technological aspects of standards in Smart Grid are mainly covered in the "Section II: Functional Description of the Standard" of a SIF, comprising the categories "K GridWise Architecture: Layers" and "L GridWise Architecture: Cross-Cutting Issues". As discussed in Section 6.3.2, differentiating technologies from technology fields can not always be done unambiguously. Technology progression and consequently the reduction of uncertainty leads to a growing understanding of initially vague technological concepts. Thus, technologies and concrete implementations will only be known in the later phases of disruptive innovation (see Section 2.2.1). In this regard, Smart Grid, as documented in [8], does not provide an exception as particular implementations of a technology or standard are hardly given.

For the purpose of demonstrating ASSET's generalizability, we propose to transfer SIF attributes to *Technology instances* as documented in Table 9.1. We identified three technological aspects that resemble Technology instances as conceptualized by ASSET (i.e., are precise enough to be implemented). These technologies, however, to not exactly match to SIF attributes, but are derived from the sub-categories that SIF applies to structure the attributes in category "L GridWise Architecture: Cross-Cutting Issues". In summary, we model resource identification, time synchronization, and time sequencing as Technology instances for creating the technology typology for Smart Grid.[61] In addition, SIFs identify an attribute to describe systems and equipment to which a standard applies in category "C Conceptual Area of Use" (C3). Thus, the set of values for C3 provide examples for technologies that could describe the subject of a standard. As SIFs, however, does not provide restrictions or guidelines on what kind of systems or equipments to name, we were not able to deduct particular technologies from C3.

SIF Attribute	*Technology Instance*
L5, L6 (sub-category)	Resource Identification
L7, L8 (sub-category)	Time Synchronization Time Sequencing
C3	- (List of values undefined)

Table 9.1.: Smart Grid: Technology Instances

Technology Fields: The set of TechnologyField instances that we derived from SIFs attributes is summarized in Table 9.2. In summary, we propose the technology typology for Smart Grid to comprise 13 *TechnologyField instances*.

The first set of TechnologyField instances is inspired by the SIF attributes that are used to assess a standard's subject with regards to the layers of the GridWise Architecture (category "K GridWise Architecture: Layers"). From the set of eight attributes that SIFs use to classify the subject of a standard K5 to K8 represent technology fields in ASSET. As discussed in Section 5.1, ASSET, however, is only designed to assess technology standards. While SIF attributes K1 to K4 provide potential scopes of Smart Grid standards, they are not considered in ASSET's technology typology for Smart Grid.[62] These aspects may, however, be considered as applicability attributes (see discussion of AttributeType instances below).

As already discussed for the identification of Technology instances, the attributes that SIFs apply to classify a standard's subject according to cross-cutting issues (see category "L GridWise Architecture: Cross-Cutting Issues" in Appendix D.3 do not directly refer to TechnologyField instances. Rather, the respective sub-categories allow for identifying technology fields. Thus, our technology typology for Smart Grid comprises nine TechnologyField instances that refer to sub-categories of SIF's sub-categories to structure cross-cutting issue.

[61] All aspects could also be modeled as TechnologyField instances. They could be transformed to Technology instances, as soon as implementations become known.

[62] An extension to ASSET that introduces a business typology (see Figure 5.2), however, might use SIF attributes K1 to K4.

There are obviously dependences between TechnologyField instances that refer to different layers of the GridWise Architecture and TechnologyFields that we derived from the sub-categories of the cross-cutting issues mentioned in the GridWise Architecture. Abstractly, all layer-based technology fields could be seen as parent fields for cross-cutting issues. We, however, refrain from structuring technology fields as a clear and complete assignment is not possible at this point.

SIF Attribute	*TechnologyField Instance*
K5	Layer 4: Semantic Understanding information model
K6	Layer 3: Syntactic Interoperability (OSI layers 5-7)
K7	Layer 2: Network Interoperability (OSI layers 3-4)
K8	Layer 1: Basic Connectivity (OSI layers 1-2)
L9 - L14 (sub-category)	Security and Privacy
L15 - L17 (sub-category)	Logging and Auditing
L18 (sub-category)	Transaction State Management
L19 - L23 (sub-category)	System Preservation
L24 (sub-category)	Other Management Capabilities
L25 - L29 (sub-category)	Quality of Service
L30 - L33 (sub-category)	Discovery and Configuration
L34 - L43 (sub-category)	System Evolution and Scalability
L44 - L47 (sub-category)	Electromechanical

Table 9.2.: Smart Grid: TechnologyField Instances

Standards Fields: Assessing the scope of a standard is hardly formalized through assessment attributes of SIFs. In contrast, this kind of information is expected to be given textually when summarizing the scope of a standard (A8). SIFs, thus, do not provide deep insights on *StandardsFields instances* that are particular for Smart Grid. Thus, they may be transferred to a StandardsField instance of ASSET. In addition, we may, however, assume that programming models, protocols and interfaces, standard components and reference architectures, and benchmarks and tests provide a first set of standards fields for Smart Grid (see Table 8.1).

In addition, the sub-category of SIF attributes that aim to describe the "shared meaning of content" may be understood as an assessment of data and exchange format. Likewise, SIF attributes that describe a standard's capabilities to support the exchange of meta data (M1) and the integration with non-functional requirements (M2) could be represented as sub-ordinate standards fields in ASSET. Table 9.3 summarizes respective instances of the StandardsField entity.

Stakeholders and Roles

ASSET's stakeholder model defines a standards developer, standards implementer, standards user, and a policy maker role, typing the participation in standardization and enabling the filtering of relevant assessment information (see Section 6.2). Moreover, ASSET's

SIF Attribute	*StandardsField Instance*
L1-L4 (sub-category)	Shared Meaning of Content
M1	Meta Data
M2	Interface

Table 9.3.: Smart Grid: StandardsFields Instances

stakeholder model foresees an unlimited amount of domain-specific roles to filter assessment information. Thus, instantiating ASSET to the Smart Grid requires identification of domain-specific roles. SIFs do not comprise information on different types of stakeholders in Smart Grid. The organization of the SGIP, however, is build to represent different interests of stakeholders using the interest groups manufacturers, asset owners, service providers & system administrators, consumers, policy & government, and SDOs & consortia.[63] In summary, ASSET identifies the following five instances of the DomainRole entity for instantiating ASSET: manufacturers, asset owners, service providers, system administrator, consumers. ASSET already considers policy & government and SDOs & consortia, using the StandardsRole and the StakeholderType entity. Thus, there is no need to create additional domain-specific roles. Moreover, ASSET, for example, allows policy makers to be consumers or service providers based on the concept of mixing different standards-specific and domain-specific roles in standards assessment.

SIFs consider stakeholders of a standard in only three attributes. A6 names the SDO that is responsible for the development of standard.[64] Likewise, B1 names the SDOs that recognize a standard. Finally, G8 and G9 lists the (approximate) amount of implementers or users of a standard. ASSET represents these types of information using the Standardization entity in combination with the StandardsRole entity. In doing so, sets of standards developers, standards implementers, and standards users can be assigned to a standard. As demonstrated in the application to cloud computing, respective amounts can be automatically be derived using interpretative attributes and interpretation services. While ASSET, thus, is capable of maintaining the same amount of information as SIF, values provided by ASSET do not provide approximations. In addition, denominating all implementers or users might be burdensome or not feasible if there is no active standards assessment community. Thus, the use of approximative values might be preferred. If so, respective descriptive attributes could be created supporting automated aggregation of different approximations.

Assessment Attributes

The last step of instantiating ASSET for Smart Grid is to define the set of attribute types that a standards profile comprises. Defining attribute types, furthermore, requires denom-

[63] For details, see `http://www.sgip.org/stakeholder-categories`.

[64] Specifically, SIFs demand for the Standards Software Organization (SSO), being less restrictive on the level of accreditation than SDO. In this thesis we differentiate different standards development organization by their type. Thus, we do not use the term SSO.

ination of technology and standards fields that a particular attribute types is relevant to. Moreover, the set of roles that is capable of assessing a particular attribute types must be defined.

Since SIFs do not provide capabilities to filter information subsets, we cannot derive information to model role-specific relevance of attribute types. Thus, we assume each attribute type to be relevant for all standards-specific and domain-specific roles in the following. Finally, we assume that all attribute values can be aggregated using majority vote or threshold-based aggregation approach.[65]

In the following, we will briefly summarize the results of transforming SIF attributes into ASSET's attribute types. We distinguish between descriptive and applicability attributes according to ASSET's conceptualization presented in Section 5.6. Thus, descriptive attributes refer to properties of a standard that are standards-specific while applicability attributes capture domain-specific aspects.

Descriptive Attribute Types: We identified a total of 40 instances of DescriptiveAT entity to represent SIF attributes with ASSET (see Table 9.4). The majority of SIF attributes defines a set of allowed values. However, these sets mostly define ternary decisions whether a standard bears a characteristic "yes", does not do so "no", or cannot be valued "not applicable | not patented | unknown". Only the attribute B5 and G18 define more comprehensive sets of allowed values. In doing so, they allow for specifying the type of a standards document (B5) as well as countries or regions that make use of the standard (G10). In addition, we model the status of the standard (B6) to correspond to an ordinal scale attribute, comprising allowed values "proposed", "in development", and "published" in ascending order. SIFs, furthermore, provide links to Uniform Resource Locators (URLs) or plain text attributes to describe the original source of a standard (A7), the process of joining a standards committee (G15), or summarize patent and licensing of a standard (G24-G28, J1). Finally, SIFs comprise information of fees to access the standards document (G1), implementing the standard (G2), or participate in standards development (G3). Using ASSET, these attributes resemble cardinal scale descriptive attributes.

Generally, SIFs may only comprise one value per attribute. However, there may be more than on region or country or links to characterize a standard. Thus, we assign an infinite cardinality to G10, G24-G28, and J1 when representing SIF attributes with ASSET.

Applicability Attribute Types: In summary, ASSET's technology typology to assess standards in Smart Grid comprises 60instances of the DescriptiveAT entity. Thereof, 22 attributes apply an ordinal scale. The remainder uses the nominal scale. For the following see Table 9.5.

Possible values of the majority of applicability attributes are constrained by a set of allowed values that is explicitly defined or can be derived from PAPs (A9), known

[65] Threshold-based aggregation is required for all attributes, having a cardinality of greater than one or infinite (see Section 5.6).

SIF Attributes	*ASSET Attribute Type* (*Subtype*, *Domain*, *Cardinality*, *Allowed Values*)
B5	DA, N, 1, {standard, report, guide, technical specification}
B6	DA, O, 1, {released, in development, proposed}
L1, L2, L3, L4, L5, L6	DA, N, 1, {not applicable, no, yes}
G12	DA, N, 1, {not patented, no, yes}
G4, G7, G11, G13, G14, G16, G19, G20, G21, G22, G23, H1, H2, H4, H5, H6	DA, N, 1, {unknown, no, yes}
G10	DA, N, -1, {{Regions} | {Countries}}
A7	DA, N, 1, TEXT | LINK
G15	DA, N, 1, TEXT
G24, G25, G26, G27, G28, J1	DA, N, -1, LINK
G1, G2, G3	DA, C, 1

Subtype: *DA*-DescriptiveAT, *AA*-ApplicabilityAT, *IA*-InterpretativeAT
Domain: *C*-cardinal, *O*-ordinal, *N*-nominal
Cardinality: -1 (infinite), 1, 2, 3...
Allowed Values: {}-set, *TEXT*-any text value, *LINK*-URL

Table 9.4.: Smart Grid: DescriptiveAT Instances

harmonization developments (M4), or existing software architectural frameworks (M5). If a standard may apply to multiple allowed values of an attribute at once, we define the attribute type's cardinality to be infinite. For example, a standard may currently apply to more than one areas (C1). Likewise, a standard may be planned to apply to more than one area of use in the future (C2).

Standards, however, may or may not provide a particular functionality (e.g., enable informed participation by customers (E1), support remote determination of device health (L21), or facilitate logging (L13). Thus, we assign a cardinality of one to corresponding ASSET attribute types. SIFs, however, allow for classifying a standard to "partially" provide a functionality (e.g., E1), to be "not applicable" for a given functionality (e.g., L21), or to provide the required functionality in an "unknown" manner (e.g., L13). The rational behind applying three different sets of allowed values to assess a standard's applicability with SIFs is questionable. For the purpose of demonstrating ASSET's generalizability, we, however, decided to not consolidate respective sets.

SIFs, additionally, classify Smart Grid standards based on their support for cyber security (L9), means for preserving privacy (L14), and supported types of reliability (L27). In contrast to classifying a standard's respective capabilities using vague yes, no, or partially/not-applicable/unknown values, the allowed values for classifying security and privacy aspects allow for referring to other standards (L9, L14) or another layer of software stack (L27). SIFs, however, provide no means to point to corresponding standards or respective layers.

Finally, there are twelve descriptive attributes (i.e., L10-L12, L24, L29, L34, L35, L38, L40-l43) whose values are not constrained. Thus, they allow stakeholders to provide a textual description of how the standard addresses or why it does not address cross-cutting issues as defined by the GridWise Architecture.

Interpretative Attribute Types: We could not find any evidence of automation support in SIFs. Still, we identified three instances of ASSET's InterpretativeAT entity, creating the Smart Grid technology typology. Table 9.6 summarizes their properties.

SIFs classify the level of a standard to be "international", "regional", "national", "ANSI", "de facto", or "single company". With ASSET, this kind of information can be derived from the jurisdiction of a stakeholder and its type respectively. If, for example, the developer of the standard is an accredited SDO on the international

SIF Attributes	*ASSET Attribute Type* (*Subtype*, *Domain*, *Cardinality*, *Allowed Values*)
C1, C2	AA, N, -1, {market, operations, service provider, generation, transmission, distribution, customer}
L7, L8, L19, L20	AA, O, 1, {not applicable, no, provided in another layer, yes}
E1, E2, E3, E4, E5, E6, F1, F2, F3, F4, F5, F6, F7, F8, L15, L16, L17, L18	AA, O, 1, {no, partially, yes}
L21, L22, L23, L30, L31, L32, L33, L36, L37, L39, L44, L45, L46, L47	AA, N, 1, {not applicable, no, yes}
L13, L25, L26, L28	AA, N, 1, {unknown, no, yes}
L9, L14	AA, N, 1, {within this standard, by other standards, not applicable}
L27	AA, N, 1, {reliable, non-guaranteed, both, provided in another layer}
A9	AA, N, -1, {{PAP}}
M4	AA, N, -1, {{Harmonization Developments}}
M5	AA, N, -1, {{Architectural Frameworks}}
L10, L11, L12, L24, L29, L34, L35, L38, L40, L41, L42, L43	AA, N, -1, TEXT

Subtype: *DA*-DescriptiveAT, *AA*-ApplicabilityAT, *IA*-InterpretativeAT
Domain: *C*-cardinal, *O*-ordinal, *N*-nominal
Cardinality: -1 (infinite), 1, 2, 3...
Allowed Values: {}-set, *TEXT*-any text value, *LINK*-URL

Table 9.5.: Smart Grid: ApplicabilityAT Instances

level, the standards level ensues to be international. An interpretation service may, thus, be used to value the level of a standard based on its standards developer. Similarly, a standard's process of standardization (G17) can automatically be derived from the types of its standards developer.

In addition, SIFs comprise information on the regions or countries that are represented in the organization that develops the standard. Again, this information can be automatically derived by analyzing ASSET's Stakeholder instances that are ascribed to the standard. An interpretation service may, therefore, query the set of jurisdictions that apply to a given standard.

SIF Attributes	*ASSET Attribute Type* (*Subtype*, *Domain*, *Cardinality*, *Allowed Values*)
B4	IA, N, -1, {international, national, regional, ANSI, de facto, single company}
G17	IA, N, 1, {ANSI accredited, international SDO, industry consortium, user group, multi company agreement, open source}
G18	IA, N, -1, {{Regions} | {Countries}}

Subtype: *DA*-DescriptiveAT, *AA*-ApplicabilityAT
Domain: *C*-cardinal, *O*-ordinal, *N*-nominal
Cardinality: -1 (infinite), 1, 2, 3...
Allowed Values: {}-set, *TEXT*-any text value, *LINK*-URL

Table 9.6.: Smart Grid: InterpretativeAT Instances

Next to defining roles that an AttributeType instance is relevant for, ASSET allows to restrict the relevance of attribute types to particular technology fields or standards fields. For our brief application of ASSET to Smart Grid, we generally assume attribute types to be relevant for all technology and standards fields. Analyzing the set of attributes, we, however, identified possibilities to filter assessment attributes with ASSET. For example, SIF attributes of category "L - GridWise Architecture: Cross-Cutting Issues" may be valued to be "not applicable" (see L1-L6 in Table 9.4 and L7, L8, L19-L23, L30-L33, L36, L37, L39, L44-L47 in Table 9.5). We may, thus, constrain the relevance of these attribute types, using corresponding TechnologyField and StandardsFields instances that we have identified from sub-categories of SIF category "L". For example, SIF attributes L30-33 can be assigned to the TechnologyField "Quality of Service" (see Table 9.2).

9.3. Classification of Smart Grid Standards

ASSET's technology typology builds the basis for representing the majority of the information that is provided by SIF. However, some information will only be instantiated when stakeholders assess a particular standard. In this section, we will demonstrate ASSET's capabilities to represent SIF-attributes that have not been transferred to instances of ASSET's technology framework, roles, or attribute types. We structure our discussion according to sequence of activities of ASSET's "classify standard" sub-process (see Section 6.3.3).

Basic Information

SIF comprise information on the standard's identifier (A1) and name (A2), its version (A4), and a link to its specification (A5). Moreover, a brief description of scope (A8) is included in the category "Identification and Affiliation". The union of properties from ASSET's BaseObject and Standard entities allows for maintaining respective information. Thus, these SIF attributes can be directly represented with ASSET.

Assign Technology Framework

The purpose of the second classification step is to select relevant technologies, technology fields, and standards fields as defined by the Smart Grid technology typology. We outlined the set of available instances for representing scopes and subjects of Smart Grid standards in Section 9.2.

Using ASSET, classifications of standards additionally comprise information on a standard's implementations and its relation to laws and regulations. While SIFs do not denominate individual implementations they include attributes to summarize the amount of implementations of the standard (G5) and corresponding test tools (G6). Moreover, SIFs comprise attributes to classify a standard's use in laws and regulations (B2 and B3). ASSET supports classification of both types of information using the Standard entity's associations to the *Implementation* and *LegalAndRegulatoryFramework* entities. Instances of respective entities, however, do not belong to the technology typology. Thus, they will only be created, if a standard is classified (i.e., the "Classify standard" sub-process in Section 6.3.3).

Dependencies and Relevance

As demonstrated in the previous section, SIFs inspired the instantiation of ASSET for Smart Grid. In addition, however, SIF include information on dependencies and relevance of standards. We will now briefly summarize how ASSET incorporates this information in standards profiles.

ASSET maintains information such as the name of the owner organization (A3) or committee that handles the development of the standard (A6), using the instances of the Standardization entity. Corresponding Stakeholder instances for standards developers (i.e., A3 and A6) are thus created in the second step of ASSET's "classify standard" sub-process.

SIFs comprise three attributes to classify a standard's dependencies to other standards. Thus, standards that the given standard provides references to (D1), generally related standards (D2), or standards that cover similar aspects (D3) can be denominated in SIFs.

Using ASSET, this kind of information maintained using the RelationshipType entity (see Section 5.4). Required subtypes of the RelationshipType entity will be instantiated when dependencies of a standard are classified in the third step of ASSET's "Classify Standard" sub-process.

Value Attributes

Stakeholders that classify standards have to provide actual values for the set of attribute types that apply for the given standard. However, only classification information that is represented by attribute types of the Smart Grid technology typology can be ascribed in this step. Thus, attribute types are only instantiated when creating the technology typology.

9.4. Results and Discussion

In this chapter, we presented a first iteration of ASSET's instantiation to Smart Grid. Therefore, we discussed how classification attributes that are used in SIFs can be represented with ASSET. As demonstrated in this chapter, most aspects of SIF attributes can be directly transferred into instances of ASSET's model entities that are required to build a Smart Grid technology typology. In addition, we presented how the remaining SIF attributes are represented by additional entities of ASSET's information model.

We did not transfer SIF attributes to classify standardization activities that build on a standard (D4). Since ASSET's aim is to classify standards, there is no means of directly classifying standardization activities that have not yet yielded into a draft specification of a standard. Likewise, ASSET is not directly capable of assessing integration pathways of standards (M3). Both aspects could be codified as descriptive attributes, providing, for example, links to Web pages or documents that document such activities or use plain text attributes to describe such activities. In our brief validation of ASSET in Smart Grid, we, however, could not identify the additional value of incorporating theses SIF attributes. We argue that such information is already contained in classifying a standard according to the set of relevant PAPs.

Analyzing the set of SIF that constitute the SGIP's CoS, we, furthermore, discovered inconsistencies (e.g., spelling errors and missing attribute rows in some SIF). Removal of inconsistencies and mistakes leads to significant efforts, requiring revision of all published SIFs. Thus, current implementation of SGIP CoS—using spreadsheets—provides an example of high manual efforts and complexity for managing standards assessment (i.e., SIF) in current practice. Implementing CoS by a standards assessment platform as presented in this thesis, thus, could help to automate consolidation activities and reduce assessment efforts.

Applying ASSET to Smart Grid, we were, however, not able to represent conditional dependencies attributes that are implicitly defined between SIF attributes. SIFs, for example, include information on the usage of patent technology in standards (G11). If patents are used, an additional attribute is used to provide information on respective royalties (G12). ASSET as presented in this thesis is not capable of representing such dependencies between attributes, i.e., G12 must only be valued if G11 is set to “yes”. Incorporating respective dependencies would enable further information filtering capabilities. Using a “not applicable” value in such cases, however, preserves ASSET’s applicability to Smart Grid.

In summary, however, we were able to represent 129 of 131 SIF attributes with ASSET. Thus, we conclude ASSET’s appropriateness for classifying standards in Smart Grid based on analyzing SIFs. Additional research will, however, be required to validate ASSET’s use in supporting a community to assess Smart Grid standards. These efforts are to include the evaluation of ASSET’s automation potentials in Smart Grid that we did not address in this thesis. Moreover, the identification of PAP provides an interesting area for validating ASSET’s status quo and roadmapping capabilities in the future.

Part IV.

Finale

10. Conclusions

Evolving environments of disruptive innovation demand capabilities to address uncertainty when assessing standards. Uncertainty comprises a technology, an organizational, a market and an environmental dimension. High levels of uncertainty in all dimensions characterize disruptive innovations. Addressing uncertainty, assessment of technology and innovation generally builds on the combination of two types of information. Organizationally independent information is used to characterize emerging technology in its varying contexts. Moreover, organizational-specific information allows for matching external information with internal capabilities, risks, and opportunities.

In this thesis, we developed a method for Assessing Standards of Emerging Technology (ASSET). Our method guides stakeholders of disruptive innovation in classifying standards, using organizational independent information. Moreover, it provides guidance on evaluating standards, i.e., matching standards profiles with internal standardization requirements. Incorporating the evolution of emerging technology in disruptive innovation, ASSET is built on separating invariant standards-specific information from volatile domain-specific information. Modularization of the conceptual information model, furthermore, contributes to keeping consequences of assessing standards in changing environments manageable.

In summary, ASSET enables providers of technologies to reduce efforts in assessing the use of standards in developing products or services. Likewise, technology consumers are supported in finding standards to ensure, for example, interoperability or portability. Moreover, Standards Development Organizations (SDOs) and policy makers may use ASSET to assess the status quo or roadmap future standardization initiatives. The assessment of standards, however, remains challenging and requires an understanding of the semantics of standards specifications and their implications for the development of products or services. Therefore, experiments with standardized products or services or performing proof-of-concept implementations will be required to complete an assessment of standards. The use of ASSET, thus, is to support the initial assessment of potentially relevant standards rather than replacing experiments that should always supplement decisions for adopting or implementing standards.

Concluding this dissertation thesis, will summarize our results in Section 10.1. Thereafter, we will provide a critical reflection of our contributions (see Section 10.2) and point to opportunities of future research (see Section 10.3).

10.1. Results

ASSET builds upon a *conceptual information model* and comprises *a stakeholder model* and *a procedural model* to enable standards assessment:

- *Conceptual information model:*

  The conceptual information model separates standards-specific from domain-specific aspects of standards assessment. While standards-specific aspects apply universally, domain-specific aspects differ in varying domains of disruptive innovation. Moreover, domain-specific data will also change over time as technological concepts of the disruptive innovation mature.

  The conceptual information model defines *standards-specific aspects* statically by naming model entities and conceptualizing their dependencies. Standards in any domain of disruptive innovation will, for example, be classified based on subject (i.e., technologies or technology fields) and scope (i.e., standards fields). Likewise, all domains of disruptive innovation will only consider two types of standards (i.e., base standards and standards profiles), four types of relationships between standards (i.e., competitors, complements, predecessors, or endorsements), or have implementations as well as a legal and regulatory framework.

  The conceptual information integrates the required flexibility of *domain-specific aspects*, using entities that allow for modeling domain-specific aspects when instantiating ASSET to a domain of disruptive innovation. Model entities as, for example, the DomainRole or AttributeType entity represent domain-specific roles (e.g., as defined in use cases) and domain-specific assessment attributes (e.g., "Service Model" for cloud computing or cross-cutting issues in Smart Grid).

  Testing the validity of the conceptual information model, we instantiated ASSET to cloud computing and Smart Grid. Thereby, we successfully created technology typologies for both domains of disruptive innovation. Moreover, we successfully codified the cloud technology typology and classified more than 20 cloud standards with the Cloud Standards Assessment Platform (CSAP), our Proof-of-Concept (PoC) implementation of ASSET. Thereby, we were able to reproduce all information of the study's cloud standards profiles. While implementing a tool for assessing Smart Grid standards was beyond the scope of validating ASSET in this thesis, we were able to successfully model 129 of the 131 assessment attributes that state-of-the-art approaches use to classifying standards in Smart Grid. Thus, we conclude the validity of our conceptual information model for representing assessment information of standards in disruptive innovation.

- *Stakeholder Model:*

  ASSET's stakeholder model complements the conceptual information model by defining standards-specific and domain-specific roles that stakeholders may enact. Thereby, ASSET supports filtering of assessment information, according to a stakeholder's set of relevant roles. ASSET's stakeholder model, therefore, defines five types of stakeholders and four standards-specific roles. While a standards developer is, for example, capable of providing information on standard's status, a standards implementer will likely be more suited to value the efforts of implementing a standard into products or services. The stakeholder model does not define the amount and types of domain-specific roles as these roles will only be known when instantiating ASSET for a given domain of disruptive information.

- *Procedural model for standards assessment:*

  Generally, ASSET's procedural model guides stakeholders of disruptive innovation in matching organizationally independent standards-information with organizational-specific information to prioritize standardization decisions.

  The goal of ASSET's procedural model is to structure assessment steps that are required to coordinate stakeholders and to support automation of standards assessment in disruptive innovation. Therefore, it defines an overall assessment process that applies sub-processes to guide the instantiation and maintenance of the domain-specific technology typology and classifications of standards. The procedural model allows stakeholders to define organization-specific information that reflects their needs, and, thus, enables the subjective evaluation of standards profiles.

  The procedural model applies an iterative approach for updating the technology typology and standard profiles. Coordinating the iterative behavior, ASSET's procedural model defines sequential constraints on standards assessment steps. Using the process events, we defined a state model that enables automated synchronization of updates to the technology typology and standards profiles.

10.2. Discussion

In this section, we will discuss how the combination of ASSET's artifacts allows for confirming the propositions of the hypotheses that guided this research work:

(a) *Hypothesis 1: "A conceptual information model for standards assessment enables information reuse [...]."*

By design, the conceptual information model aims to use as few entities as possible to represent required standards assessment information. In consequence, information that can be inferred will not be stored separately. As discussed in Section 4.3.1 and Section 8.3, information on a standard's jurisdiction or artificial standards types can be inferred from model entities by reusing information. Thus, they do not require additional representation. Supporting the reuse of this kind of information, the conceptual model introduces the InterpretativeAT entity. We validated respective information reuse capabilities by defining InterpretativeAT instances when performing the case studies. Moreover, the PoC implementation of respective automation potentials provided additional justification for successful information reuse (see Section 7.3.3).

Information reuse capabilities additionally result from the combination of the conceptual information model and ASSET's procedural model. For example, we originally designed the process requirements to support updates of classifications (PR-2) to incorporate changes of evolving environments. Designing Delphi-like approaches, we, furthermore, enable reuse of information from existing classifications. Thereby, stakeholders that perform a reclassification of a standard benefit from information that has already been assigned to the standards profile. They are, thus, only required to provide values for new attributes or change existing attribute values.

Similarly, information reuse may occur when instantiating ASSET to different domains of disruptive innovation. While reuse of standards-specific information is inherent to ASSET, instances of the DescriptiveAT and StandardsRole entities provide additional potential for supporting information reuse. Instantiating ASSET for Smart Grid, we identified that descriptive attributes for Smart Grid and cloud computing were similar. Thus, we could have reused descriptive attributes that were defined for cloud computing. Reusing this kind of structural assessment information, however, is not currently supported by CSAP. Therefore, extensions would be required to manage a repository of domain-specific information that could be reused when instantiating ASSET to different domains of disruptive innovation.

(b) *Hypothesis 1: "A conceptual information model for standards assessment enables [...] collaboration among stakeholders."*

Collaboration support that is provided by the conceptual information model is constrained to filtering and aggregating information. Information filtering capabilities results from combining information of the model's AttributeType, Role, Stakeholder, StandardsField, and TechnologyField entities (see Section 6.4.2).

Addressing the needs for consolidating varying classifications (AR-1) the conceptual information model allows for defining aggregation logic using a service-oriented concept of the AttributeType entity. However, we identified open issues with regards to ASSET's representation of a standard's technology framework, dependencies, and relevancies, if individual classifications are to be persisted. Designing the model, we aimed at reproducing the concept of a standards profiles as it has been applied in the cloud standards study. In consequence, the model, for example, represents the scope and subject of a standard by defining relations between the Standard entity and the StandardsFields and Technology or TechnologyField entities. Thus, there is no possibility of representing different classifications of scopes and subjects of stakeholders. The same reasoning applies to the classification of other aspects of the technology framework, dependencies, and relevancies. When implementing CSAP, we, thus, added a user concept that restricts rights to change a standard's technology framework, dependencies, and relevancies to administrative users. Moreover, we introduced the additional Questionnaire entity that allows for persisting individual standard classifications. Additional work might be required to decide, if this extension is to be included into the conceptual information model or if such additional functionality are to be left as extensions of tools that implement ASSET.

Finally, the conceptual information model does not support for versioning of technology typologies. Modifications to a technology typology will always be reflected in standards profiles to keep standards profiles and the technology typology in sync. Again, we restricted modifications of the technology typology to administrative users. However, a highly collaborative approach would require additional model entities that allow for versioning changes to the technology typology.

(c) *Hypothesis 2: "A structured assessment process allows for coordinating iterative execution of assessment steps [...]."*

In summary, ASSET's procedural model demonstrated good guidance on instantiating ASSET for a domain of disruptive innovation. The "Create Technology Typology" sub-process, thereby, defines an idealistic sequence of activities that ensures the availability of model constructs. Likewise, ASSET's "Classify Standard" sub-process guides the implementation of CSAP's "Classification Wizard" that allows stakeholders to classify standards. The iterative nature implements a Delphi-like approach. Thus, ASSET supports consensus building for standards profiles. ASSET's "Evaluate Standards Profiles" sub-processes ensure that stakeholders have defined their purpose of the assessment before preferences for classification attributes are collected, and standards will be ranked.

Instantiating ASSET for cloud computing and implementing a software prototype to support the assessment of cloud standards, we successfully validated ASSET's support for coordinating iterative executions of assessment steps. Implementing the procedural model into CSAP, we, however, identified additional opportunities to improve the efficiency of managing a technology typology. Therefore, an additional activity could be added to ASSET's "Create Technology Typology" sub-process that evaluates the quality of a technology typology for the given domain of disruptive innovation. A quality assessment could, for example, include measures that count the amount of references from standards to a technology, technology field, or standards field. Instances that have a small count might be considered for removal from the technology typology. Likewise, instances that have a high count might be candidates for introducing additional sub-types. Providing access to all entities of the model, CSAP provides a starting point for implementing statistical analyses.

(d) *Hypothesis 2: "A structured assessment process [...] allows for improving efficiency by enabling task automation."*

ASSET's procedural model enables the identification of automation potentials in standards assessment in disruptive innovation. The procedural model's set of events can, for example, be used to automate the coordination of updates to the technology typology and to the standards profiles. Moreover, ASSET's procedural model defines sequential constraints that implementations of ASSET—such as CSAP—may use for automating tasks.

As presented in Chapter 7, we validated ASSET's automation potentials by implementation automation into CSAP. In addition, we implemented interpretation and aggregation services to demonstrate the validity of ASSET's approach to use service for automating valuation of assessment attributes and aggregation of classification data. Moreover, CSAP demonstrates realizability of automated information filtering, automated ranking of standards according to stakeholder preferences, and automated creation of maps to support portfolio analyses. Moreover, CSAP provides automation in identifying dependencies of standards. While our validation lacks the data from a vibrant cloud standards community, the successful implementation of automation potentials provides a first indication of ASSET's support for enabling automation.

We were, however, not able to measure efficiency gains in field experiments in this thesis. Thus, the degree of efficiency gains can only be estimated to be positive at this point. Future research should address the quantification of trade-offs between the overhead that ASSET demands for creating and maintaining the technology typology and the efficiency gains in performing repeated standards assessments.

10.3. Outlook

ASSET and more specifically CSAP provide the foundations for future research. Foremost, ASSET enables the verification of assessment techniques and tools from technology and innovation management for standards assessment in disruptive innovation. Thus, our work may inspire a variety of future works that aim at incorporating standards assessment into the common practice of technology and innovation management. In the following, we will discuss a set of starting points for future research endeavors.

- *Field experiments*

  The contributions of this thesis have been validated against the hypotheses that guided this research. Moreover, we validated ASSET's artifacts against their fulfillment of method requirements as identified in Section 4.3. A comprehensive evaluation of ASSET, however, requires to include measurements of, for example, the amount of hours or costs that ASSET saves in searching, selecting, or roadmapping standards in field experiments. Moreover, evaluation of usability and quality of results (e.g., how well do proposed standards fit requirements?) should be included.

  Evaluating ASSET in field experiments, however, requires an active community that assesses standards in disruptive innovation. While conducting the research in this thesis, we were not able to realize such a community. Future work, therefore, should focus on evaluating the approach based on the first validations that are provided in this thesis. As this thesis provides instantiations of ASSET for cloud computing and Smart Grid, identification of communities should start in these domains.

- *Integration with decision support techniques*

  Incorporating ASSET's with existing decision support techniques opens another path for future research. In cloud computing, decision support techniques are frequently applied to addresses the problem of selecting services or providers [121].

Particularly, Analytical Hierarchy Processing (AHP) is frequently applied to modeling service selection [137] or provider selection problems [149]. Likewise, cloud standards selection problems could potentially be modeled using Multi-Attribute Decision-Making (MADM) approaches. Future research may particularly focus on using the conceptual information model to structure selection criteria hierarchically in four levels as demanded by AHP. While the decision problem of selecting cloud standards provides the motivation (i.e., level 1), ASSET's top-level technology fields may provide the target dimensions of AHP (i.e., level 2). Likewise, second level technology fields may resemble abstract requirements (i.e., level three) of a potential AHP model for standards selection. Finally, attributes types that are assigned to technology fields may provide the set of evaluation criteria that is required by AHP.

Moreover, there may be hidden dependencies between attributes. That is, attributes may contradict or pose requirements on other attributes. Decision support techniques may, thus, be applied to perform cross consistency analysis and, thus, identify dependencies of attributes [150].

- *Use of statistics to support aggregation of standards profiles and management of technology typologies*

  Using statistics to analyze classification data constitutes another field of further research. Traditional Delphi studies apply statistical figures to inform about the spread of opinions and, thereby, foster consensus building. In ASSET descriptive statistics could be used to indicate the spread of values for classification attributes. Based on the concepts and the implementation of CSAP, we, furthermore, envision the implementation of statistical aggregation services. A potential confidence interval aggregation service could, for example, assign all values of an attribute to a standards profile that lead to 95 percent confidence. Such services might even be configurable on a per user or stakeholder basis (e.g., users or stakeholders may define individual confidence intervals). Statistical figures might, furthermore, help in supporting discussion of appropriate granularities of TechnologyField or StandardsField instances. An above than average amount of standards that are assigned to respective instances, may, for example, indicate potential to refine a technology or standards field.

- *Extensions to the conceptual information model*

  Future research could address extensions to the conceptual information model. As discussed above, a first aspect is researching the versioning of technology typologies and representation of individual standards classifications.

  Applying ASSET to reproduce *Standards Information Form (SIF)* that are used to classify standards in Smart Grid Interoperability Panel (SGIP)'s Catalogue of Standards (CoS), we identified a need to support conditional dependencies of attributes. Extensions to the model, thus, could research possibilities to model such dependencies of attributes.

Also, the proposed model could be extended to allow for defining more *comprehensive relationships between standards*. Using information on technologies, technology fields, or standards fields would enable more fine-grained classifications of standards relationships. Two standards could, for example, be defined to compete for a given technology field. At the same time, however, they could complement one another for a different technology field.

Introducing a structure of the Role entity, would, furthermore, enable *refinement of roles*. Refinements could be helpful for structuring the varying interest and influence of stakeholders on standardization. In doing so, roles could be used to integrate more complex use case scenarios. European Telecommunications Standards Institute (ETSI)'s cloud standards coordination report, for example, applies a hierarchical concept of roles (see [64]).

Finally, future research could assess the feasibility of introducing a second association between the Role and the AttributeTypes entities. The currently applied "assessedBy"-association enables filtering of attributes based on the assessment capabilities of the particular role. The information that a stakeholder is capable of providing, however, will not always be identical to the set of information that a stakeholder requires when evaluating standards. A *"relevantFor"-association* would provide additional filtering capabilities.

- *Extensions to CSAP*

  Improving or implementing more features of CSAP, provides a last direction for future research. Currently applied filtering capabilities, for example, do not fully use the conceptual information model. Exploiting the model, calculated lists of standards could be filtered according to a particular SDO. Doing so would enable *advanced filtering capabilities* and contribute to reducing the amount of information that CSAP's select, roadmap or browse views show. Moreover, the SDO could be used as an additional selection criterion in the selection wizard (see Figure 7.8). There will, however, be a trade-off between ease of use and information filtering capabilities that affects the usability of CSAP. Future research could, thus, address the minimal amount of information that should be requested in standards selection to guarantee high-quality results.

  While we designed ASSET to incorporate measures for networks effects of standards, CSAP only provides a simple interpretation service, counting the amount of stakeholders per standard. The integration of more sophisticated measures (e.g., analysis of stakeholder graphs) could provide means to assess the varying motivations of stakeholders if CSAP provided enough information to support respective analyses. Moreover, interpretation services could be used to assess trends or hypes in standardization automatically. The integration of a Google Trends service could, for example, be used to approximate the activity of a standard's community.

  Finally, features to support *collaboration support* could be realized with CSAP. Further research could focus on improving the platform's capabilities to support communication among participants. Most obviously, a notification mechanism would allow for triggering stakeholders to reclassify a standard. Similar to International Organization for Standardization (ISO)'s standards catalogue, a notification engine could furthermore, allow user to subscribe to update events such as modifications to a standard or the appearance of a new standard.[66]

This thesis presents a novel method for assessing standards in disruptive innovation. The instantiation of ASSET to cloud computing and Smart Grid performed in this thesis demonstrates the promises of reducing assessment efforts and enabling a collaborative assessment of standards in disruptive innovation. The discussion of future research directions, however, identifies challenges that future work have to address for advancing ASSET into an accepted approach.

[66] See "Subscribe to updates" function of ISO's standards catalogue `http://www.iso.org/iso/home/store/catalogue_ics/`.

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Part V.

Appendix

A. Supplements to the Cloud Standards Study

A.1. Relevance of Cloud Standards Taxonomy

Questionnaire

<zurück zur Inhaltsübersicht>

A. Erwartbarer Nutzen von Normierung und Standardisierung

(für Cloud Computing und Trusted Cloud)

Hinweis zur Befüllung:
Welchen Nutzen erwarten Sie von Normen und Standards bzgl. folgenden Herausforderungen?
Bitte bei Bedarf spezielle Herausforderungen ihres Projektes am Ende der Liste hinzufügen.

		Nutzen von Normen und Standards zur Adressierung der Herausforderung		
Bereich	**Herausforderung**	**Erläuterung/Beispiele**	**Relevanz für Cloud Computing ***	**Relevanz für das Projekt ***
Dienstbereitstellung	Entwicklungstools & -komponenten	Standardisierte Entwicklungswerkzeuge- und -methoden für Cloud Computing	**Eher nein**	**Eher nein**
	Skalierbare Architekturen	Standardisierte Komponenten, Architekturen und Guidelines zum Aufbau und Betrieb von skalierbaren Architekturen.	**ja**	**Ja**
	Ressourcenmanagement	Standardisierung von Tools und Schnittstellen zur Verwaltung der Ressourcen durch Anwender (zuschalten, abschalten, Kostenkontrolle,...)	**Keine Angabe möglich**	**Keine Angabe möglich**
	Verfügbarkeit der Services	Standardisierung von Tools und Schnittstellen zur Überprüfung und Sicherstellung der Verfügbarkeit von Cloud Services	**Ja**	**Ja**
Dienstenutzung und Steuerung	Vertragsgestaltung inkl. Haftung	Einheitliche Texte/Bausteine zur Gestaltung von Cloud Service Verträgen	**Eher nein**	**Eher ja**
	Selbstverwaltung der Services	Standardisierung von Tools und Schnittstellen zur Verwaltung der Ressourcen durch Anwender (zuschalten, abschalten, Kostenkontrolle,...)	**Eher ja**	**Eher ja**
	Governance & Eskalationsmechanismen	Standardisiertes ggfs. zertifizierbares Rahmenwerk zur Governance von Cloud Services (vgl. ITIL, COBIT)	**Ja**	**Ja**
Transparenz in Leistungserbringung und Abrechnung	Abrechnung inkl. Lizenzmodelle	Standardisierung von Leistungseinheiten, -zeiträumen zur besseren Vergleichbarkeit der Kosten (bspw. vCPU, Compute Units, vRAM, ...)	**Ja**	**Ja**
	Qualitätsicherung und SLA Überwachung	Leitfäden und Werkzeuge zur Überwachung und Sicherstellung der Qualiät von Cloud Services	**Eher ja**	**Eher nein**
	Art und Ort Datenverarbeitung	Leitfäden und Werkzeuge zur Sicherstellung der Transparenz in der Datenverarbeitung (bspw. Art und geografischer Ort der Datenverarbeitung in der Cloud)	**Eher ja**	**Eher nein**
Informationssicherheit	Identitäts- und Rechtemanagement	Standardisierte Methoden, Werkzeuge zum Management von Identitäten und Zugriffsrechten	**Ja**	**Eher ja**
	Sicherstellung von Vertraulichkeit und Integrität	Standardisierung von Tools und Schnittstellen zur Überprüfung und Sicherstellung des Vertraulichen Umgangs mit und der Integrität von Daten, Ressourcen, ...	**Keine Angabe möglich**	**Keine Angabe möglich**
	Zugriffschutz, Logging, Abwehr von Angriffen	Einheitliche Regelung, Tools und Leitfäden zur Verwaltungen von Ressourcenzugriffen und Abwehr von Angriffen	**Ja**	**Eher ja**
	Nachweis, Zertifizierung und Management	Standardisierung von Anforderungen, Verfahren und Prozessen zur Zertifzierung und Mangement von Cloud Services	**Eher ja**	**Eher ja**
Datenschutz	Datenschutz	Standardisierte Anforderung, Verfahren, Tests zur Einhaltung der Datenschutzvorgaben	**Ja**	**Ja**
Interoperabilität	Migration in die/aus der Cloud	Standardisierung von Tools und Schnittstellen und Leitfäden zur Migration von Standardanwendungen in die Cloud	**Ja**	**Eher ja**
	Integrationsfähigkeit in on-premise IT	Standardisierung von Schnittstellen und Test zur Sicherstellung der Integrationsfähigkeit von Cloud Services und on-premise Lösungen	**Ja**	**Eher ja**
	Cloud Federation	Standardisierung von Schnittstellen, Dateiformaten und Test zur Sicherstellung der Interoperabilität zwischen Clouds	**Ja**	**Ja**
Portabilität	Portabilität zwischen Anbietern	Standardisierung von Schnittstellen, Dateiformaten und Test zur Sicherstellung der Interoperabilität	**Ja**	**Ja**
	Sicherstellung funktionierender Wettbewerb	Leitfäden, Guidelines und Mechanismen zur Sicherstellung eines funktionierenden Wettbewerbs (bspw. auf SaaS-Markplätzen)	**Eher nein**	**Eher nein**
Compliance	Compliance mit geltender Rechtslage	Standards, Guidelines, Rahmenwerke für Compliance-Test, -Audits, -Management...	**Eher ja**	**Eher nein**
Wettbewerb	Sicherstellung funktionierender Wettbewerb	Leitfäden, Guidelines und Mechanismen zur Sicherstellung eines funktionierenden Wettbewerbs (bspw. auf SaaS-Markplätzen)	**Eher nein**	**Eher nein**
	… weitere Herausforderungen			

Figure A.1.: Questionnaire: Relevance of Challenges

Results

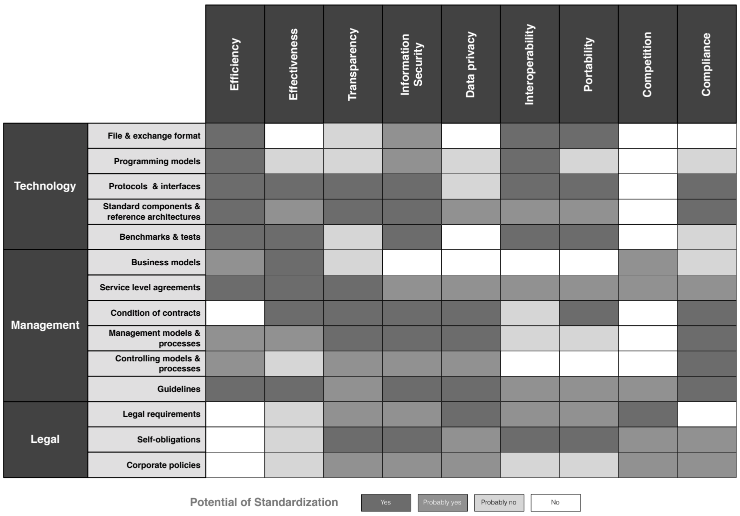


Figure A.2.: Result: Potentials for Standardization

A.2. Relevance of Standards

Questionnaire

<zurück zur Inhaltsübersicht>

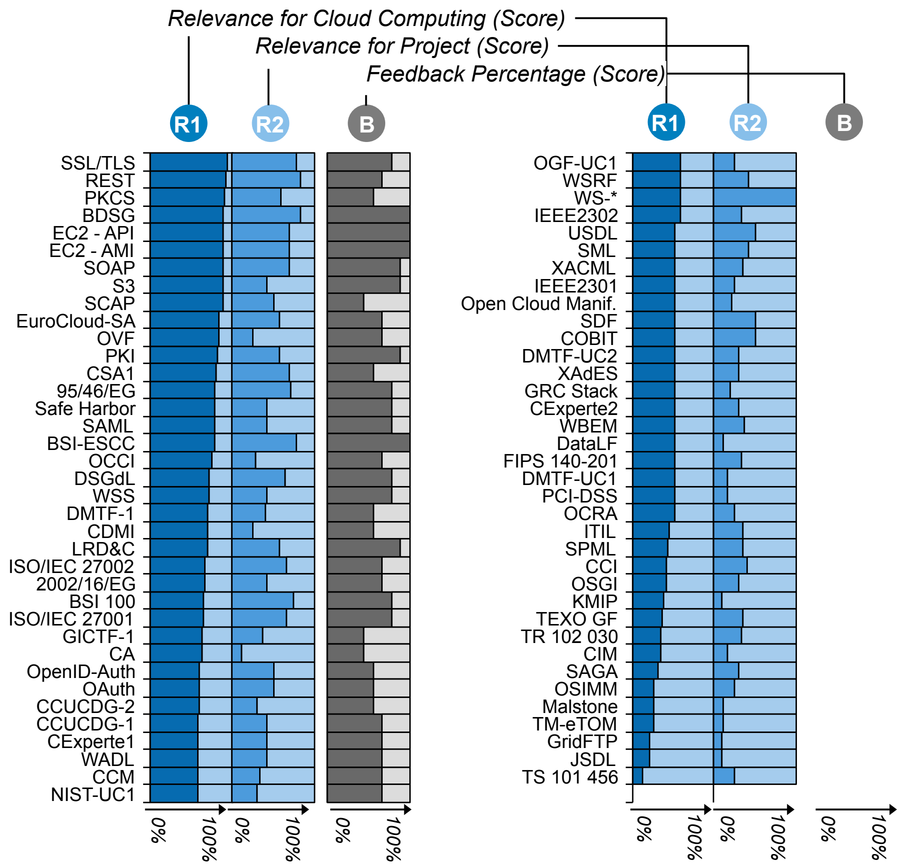
B. Bewertung von Normen und Standards für Cloud Computing

Hinweis zur Befüllung:
Bitte bei Bedarf weitere für ihr Projekt relevante Normen und Standards am Ende der Liste hinzufügen.

Akb.	Name	Institution / Link	Standard: Der Standard ist relevant für Cloud Computing *	Standard: Der Standard ist relevant für das Projekt *	Standard: Es besteht Notwendigkeit den Standard zur Nutzung im Projekt anzupassen *
2002/16/EG	2002/16/EG ("EU-Standardvertragsklauseln", Controller-	EU	Ja	Eher nein	Eher nein
EC2 - API	Amazon Elastic Compute Cloud (EC2) - API	AWS	Eher ja	Eher ja	Eher nein
EC2 - AMI	Amazon Elastic Compute Cloud (EC2) - VM Image	AWS	Eher nein	Eher ja	Eher nein
S3	Amazon Simple Storage Service (Amazon S3)	AWS	Eher ja	Eher ja	Eher nein
DMTF-1	Architecture for Managing Clouds (White Paper)	DMTF	Eher ja	Eher ja	Eher nein
BSI-ESCC	BSI Eckpunktepapier Sicherheitsempfehlungen für Cloud	BSI	Eher ja	Eher ja	Eher nein
BDSG	Bundesdatenschutzgesetz (BDSG)	DE	Eher ja	Eher nein	Eher nein
CCUCDG-1	Cloud Computing Use Cases	OpenCloudManifes	Keine Angabe möglich	Eher nein	Eher nein
CCM	Cloud Control Matrix	CSA	Eher ja	Eher nein	Eher nein
CDMI	Cloud Data Management Interface (CDMI)	SNIA	Eher ja	Eher ja	Eher nein
CExperte2	Cloud Experte - CloudSchool	CloudSchool	Eher ja	Eher ja	Eher nein
CExperte1	Cloud Experte - SaaS EcoSystem	SaaSEcosystem	Eher ja	Eher ja	Eher nein
CA	CloudAudit	CloudAudit	Eher ja	Eher ja	Eher nein
COBIT	COBIT Framework for IT Governance and Control	ISACA	Eher ja	Eher ja	Eher nein
CC	Common Criteria for Information Technology Security	NIAP	Eher ja	Keine Angabe möglich	Eher nein
CIM	Common Interface Model (CIM) infrastructure	DMTF	Eher ja	Eher ja	Eher nein
DSGdL	Datenschutzgesetze der Länder	DE	Eher ja	Eher ja	Eher nein
2301	Draft Guide for Cloud Portability and Interoperability	IEEE	Eher ja	Eher ja	Eher nein
WS-*	Web Services Platform Architecture Familie(z.B. WS-	Diverse	Eher ja	Eher ja	Eher nein
WSRF	Web Services Resource Framework (WSRF)	OASIS	Eher ja	Eher ja	Eher nein
WSS	Web Services Security (WSS)	OASIS	Eher ja	Eher ja	Eher nein
WBEM	Web-Based Enterprise Management (WBEM)	DMTF	Nicht bekannt	Nicht bekannt	Keine Angabe möglich
PKI	X.509 Public Key Infrastructure (PKI) Proxy Certificate	IETF	Eher ja	Eher ja	Eher nein
...	....	....	Eher ja	Eher ja	Eher nein
… weitere Normen und Standards					

Figure A.3.: Questionnaire: Relevance of Standards

Results



1) Scores: "Yes" = 1, "Probably yes"=0.5, #Projects=100%

Figure A.4.: Result: Relevance of Standards

B. Supplements to ASSET

B.1. Overview: Model Entities

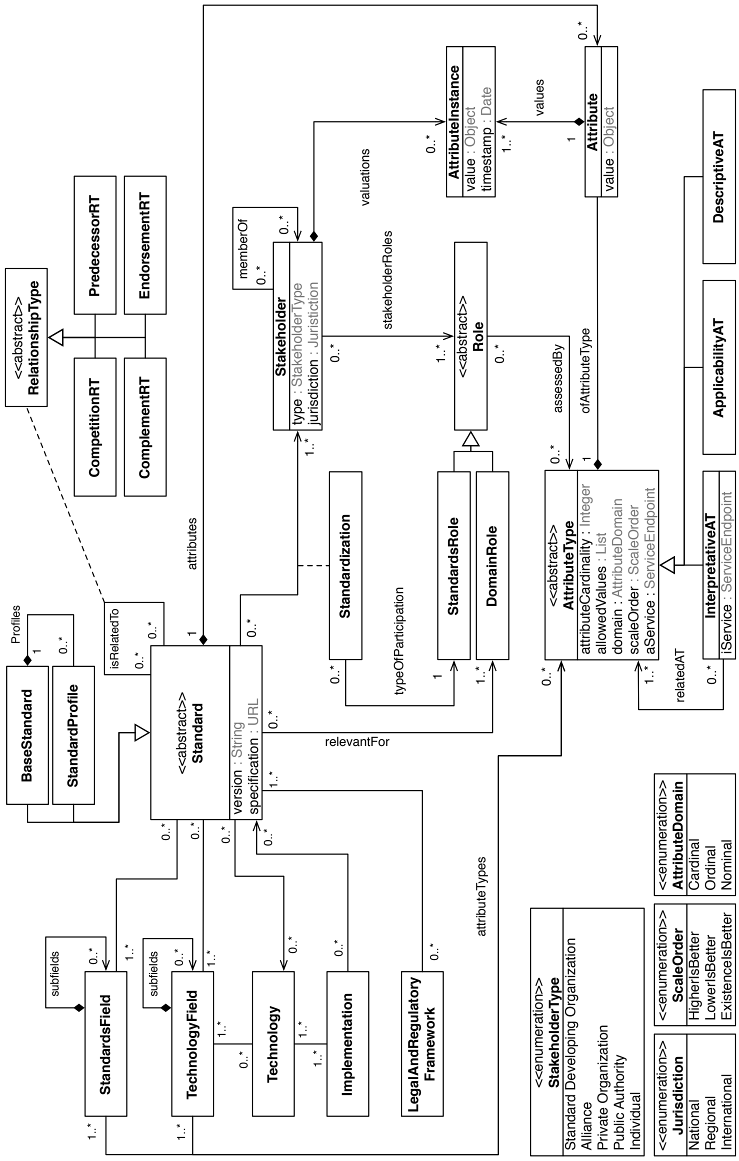


Figure B.1.: Information Model: Overview of Model Entites

B.2. Overview: Abstract Model Entities

The information model builds on a hierarchy of entities. Figure B.2 depicts an overview of the applied hierarchy of entities, omitting all non-abstract children of the BaseObject entity.

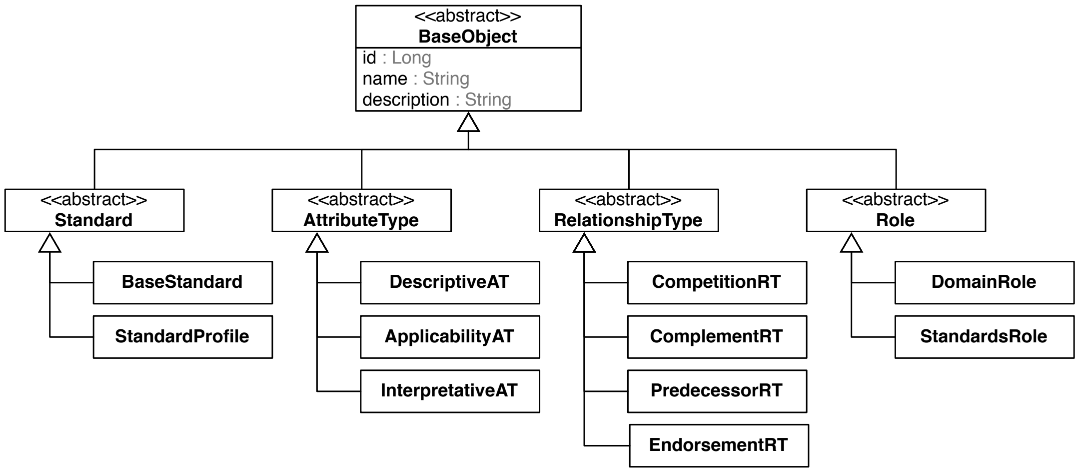


Figure B.2.: Information Model: Basic Elements

Parent of all entities is the *BaseObject* entity. Every entity, thus, comprises a basic set of *id*-, *name*-, and *description*-properties. The BaseObject is an abstract entity. Thus, it will not be instantiated directly. Next to the BaseObject entity, we conceptualize the information model to comprise four additional abstract entities: *Standard*, *AttributeType*, *Role*, *RelationshipType*. Similar to the BaseObject entity, these entities summarize common properties and dependencies that are common for all of their sub-types.

B.3. Overview: Method Requirements

ID	*Requirement*	*Rationale*
IR-1	Support classification of scope, subject, and type	Scope, subject, and type are key characteristics of standards, enabling a variety of analyses.
IR-2	Support classification of standards dependencies	The relation of two or more standards may be described from different viewpoints.
IR-3	Support domain-specific classification attributes	Different domains of disruptive innovation demand different classification attributes.
IR-4	Support measures for network effects	The value of standards is determined by network effects. Thus, information to evaluate network effects is required.
IR-5	Support stakeholders and roles	Stakeholders can only classify a subset of information.
PR-1	Support updates of the classification scheme	Dynamics of disruptive innovation require adaptations of the classification scheme.
PR-2	Support updates of classifications	Classifications might change over time.
PR-3	Coordinate updates	Changes to the classification scheme require re-classification and re-evaluation. Classification and evaluation may trigger changes to the classification scheme and vice versa.
PR-4	Support contextualization	Applying the same classification scheme to characterize the purpose of the evaluation supports selection of standards profiles.
AR-1	Consolidate values from multiple classifications	Varying stakeholders provide classifications that should be consolidated.
AR-2	Support determination of dependencies and attributes	Identification of dependency and standards attributes is well structured but tedious.
AR-3	Aggregate standards	Aggregation is required to summarize portfolios of standards.
AR-4	Rank standards	Ranking enables prioritization of standards.

Table B.1.: Method Requirements: Summary

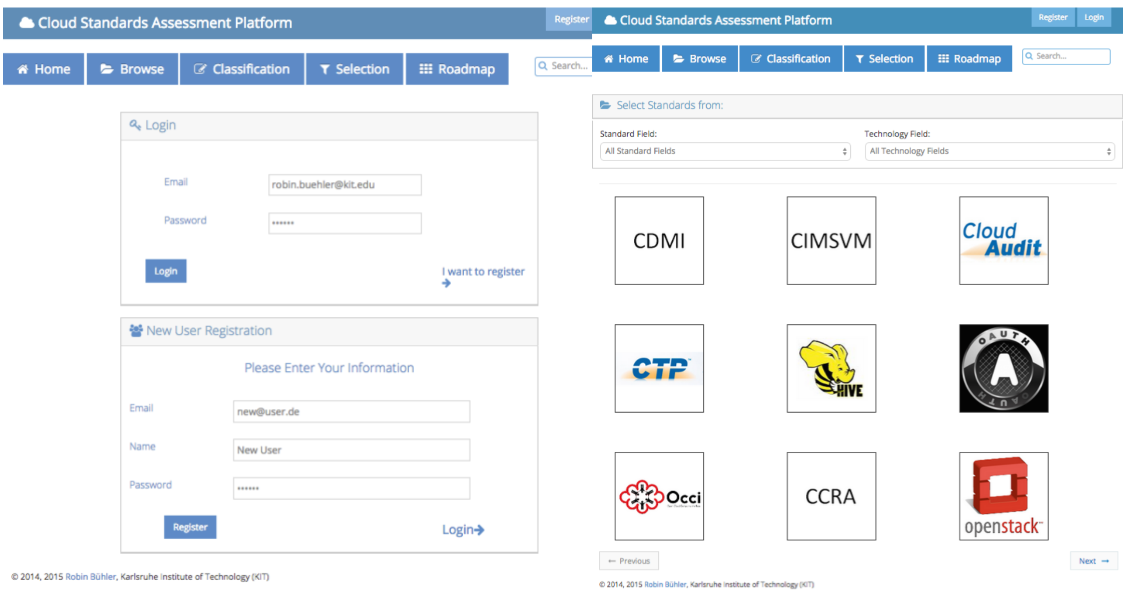
C. Documentation of CSAP

C.1. Graphical User Interface

C.1.1. Support for Anonymous Users

ASSET's stakeholder model identifies four standards-specific roles. Additionally, there may be an unspecified amount of domain-specific roles (see Section 5.5). ASSET filters information according to the set of roles that a stakeholder plays in standards assessment. In consequence, ASSET can only provide full assessment support, if stakeholder identify their respective roles. Thus, CSAP requires stakeholders to register a user account and log-on to the Web application when assessing standards. Without an active login, our prototype displays a landing page, allowing users to log-on or register a new user account. Figure C.1a presents the Graphical User Interface (GUI) elements for, both, log-on and registration.

Anonymous users may, however, browse the database of standards (see Figure C.1b). While this feature does not implement a particular assessment functionality of ASSET, it allows users to gain an impression of the amount and kind of available standards. In addition, anonymous users may use the search field to query the database of standards



(a) Login and Registration (b) Browsing Cloud Standards

Figure C.1.: CSAP: Landing Pages

for matching names of standards (see top-right of the screenshots in Figure C.1). Filtering of standards is supported by selecting technology fields and standards fields that the technology typology comprises.

After selecting a standard, CSAP loads and presents the corresponding standards profile. Following ASSET conceptualization, a standards profile is partitioned into parts that summarize information on a standard's "Basics & Technology Framework", its "Dependencies & Relevance", and associated "Domain Attributes". CSAP implements this separation of information using a tab bar and tab elements for each of the categories. Figure 8.1a, Figure 8.1b, and Figure 8.2a presentation the CSAP's implementation of a standards profile presented to anonymous users, using Cloud Data Management Interface (CDMI) as an example.

The information that is shown to anonymous CSAP users, will always represent the current set of domain- and standards-specific objects that the community of cloud assessment stakeholder has assigned to the standard. In addition, the "Domain Attributes" section will show the aggregated values of attributes as judged by the community of users. Our prototype, therefore, provides implementations of aggregation functionality such as a majority vote or threshold-based approach (see Section 6.4.3 for details).

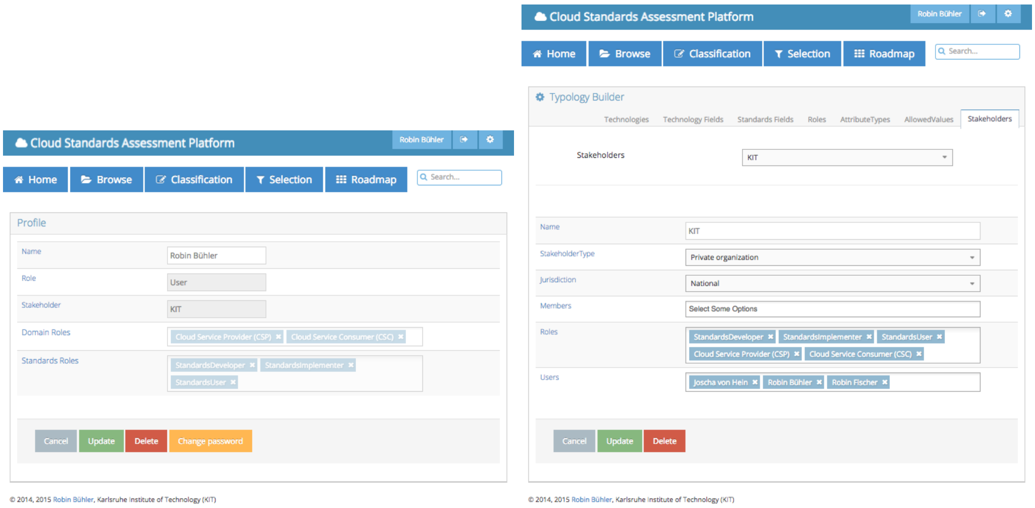
Using the common information model, our prototype additionally allows user to compare the profiles of any two standards. CSAP, therefore, presents the information of both standards profiles side-by-side, using the three above-mentioned tabs. The selection of standards that be compared, is facilitated re-using the browse screen (as depicted in Figure C.1b). Figure 8.2b depicts a screenshot of the user experience when comparing domain-specific attributes of CDMI and Open Virtualization Format (OVF).

In summary, CSAP's browse and compare functionality, however, applies only a fraction of ASSET's concepts, i.e., filters standards using the TechnologyField and StandardsField entity. In comparison to existing tool support for standards assessment, CSAP, however, already extends to the state-of-the-art (see Section 3.2). Tools such as ISO's "standards catalogue", "Perinorm" or the "Cloud Standards Wiki", for example, provide comparable functionality.

C.1.2. User and Stakeholder Management

Once a user has registered and logged-on to the CSAP, he may benefit of ASSET's full support for standards assessment. Therefore, each user is required to be assigned to a particular stakeholder, inheriting its respective roles of standardization in disruptive innovation.

Figure C.2a depicts the screenshot of a user's profile. Next to the user's registered information, it presents ASSET-specific information. Firstly, the stakeholder, to which the user is assigned to, is displayed. Secondly, the profile view presents the user's roles that are inherited from the respective stakeholder. In addition, the CSAP-specific role is displayed. This property allows for separating administrators from regular user. Regular users, for



(a) Editing Users (b) Editing Stakeholders

Figure C.2.: CSAP: Stakeholder & User Management

example, may not change the stakeholder and, consequently, the domain- and standards-specific roles that are assigned to them. Users may, however, change their names and passwords. As we will detail in Section C.1.3, functionality to change the technology typology will mostly be restricted to administrative users.

In Figure C.2b the stakeholder management screen is displayed. Manging stakeholders is an administrative task and, therefore, is restricted to administrative users. As can be seen, Karlsruhe Institute of Technology (KIT) is the stakeholder that is selected for administration. In addition, the screen depicts the stakeholder's properties and allows for defining instances of related entities. KIT, for example, is defined to be a "private organization", having a "national" jurisdiction. In the current situation, KIT does not have "member" organizations. Moreover, it applies the standards-specific roles of a "Standards Developer", "Standards Implementer", and "Standards User". Associated instances of the DomainRole entity are "Cloud Service Provider" and "Cloud Service Consumer" (see Section 8.1.2). Finally, three user's are associated to KIT.

As illustrated by the screenshots in Figure C.2, CSAP supports all Create, Read, Update, and Delete (CRUD) functionality for administering stakeholders. In addition, it allows for changing all relevant relationships. Administrative users may use the GUI presented in Figure C.2a) to modify a user's relationship to stakeholders and its CSAP-specific role.

The CSAP-prototype automatically adds newly registered users to a temporary demo stakeholder that enacts all domain- and standards-specific roles. In doing so, we support a first approach to role management. A productive version should implement additional functionality to enhance the and stakeholder management approach (e.g., automated identification of stakeholder using email verification).

C.1.3. Typology Builder

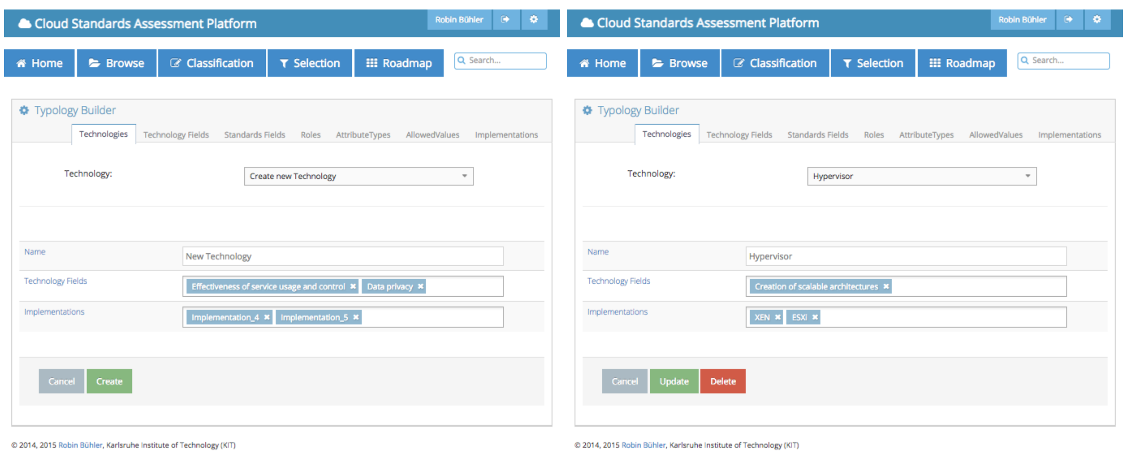
CSAP's *"Technology Technology Manager"* module implements ASSET's functionality for managing the cloud technology typology. The *"Typology Builder"*, thereby, provides the GUI-elements to perform the steps that ASSET defines in its *"Create Technology Typology"* sub-process. Figures C.3 to C.7 present the respective screens to manage technologies, technology fields, standards fields, domain roles, and attribute types.

Technologies

Defining the technology framework of disruptive innovation requires users to identify the domain's technologies, technology fields, and standards fields (see Figure 6.5). As depicted in Figure C.3a, CSAP supports the creation of instances of the Technology entity. Following ASSET's information model, users are to define the name of the technology. In addition, they may select related technology fields and define known implementations of the selected technology. Using the drop-down box at the top, users may switch between the creation of new instances or select an existing Technology instance. Figure C.3b displays the screenshot of the GUI-elements that CSAP applies for updating and deleting technologies. The footer of each page of the "Technology Builder" component will always present buttons to perform corresponding CRUD-operations (i.e., cancel, create or update, and delete).

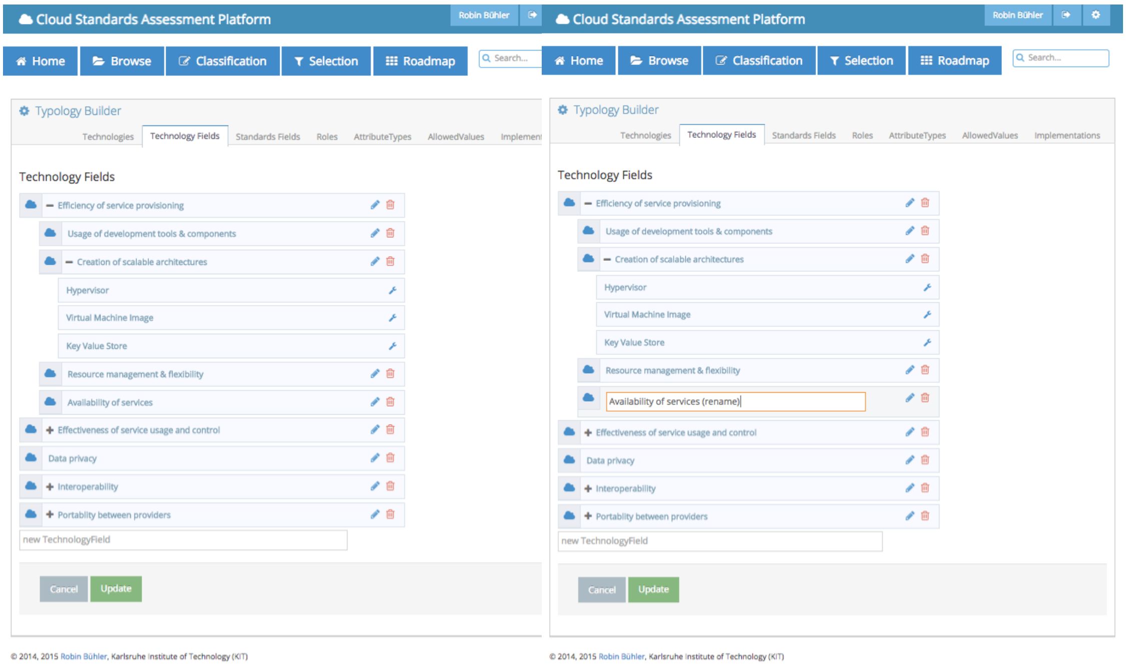
Technology and Standards Fields

Figures C.4 and C.5 present the views to manage the domain's technology and standards fields. Users may create, update, and delete instances of the TechnologyField or StandardsField entity using this functionality. In addition, user may (re-)define their respective structures. We chose to use nestable tree views to implement the functionality



(a) Create Technology (b) Update and Delete Technology

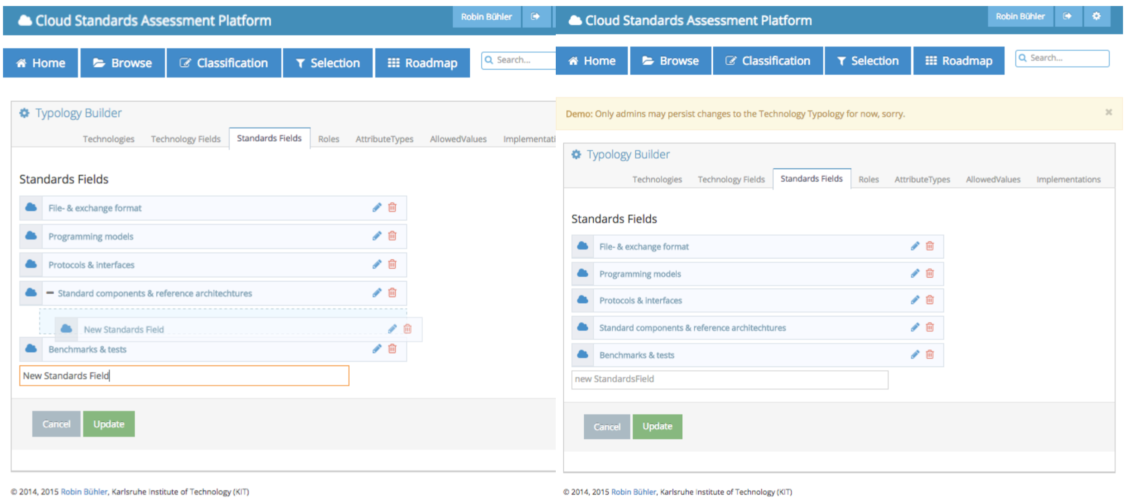
Figure C.3.: CSAP - Typology Builder: Editing Technologies



(a) Editing Technology Fields (b) Rename and Add a Technology Field

Figure C.4.: CSAP - Typology Builder: Managing Technology Fields

to manage technology and standards fields. New instances of the entities can be added at the bottom of the tree view. Thereafter, they can be placed at their position within the structure of elements by moving the small cloud icons (see drop area in Figure C.5). Renaming and deletion of respective instances is supported by the in-line buttons (see pencil and trash bin icons). Figure C.4b), for example, demonstrates the task of renaming the “Availability of service” technology field. In addition, the tree view shows technologies that are related to the respective TechnologyField instances (see Figure C.4). Thereby,



(a) Edit Standards Fields and their Structure (b) Confirmation Message

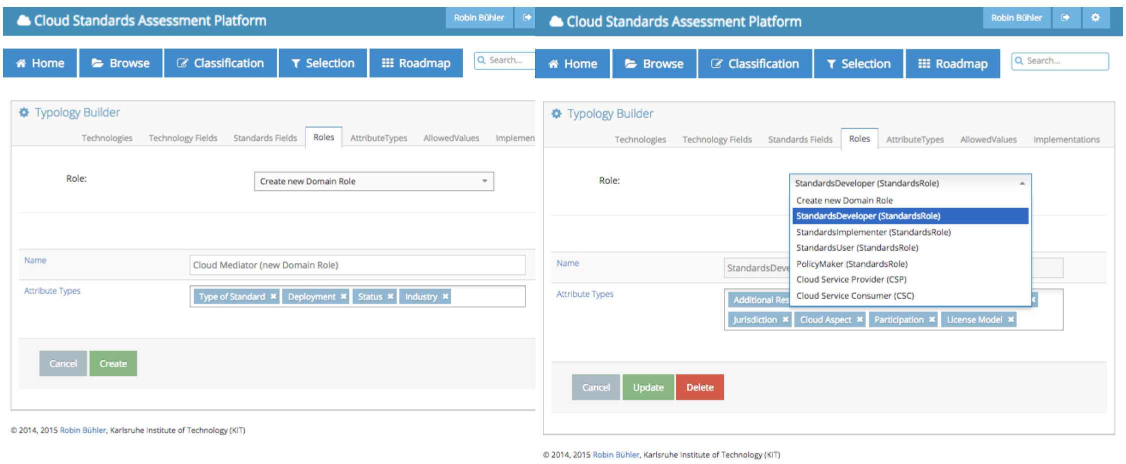
Figure C.5.: CSAP - Typology Builder: Managing Standards Fields

CSAP provides users with an overview of the respective dependencies. Assigning technologies to technology fields, however, can only be done in the technologies view as presented in Figure C.3.

Changes to technology or standards fields as well as their respective structure will be persisted, if the update button at the bottom of the respective views is clicked. Corresponding functionality is provided by the "TechnologyField Controller" and the "StandardsField Controller". CSAP applies a *flash-context* that is provided by the Play framework to notify users about changes or potential errors (e.g., in case of illegal delete operations). The flash-context, thereby, serves as temporary session store that is only valid for the time of a single Hypertext Transfer Protocol (HTTP) request and response. Figure C.5b shows, for example, the warning message that CSAP provides, if non administrative users try to modify the technology typology. Similar, messages will be shown to confirm creation, updates, and deletion of objects.

Roles

Figure C.6 presents the views of the "Typology Builder" to manage domain-specific roles. Its layout is based on the basic pattern to switch between create and update functionality as introduced for the technology view (see Figure C.3). Implementing ASSET's information model, CSAP allows users to define attribute types that are relevant for the selected role (see in Section 5.6). Users may apply full CRUD-functionality for instances of the DomainRole entity. In addition, they may modify the assignment of domain-specific attribute types to ASSET's four standards-specific roles (see Figure C.6b). The four instances of the StandarsRole entity, however, cannot be deleted or changed. Likewise, new standards-specific roles can not be added to the technology typology as ASSET defines four static standards-specific roles.



(a) Create Domain Role (b) Edit Roles

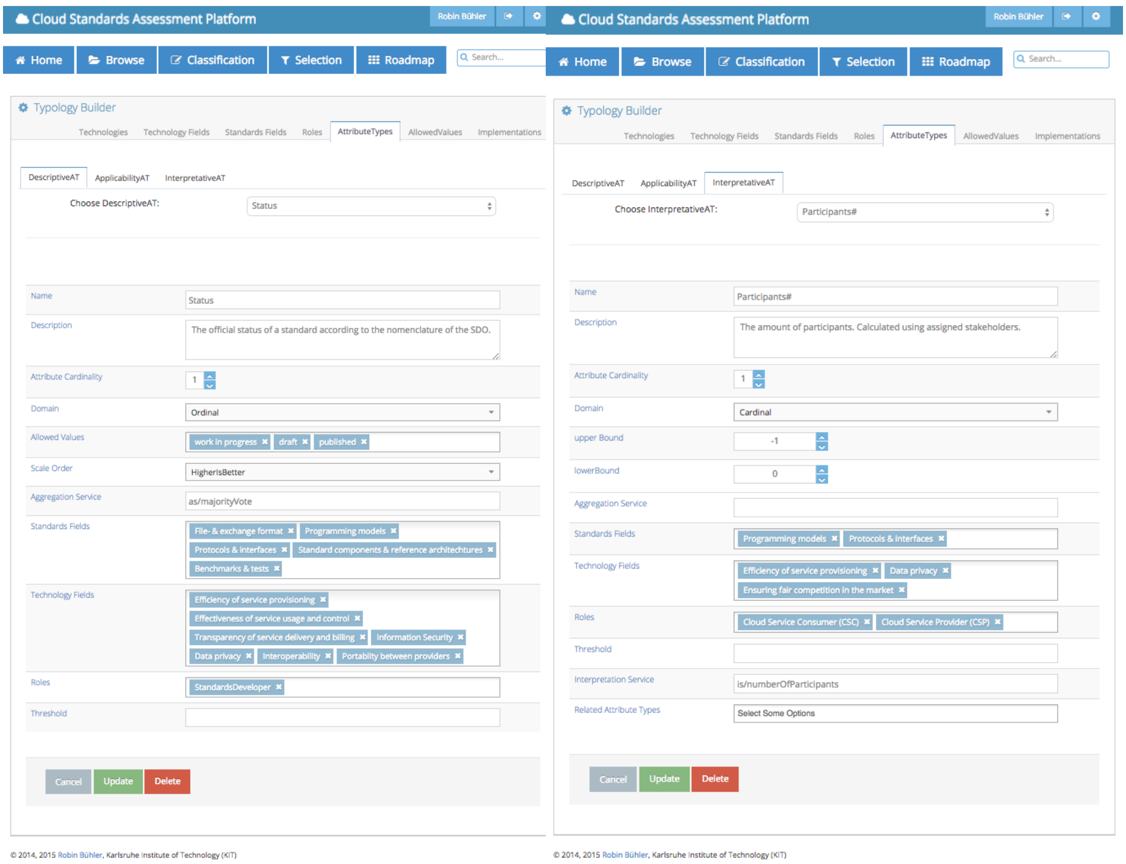
Figure C.6.: CSAP - Typology Builder: Managing Domain- and Standards-specific Roles

Attribute Types

Finally, the “Typology Builder” component provides three views to manage the instances of the AttributeType entity that the domain-specific technology typology comprise. Figure C.7 presents the views to manage descriptive and interpretative attribute types, using the attribute types “Status” (Figure C.7a) and “Participants#” (Figure C.7b) as examples. We omit the view that allows users to define instances of the ApplicabilityAT entity, since the appearance and functionality are similar to the view for descriptive attribute types presented in Figure C.7a.

Implementing ASSET’s information model, the view to manage instances of the DescriptiveAT entity presents GUI-elements to edit its respective properties (see Figure C.7a). Next to changing the name or description, users may define the amount of attributes that should be considered in a standards profile (see Attribute Cardinality), the domain of the attributes’ values, and the instances of the TechnologyField and StandardsFields entities for which the selected attribute type should be relevant (see Section 8.1.3).

Moreover, CSAP supports defining ASSET’s different value domains (i.e., cardinal, ordinal, and nominal). Figure C.7a, for example, defines a standard’s “Status” to comprise the values “work in progress”, “draft”, and “published”. Since the attribute type’s domain



(a) Editing Descriptive Attribute Types (b) Editing Interpretative Attribute Types

Figure C.7.: CSAP - Typology Builder: Editing Attribute Types is set to be ordinal, the defined allowed values provide an order. CSAP, therefore, orders the named allowed values in order of appearance according to the “Scale Order” property. Applying the “HigherIsBetter” property, defines “published” to be the maximum value.[67] The CSAP-prototype does not apply a particular order to the set of allowed values, if the domain is defined “nominal”. In addition to ASSET’s conceptualization, CSAP provides “SingleValue” as an additional attribute domain. Conceptionally, an attribute type that allows single values, resembles a nominal scale with an unknown set of allowed values. In order to ease the implementation, we decided to introduce this additional domain for values of attribute types. The user may, for example, dynamically add a link as a value of the “Additional Resources” attribute. Using a threshold-based aggregation approach, for example, CSAP additional resources will, however, only be included, if they are supported by at least the amount of classifications that is required by the threshold value. Finally, CSAP allows user to constrain the range of values, using upper and lower bound properties for cardinal attribute domains. Figure C.7b, for example, defines attribute values of the AttributeType “Participants#” do be between zero and an unbound upper bound (i.e., using the number -1). The CSAP-prototype only supports positive value ranges.

Supporting automation of standards assessment, the views allow for defining the type of attribute aggregation that CSAP should apply to calculate aggregated attribute values for a standards profile. Therefore, users have to provide the endpoint (i.e., a Uniform Resource Identifier (URI)) of a suitable aggregation service. Our implementation provides a set of aggregation services, having relative endpoint references (e.g., using the Uniform Resource Name (URN) “`as/majorityVote`”). External service may be applied, providing URIs that comprise an additional Uniform Resource Locator (URL) part. If a threshold-based aggregation should be applied, CSAP allows for defining the minimum amount of attribute value denominations that is required for an attribute value to be considered in the standards profile. User may, therefore, define the “Threshold” property. The combination of the “Aggregation Service” and the “Threshold” property enables CSAP to automate the assessment of standards in disruptive innovation.

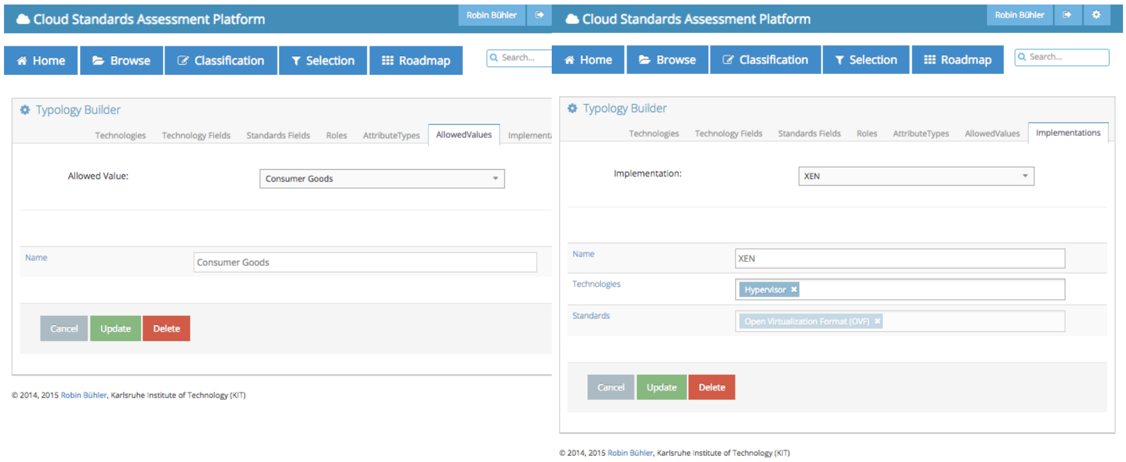
The uniqueness of the InterpretativeAT entity is defined by its capability to define dependencies between assessment attributes. While inheriting the GUI-elements to manage descriptive or applicability attribute types, the view to manage the InterpretativeAT entity allows users to define an “Interpretation Service” and its related AttributeType instances. Again, users only have to provide a URN or URL of the service endpoint. In doing so, the view builds the basis for automating attribute valuation. We will further elaborate on these aspects in Section 7.3.3.

Allowed Values and Implementations

CSAP implements two additional views to manage the overall set of instances of the AllowedValue and the Implementation entities. While the CRUD functionality for allowed values and implementations could have been handled within the individual views to, for

[67] ASSET defines “LowerIsBetter” and “ExistenceIsBetter” as additional scale order properties. See Section 5.6 for details.

example, define technologies (Figure C.3) or attribute types (Figure C.7), CSAP keeps these views clean. Figure C.8 presents screenshots of the two additional views.



(a) Edit Allowed Values

(b) Edit Implementations

Figure C.8.: CSAP - Typology Builder: Managing Allowed Values and Implementations

C.2. Modeling of AttributeTypes

C.2.1. List of AttributeTypes

Name	*C*	*D*	*SO*	*aS*	*T*	*UB*	*LB*	*iS*
Cloud Aspect	1	n	-	mv	-	-	-	-
Company Size	1	n	-	mv	-	-	-	-
Deployment	-1	n	-	t	5	-	-	-
Industry	-1	n	-	t	0.15	-	-	-
License Cost	1	c	-	mv	-	10^6	0	-
License Model	1	n	-	mv	-	-	-	-
Maturity	1	o	0	mv	-	-	-	-
Participation	1	o	1	mv	-	-	-	-
Service Model	-1	n	-	t	0.30	-	-	-
Additional Resources	2	sv	-	t	2	-	-	-
Status	1	o	0	mv	-	-	-	-
Type of Standard	1	n	-	mv	-	-	-	-
Market Potential	1	o	0	mv	-	-	-	mpa
Participants	1	c	-	-	-	-1	0	pc

C (Cardinality): -1 (infinite), 1, 2, 3...
D (Attribute Domain): *c*-cardinal, *o*-ordinal, *n*-nominal, *sv*-singleValue
SO (Scale Order): *0*-higherIsBetter, *1*-lowerIsBetter, *2*-existenceIsBetter
aS (aService): mv-as/majorityVote/:aId, t-as/threshold/:aId)
T (Threshold): [0;1]-percentage, n (actual count)
UB (Upper Bound): -1 (infinite), 0, 1, 2, 3...
LB (Lower Bound): -1 (infinite), 0, 1, 2, 3...
iS (iService): *mpa*-is/marketPotentialAnalyzer/:aId, *pc*-is/participantsCounter/:aId

Table C.1.: List of Attribute Types

C.2.2. Relevance of AttributeTypes

AT	SF	TF	R
Additional Resources	PI, FEF, PM	T, IS, DP, I, P, C	SI, SD, SU
Cloud Aspect	PM, PI, FEF	E1, T, IS, DP, I, P, C	CSP, SD, PM
Company Size	PM, PI	T, IS, DP, I, P, C	PM, SI
Deployment	PI, PM	T, IS, DP, I, P, C	SI, CSP, SD
Industry	PM, PI	E2, T, IS, DP, I, P, C	SU, PM, SI, CSP
License Model	PM, PI, SC	E2, T, IS, DP, I, P, C	CSP, SD
Market Potential	PM, PI	T, IS, DP, I, P, C	CSC, SI
Maturity	PM, PI	T, IS, DP, I, P, C	PM, SI
Participants	PM, PI	E2, T, IS, DP, I, P, C	CSP, PM, SI
Participation	PM, PI	E2, T, IS, DP, I, P, C	SD, PM, SI
Phase	PM, PI, FEF, SC, BT	E2, T, IS, DP, I, P, C	SI, CSP, CSC
Service Model	PM, PI, BT	E2, T, IS, DP, I, P, C	SU, CSP
Status	PI, FEF, PM	T, IS, DP, I, P, C	SD
Type of Standard	PI, FEF, PM	T, IS, DP, I, P, C	PM, CSC, SI, CSP, SD, SU

Standards Fields (SF):
FEF-file and exchange formats
PM-programming models
PI-protocols and interfaces
SC-standard components and reference architectures
BT-benchmarks and tests

Technology Fields (TF):
E1-efficiency of service provisioning
E2-effectiveness of service usage
T-transparency of service delivery and billing
IS-information security
DP-data privacy interoperability
P-portability
C- compliance with regulatory requirements

Roles (R):
SD-standards developer
SI-standards implementer
SU-standards user
PM-policy maker
CSP-cloud service provider
CSC-cloud service consumer

Table C.2.: Relevance of Attribute Types

C.3. Public API

Type	*URI*	*Description*
GET	`/api/standards/:standardId`	Get standards profile by id
GET	`/api/attributes/:attributeId`	Get attribute by id
GET	`/api/technologyFields`	List all technology fields
GET	`/api/technologyFields/:tfId`	Get technology field by id
GET	`/api/technologies`	List all technologies
GET	`/api/technologies/:tId`	Get technology by id
GET	`/api/standardsFields`	List all standards fields
GET	`/api/standardsFields/:sfId`	Get standards field by id
GET	`/api/roles`	List all roles
GET	`/api/roles/:rId`	Get role by id
GET	`/api/attributeTypes/descriptiveATs`	List all AttributeTypes of type “DescriptiveAT”
GET	`/api/attributeTypes/descriptiveATs/:atId`	Get DescriptiveAT by id
GET	`/api/attributeTypes/applicabilityATs`	List all AttributeTypes of type “ApplicabilityAT”
GET	`/api/attributeTypes/applicabilityATs/:atId`	Get ApplicabilityAT by id
GET	`/api/attributeTypes/interpretativeATs`	List all AttributeTypes of type “InterpretativeAT”
GET	`/api/attributeTypes/interpretativeATs/:atId`	Get InterpretativeAT by id
GET	`/api/stakeholders`	List all stakeholders
GET	`/api/stakeholders/:sId`	Get stakeholder by id

Table C.3.: CSAP: Public API

C.4. Serialization of Model Entities

C.4.1. Attribute Entity


```json
{
  "attributeInstances": [
    {
      "date": "",
      "id": 1,
      "stakeholder": "study",
      "value": "draft"
    },
    {
      "date": "2015/03/06 17:10:16",
      "id": 305,
      "stakeholder": "KIT",
      "value": "published"
    },
    {
      "date": "2015/03/08 11:42:28",
      "id": 319,
      "stakeholder": "KIT",
      "value": "published"
    }
  ],
  "attribute_type_id": 2,
  "id": 1,
  "standard_id": 1,
  "value": "published"
}
```


Listing C.1: JSON-Representation of an Attribute

C.4.2. AttributeType Entity

```json
{
  "aService": "as/majorityVote/:attributeId",
  "allowedValues": [
    {
      "id": 29,
      "scaleOrder": 2,
      "value": "high"
    },
    {
      "id": 30,
      "scaleOrder": 1,
      "value": "middle"
    },
    {
      "id": 31,
      "scaleOrder": 0,
      "value": "low"
    }
  ],
  "attributeCardinality": 1,
  "description": "InterpretativeAT uses external logic to value the standard's market potential.",
  "domain": "Ordinal",
  "iService": "is/marketPotential/:attributeId",
  "id": 14,
  "name": "Market Potential",
  "relatedAttributeTypes": [
    {
      "id": 15,
      "name": "Number Of Participants"
    }
  ],
  "roles": [
    {
      "id": 2,
      "name": "StandardsImplementer"
    },
    {
      "id": 6,
      "name": "Cloud Service Consumer (CSC)"
    }
  ],
  "scaleOrder": "HigherIsBetter",
  "threshold": ""
}
```

Listing C.2: JSON-Representation of an AttributeType (InterpretativeAT)

C.4.3. Standard Entity

```
{
  "attributes": [
    {"id": 1, "value": "published"},{"id": 2,"value": "industrial standard"},{"id": 3,"value": "explicit"},{"id": 4,"value": "7"},{"id": 5,"value": "IaaS"},{"id": 6,"value": "public"},{"id": 7,"value": "private"},{"id": 8,"value": "global"},{"id": 9,"value": "small enterprise"},{"id": 10,"value": "large enterprise"},{"id": 11,"value": "middle"},{"id": 12,"value": "low"},{"id": 13,"value": "limited"},{"id": 14,"value": "not applicable"},{"id": 15,"value": "Materials"},{"id": 16,"value": "Open Source"}
    ],
  "description": "The Cloud Data Management Interface defines the functional interface that applications will use to create, retrieve, update and delete data elements from the Cloud. ",
  "document": "http://www.snia.org/sites/default/files/CDMI_Spec_v1.1.pdf",
  "domainRoles": [5,6],
  "id": 1,
  "implementations": [6,7],
  "name": "Cloud Data Management Interface (CDMI)",
  "relatedStandards": [
    {"id": 21,"name": "Cloud Data Management Interface (CDMI)","type": "PredecessorRT"},{"complementaryRTType": "Technology","id": 7,"name": "Open Cloud Computing Interface (OCCI)","type": "ComplementaryRT"},{"id": 9,"name": "OpenStack Software Solutions (OpenStack)","type": "CompetingRT"}
  ],
  "stakeholders": [
    {"id": 1,"name": "SNIA","type": "StandardsDeveloper"},{"id": 1,"name": "SNIA","type": "StandardsImplementer"},{"id": 33,"name": "NetApp","type": "StandardsImplementer"},{"id": 22,"name": "IBM","type": "StandardsUser"},{"id": 8,"name": "The Open Group","type": "StandardsUser"},{"id": 30,"name": "KIT","type": "StandardsUser"},{"id": 11,"name": "NIST","type": "PolicyMaker"}
  ],
  "standardsFields": [3,4],
  "technologies": [3],
  "technologyFields": [1,2,6],
  "version": "1.1"
}
```

Listing C.3: JSON-Representation of a Standard

C.5. CSP Util

C.5.1. Service Invocation Helper

```
public static String invokeService(String endpointURL){

  //Prepare Async Call
  final F.Promise<String> resultPromise =
    //Use play.lib.WS
    WS
    //Set Endpoint
    .url(endpointURL)
    //Perform HTTP GET
    .get()
    //Handle Result or Failure
    .map(
      new F.Function<WS.Response, String>() {
        public String apply(WS.Response response) throws
            IllegalArgumentException {
          if(response.getStatus() != 200){
            throw new IllegalArgumentException(
              response.getStatusText()
                + " - " + response.getBody()
                + " [" + response.getUri() + "]" );
          }
          return response.getBody();
        }
      }
    );

  //Get result
  return resultPromise.get(SERVICE_TIMEOUT);
}
```

Listing C.4: CSAP: Util - Handling Services Calls

C.5.2. Contextualization Helper

Get Standards by Contextual Typology

```
public static Set<Standard> getStandardsForContextualTypology(
        List<StandardsField> standardsFields,
        List<Technology> technologies,
        List<TechnologyField> technologyFields
){
    Set<Standard> standards = new ArraySet();

    standards.addAll(Standard.getByStandardsFields(standardsFields));
    standards.addAll(Standard.getByTechnologyFields(technologyFields));
    standards.addAll(Standard.getByTechnologies(technologies));

    return standards;
}
```

Listing C.5: CSAP: Contextualization Helper - Get Standards by Contextual Typology

C.5.3. Ranking Helper

Assess Gaps for Roadmap

```
public static int getGapForRoadmap(
  int standardizationPotential,
  int standardPotential){

  if (standardizationPotential == 4 && standardPotential == 4)
    return 4; //High Priority Gap
  else if (standardizationPotential > 2 && standardPotential > 2)
    return 3; //Increased Priority Gap
  else if (standardizationPotential > 0 && standardPotential > 0)
    return 2; //Existing Gap
  else
    return 1; //No Gap
}
```

Listing C.6: CSAP: Ranking Helper - Assess Gaps for Roadmap

Get Ordered List of Standards

```java
public static TreeMap<Integer, List<FindResult>> rankStandards(
    Set<Standard> standards,
    List<StandardsField> standardsFields,
    List<Technology> technologies,
    List<TechnologyField> technologyFields,
    HashMap<Long, WeightedAttribute> preferenceMap){

  //Prepare Ordered Result Map
  TreeMap<Integer, List<FindResult>> rankedStandards =
      new TreeMap<Integer, List<FindResult>>(
          new Comparator<Integer>() {
            public int compare(Integer i1, Integer i2) {
              if (i1.intValue() > i2.intValue()) return -1;
              else if (i1.intValue() == i2.intValue()) return 0;
              else return 1;
            }
          }
      );

  //Loop all Standards
  for(Standard s : standards){
    int score = 0;
    FindResult current = new FindResult();
    current.standard = s;
    //Calculate Score for each Attributes
    for (Attribute a : s.attributes){
      //If in Preferences
      if (preferenceMap.containsKey(a.attributeType.id)){
        int weight = 0;
        WeightedAttribute wa = preferenceMap.get(a.attributeType.id);

        //Check Domain of Attribute
        if(a.attributeType.domain == AttributeDomain.Cardinal){
          //Cardinal so check if value is in bounds
          Long attributeValue = Long.parseLong(a.value);
          int tmpWeight = preferenceMap.get(a.attributeType.id).weight;
          if(wa.operator == WeightedAttribute.OPERATOR.EQ){
            if(attributeValue == wa.cardinalValue)
              weight = tmpWeight;

          } else if (wa.operator == WeightedAttribute.OPERATOR.GT){
            if(attributeValue > wa.cardinalValue)
              weight = tmpWeight;
          } else {
            if (attributeValue < wa.cardinalValue)
              weight = tmpWeight;
          }




//(Continued on next page...)
```

```
//(Continued from previous page...)
        } else {
          //Not cardinal so compare strings
          if(a.value.equals(
            AllowedValue.find.byId(wa.allowedValue).value)){
            //get weight
            weight = preferenceMap.get(a.attributeType.id).weight;
          }
        }
        //Add Matched Attribute to Result Set
        if(weight > 0 ){
          current.matchedWAs.add(wa);
          score += weight;
        }
      }
    }

    //score matches for contextual typology
    for(StandardsField sf : s.standardsFields){
      if(standardsFields.contains(sf)){
        current.matchedStandardsFields.add(sf);
        score++;
      }
    }
    for(TechnologyField tf : s.technologyFields){
      if(technologyFields.contains(tf)){
        current.matchedTechnologyFields.add(tf);
        score++;
      }
    }
    for(Technology t : s.technologies){
      if(technologies.contains(t)){
        current.matchedTechnologies.add(t);
        score++;
      }
    }

    //Add Standard to Result Map
    List<FindResult> matches = new ArrayList<FindResult>();
    if(rankedStandards.containsKey(score)){
      matches = rankedStandards.get(score);
    }
    matches.add(current);
    rankedStandards.put(score, matches);
  }
  return rankedStandards;
}
```

Listing C.7: CSAP: Ranking Helper - Get Ordered List of Standard

C.5.4. Dependency Helper

Find Competitor Candidates

```
public static List<Standard> findCompetingCandidates(
    Long standardId,
    List<Technology> technologies,
    List<StandardsField> standardsFields){

  //Get current
  Standard standard = Standard.find.byId(standardId);

  //Get Query
  Set<Standard> competitorCandidates = Standard.find
      .fetch("standardsFields")
      .fetch("technologies")
      .where()
        //Implicit AND
        .in("standardsFields", standardsFields)
        .in("technologies", technologies)
      .findSet();

  //Can't compete with itself
  competitorCandidates.remove(standard);

  return new ArrayList<Standard>(competitorCandidates);
}
```

Listing C.8: CSAP: Dependency Helper - Find Competitor Candidates

Find Standards Field Complement Candidates

```
public static List<Standard> findCandidateStandardsFieldComplement (
    Long standardId,
    List<Technology> technologies,
    List<TechnologyField> technologyFields,
    List<StandardsField> standardsFields) {

  Standard standard = Standard.find.byId(standardId);

  Set<Standard> complementCandidates = Standard.find
      .fetch("technologyFields")
      .where()
      .not(Expr.in("standardsFields", standardsFields))
      .in("technologyFields", technologyFields)
      .findSet();

  complementCandidates.addAll(Standard.find
      .fetch("technologies")
      .where()
      .not(Expr.in("standardsFields", standardsFields))
      .in("technologies", technologies)
      .findSet()
  );

  //Standards can't relate to themselves
  complementCandidates.remove(standard);
  return new ArrayList<Standard>(complementCandidates);
}
```

Listing C.9: CSAP: Dependency Helper - Find Standards Field Complement Candidates

Find Technology Complement Candidates

```
public static List<Standard> findCandidateTechnologyComplement (
    Long standardId,
    List<Technology> technologies,
    List<TechnologyField> technologyFields,
    List<StandardsField> standardsFields) {


  Standard standard = Standard.find.byId(standardId);

  //T Complements must not share all Technologies
  Set<Standard> complementCandidates = Standard.find
      .fetch("standardsFields")
      .where()
      .in("standardsFields", standardsFields)
      .not(Expr.in("technologies", technologies))
      .findSet();

  //Add T_Complements that do not share TFs
  complementCandidates.addAll(Standard.find
      .fetch("standardsFields")
      .where()
      .in("standardsFields", standardsFields)
      .not(Expr.in("technologyFields", technologyFields))
      .findSet()
  );

  complementCandidates.remove(standard);
  return new ArrayList<Standard>(complementCandidates);
}
```

Listing C.10: CSAP: Dependency Helper - Find Technology Complement Candidates label

Find Predecessor Candidates

```
public static List<Standard> findPredecessorCandidates(
    Long standardId,
    List<Technology> technologies,
    List<TechnologyField> technologyFieldsOfStandard){

  Standard standard = Standard.find.byId(standardId);
  //Get TechnologyFields via Technology
  Set<TechnologyField> technologyFields = TechnologyField.find
      .fetch("technologies")
      .where()
      .in("technologies", technologies)
      .findSet();

  //Get Standards TechnologyFields
  technologyFields.addAll(technologyFieldsOfStandard);

  //Add Parents and Childs
  Set<TechnologyField> matchingContext = new HashSet<TechnologyField>()
      ;
  for(TechnologyField tf : technologyFields){
    matchingContext.add(tf);
    matchingContext.addAll(tf.getWithParentsAsList());
    matchingContext.addAll(tf.getAllChildrenAsList());
  }

  //Get All Standards that match context
  Set<Standard> predecessorCandidates = Standard.find
      .fetch("technologyFields")
      .where()
      .in("technologyFields", matchingContext)
      .findSet();

  //Get all standards with Technologies that match context
  predecessorCandidates.addAll(Standard.find
      .fetch("technologies")
      .where()
      .in("technologies.technologyFields", matchingContext)
      .findSet()
  );

  predecessorCandidates.remove(standard);
  return new ArrayList<Standard>(predecessorCandidates);

}
```

Listing C.11: CSAP: Dependency Helper - Find Predecessor Candidates label

Find Endorsement Candidates

```
public static List<Standard> findEndorsementCandidates(
    Long standardId,
    List<Technology> technologies,
    List<TechnologyField> technologyFields,
    List<StandardsField> standardsFields) {

  Standard standard = Standard.find.byId(standardId);
  Stakeholder standardsDeveloper = standard.getStandardsDeveloper();

  Set<Standard> endorsementCandidates = Standard.find
      .fetch("standardsFields")
      .fetch("technologyFields")
      .fetch("technologies")
      //.fetch("standardizations")
      .where()
      .ne("standardizations.stakeholder", standardsDeveloper)
      .findSet();

  //TODO: Include this in query?
  Set<Standard> candidatesClean = new HashSet<Standard>();
  for(Standard candidate : endorsementCandidates){
    if(standardsFields.containsAll(candidate.standardsFields)
        && candidate.standardsFields.containsAll(standardsFields)
        && technologyFields.containsAll(candidate.technologyFields)
        && candidate.technologyFields.containsAll(technologyFields)
        && technologies.containsAll(candidate.technologies)
        && candidate.technologies.containsAll(technologies)){
      candidatesClean.add(candidate);
    }
  }


  candidatesClean.remove(standard);
  return new ArrayList<Standard>(candidatesClean);

}
```

Listing C.12: CSAP: Dependency Helper - Find Endorsement Candidates label

Find Base Standard Candidates

```
public List<BaseStandard> getBaseStandardCandidates(List<StandardsField
    > standardsFields){

  Set<BaseStandard> candidates = BaseStandard.find
      .fetch("standardsFields")
      .where()
        .in("standardsFields", standardsFields)
      .findSet();

  return new ArrayList<>(candidates);

}
```

Listing C.13: CSAP: Dependency Helper - Find Base Standard Candidates label

C.6. Adapters

C.6.1. Interpretation Service Adapter

```
public static AttributeInstance interpret(Long attributeId){

  //Get Attribute Object
  Attribute attribute = Attribute.find.byId(attributeId);

  //Get Interpretative Attribute Type
  InterpretativeAT iat = (InterpretativeAT) attribute.attributeType;
  //Prepare Service Call...
  String endpointURL = "";
  if(!iat.iService.startsWith("http://")){
    //Do local call externally
    endpointURL = CSPUtil.URL;
  }

  //Put AttributeId in URI
  endpointURL += iat.iService.replace(":attributeId", attributeId.
     toString());
  //Invoke Service
  String value = CSPUtil.invokeService(endpointURL);
  //Return wrapper Result
  return new AttributeInstance(value, new Date(), CSPUtil.SYSTEMUSER);
}
```

Listing C.14: CSAP: Interpretation Service Adapter

C.6.2. Aggregation Service Adapter

```
public static String aggregate(Long attributeId) {

  //Get Attribute Object
  Attribute attribute = Attribute.find.byId(attributeId);

  //Prepare Service Call
  String endpointURL = "";
  if(!attribute.attributeType.aService.startsWith("http://")){
    //Do local call externally
    endpointURL = CSPUtil.URL;
  }

  //Put AttributeId in URI
  endpointURL += attribute.attributeType.aService
    .replace(":attributeId", attributeId.toString());
  return CSPUtil.invokeService(endpointURL);
}
```

Listing C.15: CSAP: Aggregation Service Adapter

C.7. Aggregation Services

C.7.1. Threshold Service

```java
public static Result threshold (Long aId){
  //Get the current Attribute
  String endpointURL = CSPUtil.URL + "api/attributes/" + aId;
  String result = CSPUtil.invokeService(endpointURL);
  ObjectMapper mapper = new ObjectMapper();
  JsonNode aNode = mapper.readTree(result);

  //Get AttributeType
  Long aTId = aNode.findValue("attribute_type_id").longValue();
  endpointURL = CSPUtil.URL + "api/attributeTypes/" + aTId;
  JsonNode aTNode = mapper.readTree(CSPUtil.invokeService(endpointURL))
      ;

  //Parse Properties
  Long sId = aNode.findValue("standard_id").longValue();
  String proposedValue =
    aNode.get("attributeInstances").findValue("value").asText();
  int cardinality = aTNode.get("cardinality").asInt();
  Double threshold = aTNode.get("threshold").asDouble();
  String aTName = aTNode.get("name").asText();

  //Get Standard's Attributes of same Attribute Type
  endpointURL = CSPUtil.URL
      + "api/attributes/standards/" + sId
      + "/type/" + aTId;
  JsonNode attributesNode = mapper.readTree(
      CSPUtil.invokeService(endpointURL));

  //Count AttributeInstance per Attribute
  Map<String, Integer> map = new HashMap<>();
  double noOfInstances = 0;
  for(JsonNode aNode : attributesNode){
    int count = aNode.get("attributeInstances").size();
    map.put(
        aNode.get("attributeInstances").findValue("value").asText(),
        count);
    noOfInstances += count;
  }

  // Sort List by Number of Attribute Instances
  ThresholdComparator tc = new ThresholdComparator(map);
  TreeMap<String, Integer> sortedMap = new TreeMap<>(tc);
  sortedMap.putAll(map);
  ArrayList<String> sortedValues = new ArrayList<>(sortedMap.keySet());




  //(Continued on next page...)
```

```java
  //(Continued from previous page...)
  //Do the calculation
  if (cardinality == -1 || sortedValues.indexOf(proposedValue) < cardinality){
    //threshold is relative (percentage)
    if(threshold < 1 && threshold > 0){
      double count = aNode.get("attributeInstances").size();
      double percentage = count / noOfInstances;
      if( percentage  >= threshold){
        return ok(proposedValue);
      }
    }
    //threshold is absolute
    else if(aNode.get("attributeInstances").size() >= threshold) {
      return ok(proposedValue);
    }
  }
  //no match: return nothing -> value will be set to ""
  return ok();
}
```

Listing C.16: CSAP: Threshold Service (Aggregation Service)

C.7.2. Maximum Service

```java
public static Result maximum(Long aId){

  //Get the current Attribute
  String endpointURL = CSPUtil.URL + "api/attributes/" + aId;
  String result = CSPUtil.invokeService(endpointURL);
  ObjectMapper mapper = new ObjectMapper();
  JsonNode attributeNode = mapper.readTree(result);

  //Get AttributeType and parse required Properties
  Long aTId = attributeNode.findValue("attribute_type_id").longValue();
  Logger.debug("attributeType = " + aTId);
  endpointURL = CSPUtil.URL + "api/attributeTypes/" + aTId;
  JsonNode aTnode = mapper.readTree(CSPUtil.invokeService(endpointURL));
  String scaleOrder = aTnode.get("scaleOrder").asText();
  String domain = aTnode.get("domain").asText();

  //Parse AllowedValues
  Map<String, Integer> allowedValues = new HashMap<>();
  for(JsonNode av : aTnode.get("allowedValues")){
    System.out.println("av = " + av);
    allowedValues.put(
      av.get("value").asText(),
      av.get("scaleOrder").asInt());
  }

//(Continued on next page...)
```

```
//(Continued from previous page...)
  //Get Attribute Instances
  Map<Long, String> attributeInstances = new HashMap<>();
  for(JsonNode ai : attributeNode.get("attributeInstances")){
    attributeInstances.put(
      ai.get("id").longValue(),
      ai.get("value").asText());
  }

  //Do Calculation
  if(domain.equals(AttributeDomain.Cardinal.toString())){
    double maxValue = 0;
    for (String value : attributeInstances.values()){
      double l_value = Double.parseDouble(value);
      if(l_value > maxValue)
        maxValue = l_value;
    }
    return ok("" + maxValue);
  } else if (domain.equals(AttributeDomain.Ordinal.toString())){
    String maxValue = "";
    if (scaleOrder.equals(ScaleOrders.HigherIsBetter.toString())){
      int currentRank = -1;
      for (String value : attributeInstances.values()){
        if (allowedValues.get(value) > currentRank) {
          currentRank = allowedValues.get(value);
          maxValue = value;
        }
      }
    } else if (scaleOrder.equals(ScaleOrders.LowerIsBetter.toString()))
      {
      int currentRank = Integer.MAX_VALUE;
      for (String value : attributeInstances.values()){
        if (allowedValues.get(value) < currentRank) {
          currentRank = allowedValues.get(value);
          maxValue = value;
        }
      }
    }
    return ok(maxValue);
  }
  return badRequest("Only use with cardinal and ordinal attributes!");
}
```

Listing C.17: CSAP: Maximum Service (Aggregation Service)

C.7.3. Majority Vote

```java
public static Result majorityVote(Long aId){

  //Get the current Attribute
  String endpointURL = CSPUtil.URL + "api/attributes/" + aId;
  String result = CSPUtil.invokeService(endpointURL);
  ObjectMapper mapper = new ObjectMapper();
  JsonNode attributeNode = mapper.readTree(result);

  //Check if exists
  if(attributeNode == null)
    return badRequest("No such attribute");

  //Get Attribute Instances
  Map<Long, String> attributeInstances = new HashMap<>();
  for(JsonNode ai : attributeNode.get("attributeInstances")){
    attributeInstances.put(
      ai.get("id").longValue(),
      ai.get("value").asText());
  }

  //Count Votes for each value
  Map<String,Integer> votes = new HashMap<>();
  for (String value : attributeInstances.values()){
    if (votes.keySet().contains(value)) {
      int currentVotes = votes.get(value) + 1;
      votes.put(value, currentVotes);
    }
    else {
      votes.put(value, 1);
    }
  }

  //Determine Value with most Votes
  String valueWithMostVotes = "";
  int votesForValue = 0;
  for (String key: votes.keySet()) {
    if (votes.get(key) > votesForValue) {
      valueWithMostVotes = key;
      votesForValue = votes.get(key);
    }
  }
  // Return value with most votes
  return ok(valueWithMostVotes);
}
```

Listing C.18: CSAP: Majority Vote Service (Aggregation Service)

C.7.4. Latest Service

```
public static Result latest(Long aId){

  //Get the current Attribute
  String endpointURL = CSPUtil.URL + "api/attributes/" + aId;
  String result = CSPUtil.invokeService(endpointURL);
  ObjectMapper mapper = new ObjectMapper();
  JsonNode attributeNode = mapper.readTree(result);

  //Get Attribute Instances
  Date latest = null;
  String latestValue = "";
  for(JsonNode ai : attributeNode.get("attributeInstances")){
    String dateAsText = ai.get("date").asText();
    Date current = CSPUtil.DATE_FORMATTER.parse(dateAsText);
    if(latest == null){
      latest = current;
    } else if(current.after(latest)){
      latest = current;
      latestValue = ai.get("value").asText();
    }
  }

  if(latest == null)
    return badRequest("No such attribute (id:" + aId + ")");

  return ok(latestValue);
}
```

Listing C.19: CSAP: Latest Service (Aggregation Service)

C.8. Intepretation Services

C.8.1. Participants Counter

```
public static Result participantsCounter(Long aId){

    //Get Attribute
    String endpointURL = CSPUtil.URL + "api/attributes/" + aId;
    String result = CSPUtil.invokeService(endpointURL);

    //Get StandardId from JSONResponse
    ObjectMapper mapper = new ObjectMapper();
    JsonNode response = mapper.readTree(result);
    Long standardId = response.get("standard_id").longValue();

    //Get Standard
    endpointURL = CSPUtil.URL + "api/standards/" + standardId;
    response = mapper.readTree(CSPUtil.invokeService(endpointURL));

    //Parse unique Stakeholders
    Set<Long> uniqueIds = new HashSet();
    for(JsonNode stakeholder : response.get("stakeholders")){
        Logger.debug("stakeholder = " + stakeholder);
        uniqueIds.add(stakeholder.get("id").longValue());
    }

    //Return amount of unique stakeholders
    return ok("" + uniqueIds.size());
}
```

Listing C.20: CSAP: Participants Counter (Interpretation Service)

C.8.2. Market Potential Analyzer

```
public static Result marketPotentialAnalyzer(Long aId){

  //Get the current Attribute
  String endpointURL = CSPUtil.URL + "api/attributes/" + aId;
  String result = CSPUtil.invokeService(endpointURL);
  ObjectMapper mapper = new ObjectMapper();
  JsonNode aNode = mapper.readTree(result);

  //Get Standard
  Long sId = aNode.findValue("standard_id").longValue();
  endpointURL = CSPUtil.URL + "api/standards/" + sId;
  JsonNode sNode = mapper.readTree(
    CSPUtil.invokeService(endpointURL));

  //Get Attribute Type
  Long aT = aNode.findValue("attribute_type_id").longValue();
  endpointURL = CSPUtil.URL + "api/attributeTypes/" + aT;
  JsonNode aTNode = mapper.readTree(
    CSPUtil.invokeService(endpointURL));

  //Get Related Attribute's Value
  ///Get Ids of related AttributeTypes
  Set<Long> relATs = new HashSet<>();
  for(JsonNode relatedAT : aTNode.get("relatedAttributeTypes")){
    relATs.add(relatedAT.get("id").longValue());
  }

  //Get their values
  List<JsonNode> relAs = new ArrayList<>();
  for (Long aTId : relATs){endpointURL = CSPUtil.URL
      + "api/attributes/standards/" + sId
      + "/type/" + aTId;
    JsonNode relatedAttribute = mapper.readTree(
      CSPUtil.invokeService(endpointURL));
    relAs.add(relatedAttribute);
  }

  //There should only be one attribute, so get first
  int stakeholders = relAs.get(0).findValue("value").asInt();
  int implementations = sNode.get("implementations").size();

  // Calculate value
  result = "low";
  if (stakeholders > 10 && implementations > 5) {result = "high";}
  else if (stakeholders > 5 && implementations > 1) {result = "middle";}
  return ok(result);
}
```

Listing C.21: CSAP: Market Potential Analyzer (Interpretation Service)

D. Supplements to Smart Grid Standards Assessment

Standards Information Form (SIF)

A	*Identification and Affiliation*
1	Identifier of the standard
2	Title of the standard
3	Name of owner organization
4	Latest versions, stages, dates
5	URL(s) for the standard
6	SSO Working Group / Committee responsible for the standard
7	Original source of the content (if applicable)
8	Brief description of scope
9	Priority Action Plan (PAP) working with this standard (if established by SGIP)
B	*Level of Standardization*
1	Names of standards development organizations that recognize this standard and/or accredit the owner organization
2	Has this standard been adopted in regulation or legislation, or is it under consideration for adoption?
3	Has it been endorsed or recommended by any level of government? If "Yes", please describe
4	Level of Standard (check all that apply)
5	Type of document
6	Level of Release
C	*Conceptual Model Areas of Use*
1	Currently applies to which domains? (check all that apply)
2	Planned for use in which domains? (check all that apply)
3	Please describe the Smart Grid systems and equipment to which this standard is applied
D	*Relationship to Other Standards or Specifications*
1	Which standards or specifications are referenced by this standard?
2	Which standards or specifications are related to this standard?
3	Which standards or specifications cover similar areas (may overlap)?
4	What activities are building on this work?

Table D.1.: SGIP SIF: Part One

E	*Dept of Energy Smart Grid Characteristics*
1	Enables informed participation by customers
2	Accommodates all generation and storage options
3	Enables new products, services and markets
4	Provides the power quality for a range of needs
5	Optimizes asset utilization and operating efficiency
6	Operates resiliently to disturbances, attacks, and natural disasters
F	*Priority Areas Previously Mentioned by FERC and NIST*
1	Cybersecurity and physical security
2	Communicating and coordinating across inter-system interfaces
3	Wide area situational awareness
4	Smart grid-enabled response for energy demand
5	Electric storage
6	Electric vehicle transportation
7	Advanced metering infrastructure
8	Distribution grid management
G	*Standards Development Process*
1	Amount of fee (if any) for the documentation
2	Amount of fee (if any) for implementing the standard
3	Amount of fee (if any) to participate in updating the standard
4	Is the standard documentation available online?
5	Are there open-source or reference implementations?
6	Are there open-source test tools?
7	Would open-source implementations be permitted?
8	Approximately how many implementers are there?
9	Approximately how many users are there?
10	Where is the standard used outside of the USA?
11	Is the standard free of references to patented technology?
12	If patented technology is used, does the holder provide a royalty-free license to users of the standard?
13	Can an implementer use the standard without signing a license agreement?
14	Are draft documents available to the public at no cost?
15	How does one join the working group or committee that controls the standard?
16	Is voting used to decide whether to modify the standard? If Yes, explain who is permitted to vote.
17	What type of process is used (check all that apply)?
18	What countries are represented in the working group or committee that controls the standard?
19	Is there openness
20	Does the standard ballot process ensure balance of interests
21	Is there due process?
22	Is there an appeals process?
23	Does the process seek to achieve consensus?
24	The SSO's IPR Policy documents (including policies, bylaws, process documents, lists of defined terms and guidance documents published by the SSO) applicable to the Standard, as provided by the SSO. Insert hyperlink here or otherwise provide the SGIP with such documentation in electronic form.

Table D.2.: SGIP SIF: Part Two

G	*Standards Development Process (Cont'd)*
25	The SSO's Information, if any, regarding IPR-related Disclosures and Licensing applicable to the Standard (to the extent this information is publicly available), as provided by the SSO. Insert hyperlink here or otherwise provide the SGIP with such documentation in electronic form.
26	With regard to the Standard, did any entity notify the SSO in writing that it holds a Necessary Patent and it is not willing to provide licenses in accordance with the SSO's IPR Policy? If yes, please insert hyperlink here or otherwise provide the SGIP with such documentation in electronic form.
27	Does the SSO have any information in writing regarding any published licensing program(s) (such as published licensing terms or a patent pool) where Necessary Patents with regard to the Standard are included? If yes, please insert hyperlink here or otherwise provide the SGIP with such documentation in electronic form.
28	With regard to the Standard, did the SSO receive any notification in writing that any Necessary Patents were developed with government funding? If yes, please insert hyperlink here or otherwise provide the SGIP with such documentation in electronic form.
H	*Support, Conformance, Certification and Testing*
1	Is there a testing and certification authority operating a program in support of this standard? If yes, provide program name in the comments column.
2	Is there a testing and certification authority in development to support this standard? If yes, provide program name in the comments column.
3	Are test programs supporting this standard focused on conformance, interoperability (or both)?
4	Are there test laboratories offering conformance and/or interoperability testing services based on this standard? If yes, provide examples of labs providing these services.
5	Does the testing and certification authority implement the SGTCC Interoperability Process Reference Manual (IPRM) recommendations. Select Not Applicable if there is no existing testing and certification authority.
6	Are there products certified (by an ISO 65 accredited organization) against this standard commercially available?
J	*Notes*
1	Please present here any additional information about the standard that might be useful:
K	*GridWise Architecture: Layers*
1	Layer 8: Economic/Regulatory Policy
2	Layer 7: Business Objectives
3	Layer 6: Business Procedures
4	Layer 5: Business Context
5	Layer 4: Semantic Understanding information model)
6	Layer 3: Syntactic Interoperability (OSI layers 5-7)
7	Layer 2: Network Interoperability (OSI layers 3-4)
8	Layer 1: Basic Connectivity (OSI layers 1-2)

Table D.3.: SGIP SIF: Part Three

L	*GridWise Architecture: Cross-Cutting Issues*
Shared Meaning of Content	
1	Do all implementations share a common information model?
2	Can data be arranged and accessed in groups or structures?
3	Can implementers interoperably extend the information model?
4	Can implementers interoperably use a subset of the information model?
Resource Identification	
5	Can data be located using human-readable names?
6	Can names and addresses be centrally managed without human intervention?
	Time Synchronization and Sequencing
7	Can the standard remotely synchronize time?
8	Can the standard indicate the quality of timestamps?
Security and Privacy	
9	Does the standard address cybersecurity?
10	If not, why is cybersecurity not addressed?
11	What aspects of cybersecurity does the standard not address? Which of these aspects should it address? Which should be handled by other means?
12	What work, if any, is being done currently or is planned to address the gaps identified above?
13	Does the standard facilitate logging and auditing of security events?
14	Where is privacy provide [sic!] for this standard?
Logging and Auditing	
15	Does the standard address logging and auditing of critical operations and events?
16	Can the standard gather statistics on its operation?
17	Can the standard address reporting of alerts, events, and warnings?
	Transaction State Management
18	Can the standard remotely enable or disable devices or functions?
System Preservation	
19	Can the standard automatically recover from failed devices or links?
20	Can the standard automatically re-route messages?
21	Can the standard remotely determine the health (as opposed to just connectivity) of devices or software?
22	Does the standard enhance Dependability
23	Does the standard enhance Availability
Other Management Capabilities	
24	Please describe any other system or network management capabilities the standard provides.
Quality of Service	
25	Is data transfer bi-directional?
26	Does the standard enable prioritization for executing communications Quality of Service?
27	What types of reliability are provided?
28	Does the standard enable multicast or broadcast functions?
29	Please describe any other methods the standard uses to manage quality of service.

Table D.4.: SGIP SIF: Part Four

L	*GridWise Architecture: Cross-Cutting Issues (Cont'd)*
Discovery and Configuration	
30	Can the software or firmware be upgraded remotely?
31	Can configuration or settings be upgraded remotely?
32	Can implementations announce when they have joined the system?
33	Can implementations electronically describe the data they provide?
System Evolution and Scalability	
34	What factors could limit the number of remote devices or number of networks supported?
35	What steps are required to increase the size of a system deploying this standard?
36	Is the information model separate from the transport method?
37	Does the standard support alternate choices in the OSI layers(s) below it?
38	List the most common technology choices for layers implemented below this standard
39	Does the standard support multiple technology choices in the layers above it?
40	List the technologies or entities that would most commonly use this standard in the layer above
41	Please describe any mechanism or plan to ensure the standard is as backward-compatible as possible with previous versions
42	Please describe how the design of this standard permits it to be used together with older or legacy technologies. Were there any changes that limit the integration of previous versions (e.g. addressing changes, information model changes, ontology changes,...)
43	Please describe how the design of this standard permits it to co-exist on the same network or in the same geographic area with similar technologies, and give examples
Electromechanical	
44	Does the standard deal with Electromagnetic Compatibility (EMC)
45	Does the standard deal with Electromagnetic Field (EMF)
46	Does the standard deal with Safety
47	Does the standard define physical characteristics
M	*Architectural Attributes*
1	Does the standard enable the exchange of meta data?
2	Does the standard enable the integration of non-functional requirements?
3	Does the standard have an integration pathway or migration across domains?
4	Is the standard part of a harmonization development with other key standards?
5	Is the standard part of a development effort under an architectural framework? Frameworks include but are not limited to IEC TC 57 Architecture, IEEE P2030, TOGAF, RM-ODP, Service Oriented Architecture, Zachman, or other.

Table D.5.: SGIP SIF: Part Five

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