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ORIGINAL ARTICLE

Data standards quality measured for achieving enterprise interoperability: the case of the SETU standard for flexible staffing

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Abstract Data standards should play an important role in achieving inter-organizational interoperability. Millions are spent on development and adoption of these standards, but does it lead to interoperability? This important question is often not addressed. In this study data interoperability in the Dutch temporary staffing industry is studied by focusing on the quality of the SETU standard and its implementations in practice. The Stichting Elektronische Transacties Uitzendbranche (foundation for electronic transactions in the staffing industry) or SETU, develops and maintains standards for exchange of electronic data in the staffing industry. Our results show that although the SETU standard is equipped for achieving interoperability, this in practice has not been achieved due to low quality implementations. We raise the question why these studies are not being performed on every standard. Another result is that localizations (profiles) may be needed for

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high quality standards; without localizations interoperability is limited in the SETU case.

Keywords Data standards · Standardization · Interoperability · Quality

1 Introduction

Achieving interoperability in many industries is challenging but has great impact. Studies of the US automobile sector, for example, estimate that insufficient interoperability in the supply chain adds at least one billion dollars to operating costs, of which 86 % is attributable to data exchange problems (Brunnermeier and Martin 2002). Later studies mention 5 billion dollars for the US automotive industry and 3.9 billion dollars for the electro technical industry, both representing an impressive 1.2 % of the value of shipments in each industry (Steinfield et al. 2011). The adoption of standards to improve interoperability in the automotive, aerospace, shipbuilding and other sectors could save billions (Gallaher et al. 2002).

The already huge importance of standards and interoperability will continue to grow. Networked business models are becoming indisputable reality in today's economy (Legner and Lebreton 2007). A recent Capgemini study concludes that to be ready for 2,020 companies need to "significantly increase their degree of collaboration as well as their networking capability" (Falge et al. 2012).

Standards are important for ensuring interoperability (Rada 1993). "Standards are necessary both for integration and for interoperability" (Dogac et al. 2008). "Adopting standards-based integration solutions is the most promising way to reduce the long-term costs of integration and facilitate a flexible infrastructure" (Chari and Seshadri 2004). Some go even further: "Inter-organizational collaboration requires systems interoperability which is not possible in the absence of common standards" (Gerst et al. 2005). And the potential of standards, in relation to the problematic introduction of proprietary solutions, is shown in a case study from the automotive industry (Steinfield et al. 2011).

There is hardly any research on the achievements of data standards in achieving interoperability. A survey among Data standards organizations shows that the vast majority believe that their standards can be improved, and that improvements will lead to more interoperable systems. However, standard developers need statistical support to find the needed improvements (Folmer et al. 2011).

2 Background

2.1 Interoperability explored

Like standards, interoperability is a concept with many different meanings. A study on interoperability definitions found 22 different meanings (Kosanke 2006). An often-used definition is the definition from "Interoperability is the ability of two or more systems or components to exchange information and to use the information

that has been exchanged" (Legner and Lebreton 2007; Rukanova et al. 2006). Another often-used definition is from the U.S. Department of Defense in their LISI (Levels of Information Systems Interoperability): The ability of systems, units, or forces to provide services and accept services from other systems (Legner and Lebreton 2007).

Based on a comparison of different definitions, Van Lier (2009) concludes that interoperability deals with agreement making on three levels: Technical (technical exchange), semantic (content and meaning) and context (interpretation, processing, apply).

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

- *Technical* Interconnecting computer systems and services on a technical level (e.g. data integration, message transfer, and network).
- *Semantic* Creating a common understanding and guaranteeing process ability of exchanged information in a "meaningful manner" (e.g. data processing, data standards).
- *Organizational* Definition of cross-organizational business goals and business process modeling (e.g. administrative issues, collaboration agreements).

Based on the original EIF, but with an additional distinction between technical and syntactic layers, Kubicek and Cimander (2009) arrived at a four level interoperability approach similar to ETSI's approach (Van der Veer and Wiles 2006), by adding a syntactic layer (processing of received data) between technical and semantic. Pragmatic interoperability, the effect of data exchange, is sometimes used in combination with semantic interoperability as well (Asuncion and Van Sinderen 2010).

2.2 Data standards defined

Data (exchange) standards reside at the presentation and application layer of the OSI model (Steinfield et al. 2007). They include business transaction standards, inter-organizational information system (IOS) standards, semantic (information system) standards, ontologies, vocabularies, messaging standards, document-based, e-business, horizontal (cross-industry) and vertical industry standards. The often used examples are RosettaNet for the electro technical industry, HealthLevel7 for the health care domain, HR-XML for the human resources industry and Universal Business Language (UBL) for procurement. Data standards are designed to promote communication and coordination among organizations; these standards may address product identification, data definition, business document layout, and/or business process sequences (adapted from Steinfield et al. 2007).

The core of the data standard is often its specification document but there is more. Earlier work (Otto et al. 2011) shows that characteristics of a data standard include its context, the content, the development and maintenance approach, and the application aspects of the standard. The full characteristics model of a data standards is depicted in Fig. 1.

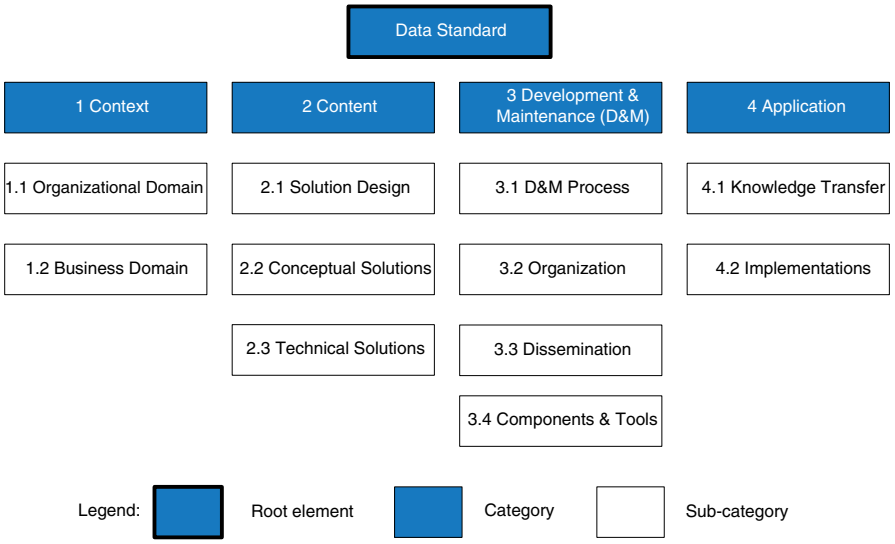

Fig. 1 Characteristics model of a data standard [adapted from (Otto et al. 2011)]

2.3 Data standards and quality frameworks

The literature on data (exchange) standards is often related to case studies regarding the adoption of the standard (Folmer et al. 2009). For example, the adoption of STEP (Thomas et al. 2008), MISMO (Markus et al. 2006) and RosettaNet (Boh et al. 2007). These case studies cover mainly knowledge about the development and adoption/diffusion process of standards, but also point out that these data standards are different to other kind of standards. Eg, Based on a case study, Steinfield et al. (2007) points out that specifically for data standards, ongoing maintenance is of huge importance, since the user requirements of the industry domain can change often in order to react to a flexible environment.

As standards are a means to an end, that is, interoperability, a general assumption is that a good standard will improve interoperability. Surprisingly, the question as to what makes a standard good is relatively rarely elaborated in standardization literature (De Vries 2007). However, Markus et al. (2006) note that a standard's technical content will have an impact on the standard's diffusion. However, diffusion or adoption involves acceptance and implementation, and does not necessarily mean that interoperability will be achieved. In other words, not all successful standards (high adoption) are high-quality standards that lead to interoperability.

To overcome the gap of quality related to data standards, Folmer (2012) developed a quality model for data standards that consists of three parts: product quality, process quality, and the quality in practice. This maps the previous described characteristics model of a data standard since product quality deals with the content (the specification), the process quality relates to the development and

maintenance processes as carried out by the development organization, whereas quality in practice deals with the application context, the performance of the implementations of the standard.

Dependent on the information needs in practice, only parts of the quality model have to be used. For example the following information needs can be mapped onto the three parts above (Fig. 2) accordingly:

1. The internal quality of the standard?—Part A
2. The implementability of the standard?—Part A + B
3. The durability (future-proofness) of the standard?—Part B + A (partly)
4. Should I select the standard?—Mainly part C
5. Does the application of the standard lead to interoperability? (Part C)
6. Is the standard a good solution for the interoperability problem?—All parts

Since this research focuses on quality in practice (question 5), we list the measurable concepts for quality in practice in Table 1.

2.4 Quality measured in application: relevance and completeness

This quality in practice model contains many quality aspects to be measured. Key is to perform this measurement in a way that leads to valuable results. In this section we focus on two elements, completeness (C2.2.3) and relevance (C2.2.4) from the model and describe how this can be measured.

Zhu and Wu have introduced how relevance and completeness can be measured in standards' implementations (Zhu and Fu 2009; Zhu and Wu 2010, 2011). The completeness and relevancy of the same data standard can be different to different users. Further, they can be different between an individual user and the user

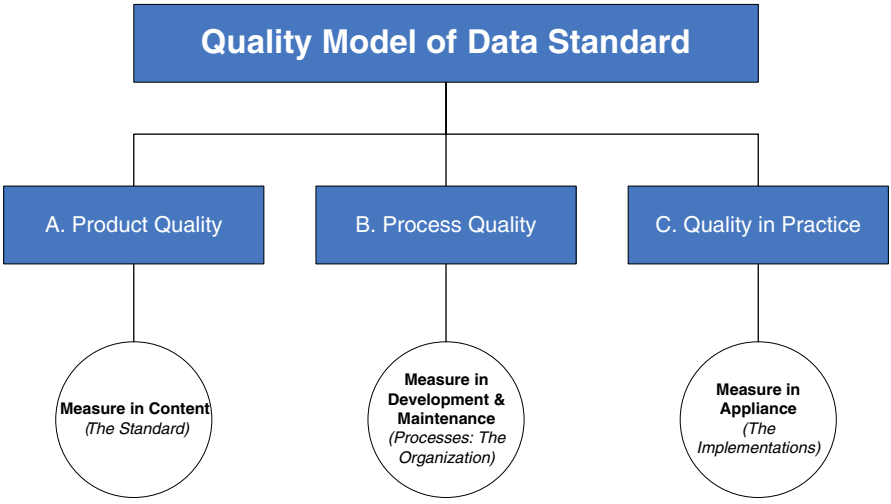

Fig. 2 Structure of the quality model for data standards (Folmer 2012)

Table 1 Measurable concepts of quality in practice

Measurable concept	Definition
C. Quality in practice	The extent to which a standard can be used by specified users to meet their needs to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use. (ISO 14598)
C1. Acceptance	The adoption of the standard within the domain
C1.1 Solution providers	The extent to which solutions providers have adopted the standard
C1.1.1 Implementations in end user products/services	The level of implementations in the products and services offered by solution providers and to be used by end users
C1.1.2 Availability of implementation support tools	The availability of tools and components that can be used to simplify implementations of the standard
C1.1.3 Availability of implementation support	The availability of consultants, and implementation partners as a support for implementation
C1.2 End users	The extent to which the end users have adopted the standard
C1.2.1 Market penetration	The level of usage within the intended end user audience
C1.3 Recognition	The extent to which the standards receive external recognition
C1.3.1 Recognition achievements	The external formal recognition of the standard
C2. Interoperability	The ability of two or more systems or components to exchange information and to use the information that has been exchanged. (Legner and Lebreton 2007)
C2.1 Maturity	The capability of the standard to be a stable and proven solution
C2.1.1 Stability	A stable release schema means ample time in between releases
C2.1.2 Changes per release	The number of changes that have been made to the standard
C2.1.3 Versions in use	The number of versions that are concurrently in use
C2.1.4 Life cycle	The stage of the standard in the life cycle model of standards, but also inclusion of the timing in the market
C2.2 Correctness	Extent to which an implementation of a standard satisfies its specifications and fulfills the user's mission objectives. (McCall et al. 1977)
C2.2.1 Interoperable implementation	The level of interoperability that is achieved by the current implementations
C2.2.2 Fault tolerance	The degree to which the standard supports free of disturbances when minor deviations occur. (Delen and Rijsenbrij 1992)

Table 1 continued

Measurable concept	Definition
C2.2.3 Completeness elements	The extent to which the data standard specifies all the data elements needed by the standard user. (Zhu and Wu 2011)
C2.2.4 Relevancy elements	The extent to which the data of the standard only specifies the data elements needed by users of the standard. (Zhu and Wu 2011)
C2.3 Cost and benefits	The extent to which the benefits cover the costs of standardization
C2.3.1 Value added	The extent to which a standard is beneficial and provides advantages when used. (Kahn et al. 2002)
C2.3.2 Cost-effectiveness	The extent to which the cost of collecting appropriate knowledge and implementing the standard is reasonable. (Wand and Wang 1996)

community. To formalize the metrics, let the S be the set of data elements specified in the data standard, U_i be the data elements required by the user i. From the user i's perspective, the metrics can be defined as (Zhu and Wu 2010)

$$Completeness_i = \frac{|U_i \cap S|}{|U_i|}, \text{ and } Relevancy_i = \frac{|U_i \cap S|}{|S|}$$

From the user community's perspective, the metrics can be defined as

$$Completeness_c = \frac{\left|\left(\bigcup_i U_i\right) \cap S\right|}{\left|\bigcup_i U_i\right|}, and\ Relevancy_c = \frac{\left|\left(\bigcup_i U_i\right) \cap S\right|}{|S|}$$

Although the concept of completeness and relevancy is a limited, incomplete view on standard quality, it is an important contribution since it is the only notion of quality in practice that can be objectively measured using a large number of data instances.

Zhu and Wu focused on the standard of public financial reporting in US based on US-GAAP (United States Generally Accepted Accounting Principles). This reporting standard is one of the most important standards based on Extensible Business Reporting Language (XBRL). Thousands of companies are mandated to report quarterly and annual financial reports to US Stock and Exchange Commission, using the US-GAAP XBRL standard. Applying automated tools to thousands of public financial reports, Zhu and Wu were able to perform a series of analyses on the quality of US-GAAP XBRL standard and interoperability of public financial reports, including trend and industry-based analyses. Most importantly, Zhu and Wu's studies produced a number of practical suggestions to both the standard defining body and standard users/implementers (i.e. the individual reporting companies), which may substantially improve standard compliance and data interoperability.

The XBRL standard in Zhu and Wu's studies are used in financial reports, which are relatively static information. No researchers have yet studied the quality of electronic standards used for dynamic business processes, using similar implementation-based metrics.

2.5 Other quality aspects related to XML-based syntax

Nowadays most data standards are ultimately expressed in the technical format of XML (Nelson et al. 2005). The XML (eXtensible Markup Language) 1.0 specification was introduced in 1998 by the World Wide Web Consortium (W3C) and was designed to improve the functionality of Internet by providing flexible information structuring (Nurmilaakso and Kotinurmi 2004). An XML document can be validated against an XML schema (XSD) that is included or referenced from the XML document. XML Schema Definition Language is an XML language for describing the valid structure of XML documents (Nurmilaakso and Kotinurmi 2004).

Although the technical format is a representation of the content of the semantic standard it still might be useful as an indicator of the quality of the semantic standard.

Based on ISO 9126, a set of XML Schema metrics were developed to measure the quality of the XML Schema and the exploitation of advanced features of XML Schema. These are (McDowell et al. 2004):

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

Based on these 11 metrics two indices have been set up: Complexity and Quality. Element fanning is the average of the number of child elements and number of references each element has. Each of those measures are indicators of quality and complexity: for instance a large number of Complex Type Declarations will indicate a complex XML Schema, while a large number of annotations will indicate a well-documented XML Schema.

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

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

To improve the effectiveness and interoperability of standards, conformance testing tools and "use profiles" based on customization rules are recommended (Brutti et al. 2011). Customization rules deal with identifying subsets for specific context, coding of values, declaration of rules for context dependent data structures and constraints arising from data dependencies. Customization rules depending on the dynamic execution of the data exchange are related to constraints based on the role of the actors involved, or based on the position of the current transaction in the running business process (Brutti et al. 2011).

Another practical measure is to check if all tags used in the XML Schemas are listed in the data dictionary (Table 2). Based on a study of 26 semantic standards it was found that 15 % of the tags are not listed (Bedini et al. 2011). For the Danish government some quality indicators have been gathered, to a large extent related to XML specifics (Gottschick and Restel 2010).

Technically speaking, the following 'common sense' recommendations can be made related to XML based on literature:

1. Reduction of XML Schema elements in the library (delete unused components, and refine cardinalities) makes it much easier to manage and understand (Brutti et al. 2010).
2. Definition in the library, using the Schematron code, of constraints that are common for multiple standards (XML Schemas) (Brutti et al. 2010).

Table 2 Quality indicators XML related (Gottschick and Restel 2010)

Name	Document	Bad smell description
NDRs	XML schema	Evaluates violations against OIOXML naming and design rules
Spelling	Free text	Evaluates spelling weakness in free text
Readability	Free text	Evaluates the readability using the "Flesch-Kincaid Reading Ease Score"
Documentation coverage	XML related	Evaluates comment coverage in XML and XML Schema documents
Formatting rules	XML, RFC	Evaluates violations against predefined format rules (e.g. after RFC 2223 or W3C Pubrules)
Namespace rules	XML Schema	Evaluates missing namespace declarations in XML schema documents
Unfinished documents	Free text, XML	Evaluates unfinished documents by checking for keywords like "todo", "fixme", etc.
Modularization	XML related	Evaluates poor modularisation (e.g. detects too long XML files)

3. If a standard is encoded in XML Schema then its syntax and semantics must conform to W3C XML Schema specification (Kulvatunyou et al. 2008).
4. Best practices like the UN/CEFACT naming and design rules (NDR) to be used (Kulvatunyou et al. 2008).

Tools for testing the XML design are available. For instance the XML Schema Quality of Design (QOD) developed by NIST.

3 The SETU standard

SETU stands originally for the Stichting Elektronische Transacties Uitzendbranche (foundation for electronic transactions in the staffing industry). The SETU standard is a Data standard trying to achieve interoperability among different actors in the business processes related to flexible staffing. The staffing industry consists of a large number of customers and suppliers, and increasingly relies on electronic transactions.

The SETU standard has been acclaimed by the Dutch government for achieving interoperability within the process of hiring temporary staffers through staffing organizations. Since May 2009, SETU is listed on the "comply or explain" list, which means that every (semi) public organization in the Netherlands has to comply with using the SETU standard when ordering temporary staffing electronically. The endorsement of the Dutch government suggests that SETU is expected to be of high quality.

SETU is a set of specifications, including XML Schemas, for amongst others assignments, timecards, and invoices related to temporary staffing. It is a Dutch localization of the international HR-XML standard. SETU standardizes additional rules on top of HR-XML, and thereby limits the options within HR-XML. An instance that validates correctly with HR-XML does not necessarily comply with

SETU. However the other way around is always true: Each instance that is SETU compliant is compliant to HR-XML as well.

Since SETU uses the same XML Schema files as HR-XML does, the additional rules are captured within text (the SETU specifications) and the business rules in Schematron. The SETU standard comprises of different sub-standards. Our focus is on SETU Standard for Invoicing Version 1.1, and SETU Standard for Reporting Time and Expenses 1.1, both of which are freely available at www.setu.nl.

4 Research approach

On a high level we want to know if we can assess the quality of the standard by assessing the implementations of the standard. We study this question by performing a case study on the SETU standard. We selected this standard because it is important to workforce mobility and integration, and highly acclaimed for its quality, adoption success and business savings. Our main research question is: What is the quality of the SETU *standard in practice*? In particular does the SETU standard lead to interoperability?

Our second research aim is to study whether this implementation measuring approach is useful in identifying improvement suggestions for data standards. In this specific case we will identify improvement suggestions for the SETU standard. In other words, can our approach be used as quality assessment instruments much requested by standard developers (Folmer et al. 2011)?

We select from the quality model three factors: Interoperable Implementations (C2.2.1), Completeness of Elements (C2.2.3) and Relevancy of Elements (C2.2.4). Although more factors, and even others, could have been selected, we select these mainly because of the fact that the first factor test the interoperability of the implementation, while the latter two test the role of the standard (the specification) in achieving that interoperability. Other reasons include the tangible and objective measurement of these factors, and the availability of implementation data. Two of the authors have been involved in developing the SETU standards.

To be able to answer the research questions we have to analyze the implementations of the SETU standard and search for (avoidable) errors that negatively affect the quality of both the standard and implementations. The SETU standard has to be compared with other standards in terms of quality but so far only quality results from XBRL are readily available for comparison.

Our approach of selecting a set of factors, and not aiming for the full set, may lead to an incomplete view on the SETU quality. But following the usage process of the quality model (Folmer 2012), our approach will lead to a certain perspective on quality, and also support us in answering the second research question: the usefulness of this quality measurement approach.

4.1 Data collection

For our research approach we need to collect data from SETU implementations. Since SETU is only intended for the Dutch market we choose to ask the four largest

temporary staffing organizations, which include the two dominant players in the Netherlands with the biggest market share: Randstad and USG. Although by doing this we get the data from the largest implementation in industry responsible for by far the largest amount of actual data exchanges. But this sample from the four largest companies is not representing the whole set of SETU implementations, especially not the ones related to small and medium enterprises. Most of these smaller players work together with commercial off-the-shelf system providers. Therefore we decided to collect data from the three system providers that advertise themselves about having SETU implemented in their system. These system provider implementations represent many implementations among small and medium staffing organizations and customers using these three systems.

Data of four large staffing organizations has been gathered, just as the data from 3 system providers, which all have been anonymized. In total 54 "messages" have been gathered including 32 timecards and 22 invoices. These messages are instantiations based on the SETU standards: For instance a specific invoice for worker X, week Y, sent by staffing organization A to staffing customer B. The data then contains invoices from staffing organizations to staffing customers. There is some overlap in data, since the staffing customer may overlap for different instantiations of staffing organizations. Also, some staffing organizations make extensive use of system providers. Therefore the data gathered from the system providers may include the same data received from a staffing organization.

We included data from all SETU implementations to our knowledge. Although we can only guess about what we don't know, there might be a small number of implementations that we are not aware of. Still we are quite confident that this data represents the great majority of SETU implementations.

4.2 Validation process

As first step we decided to take one set of message: the invoices. From our data set 22 are invoices, of which 2 have the same system-staffing organization—staffing customer configuration and will therefore have the same characteristics. These two have been removed from the data set. Our approach consisted then of 3 steps:

1. Validate the messages in the SETU eValidator. This Validation Service is available at www.setu.nl and validates the instances three way: (a) XML well-formedness, (b) XML Schema validation and (c) Business Rules validation. The last is a set of Schematron expressions that has been set up by the SETU organization that encapsulates additional rules described in the SETU specification that cannot be validated with XML Schema.
2. Count and check the usage of elements within the implementations; by doing that we find frequently used or totally unused elements.
3. Analyze and calculate metrics. In this step we analyze previous results and calculate error percentages and the completeness and relevance metrics.

Step 1 is the measurement of interoperable implementations (C2.2.1), while step 2 and 3 are needed for the measurement of completeness and relevance (C2.2.3 and

C2.2.4). After finalizing these steps for the invoice data, we repeat the same steps for the timecard data.

5 SETU measurement results for the invoice standard

This section contains the results of the measurement of the SETU invoice implementations. We will start by explaining the validation results, followed by looking at more details into the data elements. Next we will discuss the results on relevance and completeness metrics. Finally we also present in summary the results of the same analyse but then for the timecard standard.

5.1 Validation errors

Table 3 contains the validation results. For each usage scenario (such as StaffinOrg1 invoicing StaffingCustomer1), the numbers of XML structure errors, HR-XML schema validation errors and SETU business rules errors are counted. Although most errors are counted by occurrences, when structure errors occur the tool may exit immediately and therefore a yes/no is used for scoring.

5.1.1 Validation data explanation

The * denotes the fact that due to schema errors the business rules validation was cancelled. We collected more invoices from System implementations, but since they have the same errors we excluded them from the data set. This is logical since as long as invoices are created by the same system, even if we collect 1, 10 or 1,000 instances of the invoice, they will all have the same errors. System 2 is excluded from this set because it has only timecards implemented and no invoices.

The data gathered from an organization often contain the same characteristics and errors. For example Staffing Organization one succeeded in their implementation in avoiding schema errors. StaffingOrg 4 has 16 schema errors which are in fact the same error repeated in many places. It shows that the number of errors in itself is not always useful. For instance if the amount is missing on an invoice line, and there are 20 invoice Lines, it will count as 20 rule errors.

Above explanations show that the analysis is valuable, however carefulness is needed when quantifying measurements.

5.1.2 Validation data analysis

It is valuable to summarize the numbers of implementations that have or have not errors. Below are some statistics:

- 1 out of 20 is not well-formed, and has basic structure errors
- 5 out of 20 have basic XML Schema errors and do not validate against schema
- 19 out of 19 (100 %) have Business Rules errors and do not comply to the SETU standard

Table 3 Validation results for SETU invoices

#	Usage scenario (invoice type)	Structure errors	Schema errors	Rule errors	Total errors
1	StafOrg1-StafCust1	No	0	2	2
2	StafOrg1-StafCust2	No	0	2	2
3	StafOrg1-StafCust3	No	0	2	2
4	StafOrg1-StafCust4	No	0	2	2
5	StafOrg1-StafCust5	No	0	2	2
6	StafOrg1-StafCust6	No	0	2	2
7	StafOrg2-StafCust1	No	0	3	3
8	StafOrg2-StafCust2	No	0	1	1
9	StafOrg2-StafCust3	No	0	3	3
10	StafOrg2-StafCust4	No	0	3	3
11	StafOrg3-StafCust3	No	1	2	3
12	StafOrg3-StafCust4	No	11	14	25
13	StafOrg4-StafCust1	No	0	4	4
14	StafOrg4-StafCust2	No	0	4	4
15	StafOrg4-StafCust3	No	16	4	20
16	System1-StafOrg1-StafCust1	No	0	2	2
17	System1-StafOrg1-StafCust2	No	0	2	2
18	System1-StafOrg2-StafCust3	No	0	2	2
19	System1-StafOrg3-StafCust4	No	1	–*	1*
20	System3-StafOrg1-StafCust1	Yes	7	3	10
	Invoice errors		36	59	95

The first two statistics may vary upon sample data sets, but it is remarkable that these errors exist at all in practice. The fact that 100 % contain business rules errors and no instance is SETU compliant is even more remarkable. If we look in into the error detail:

- XML Schema errors:

  A wide range of "clumsy" errors. For instance incorrect use of date notation within DocumentDateTime element, a missing element, or usage of a non-existent value from the code list. All these errors can be easily avoidable.

- Business Rules:

  In contrast to the XML Schema errors, the Business Rules errors have a lot of similarities in all implementations. We found two groups of errors:
  Group 1: Incorrect usage of "SupplierParty", "BillToParty" and "RemitToParty".
  Group 2: The usage of "Invoice Lines" without "Amount" or "Price per Quantity".

It seems like implementers have difficulties with using these elements correctly. This might indicate that the specification is not clear about how to use these elements.

Table 4 Most used items from customer reporting requirements

Element	Count
PurchaseOrderLineItem	14
AdditionalRequirement	12
CostCenterCode	10
PurchaseOrderNumber	8
CustomerReferenceNumber	6
CostCenterName	2
ProjectCode	1

5.2 Data elements

Our analysis shows that several data elements from the standard are never used within our data set. These unused elements are: DiscountAmount, DiscountPercentage, DepartmentCode, and CostCenterName. On the other hand there are several data elements that are used in every instance: DocumentDateTime, Header, Id, IdValue, Invoice, Line, LineNumber, PercentQuantity, TaxBaseAmount, Total, TotalAmount, TotalTax, Type. The customer reporting requirement module is a set of optional elements that allow flexible usage for specific needs of staffing customers. The most used items of the customer reporting requirements are listed in Table 4.

The list of frequencies of these optional elements provides many insights. For instance since PurchaseOrderLineItem is used often, it might be questioned whether the element should be mandatory.

Additional to the optional elements within the Customer Reporting Requirements, the SETU standard allows users to define custom fields in the "AdditionalRequirement" element. Out of the 22 invoices, 16 of them have defined AdditionalRequirement with the list of custom fields below. Several organizations independently developed same or similarly titled custom fields, which may suggest a need for these elements to be included in the SETU standard. Remarkably "birthdate" (geboortedatum) is not allowed by Dutch law to be used in this data exchange.

requirementTitle = "TotalHours"
requirementTitle = "geboortedatum"
requirementTitle = "Postcode"
requirementTitle = "werkweeknummer"
requirementTitle = "plaatsingsnummer"
requirementTitle = "TotalHours"
requirementTitle = "Weeknr"
requirementTitle = "Uitzendkracht"
requirementTitle = "Jaar"
requirementTitle = "MP_Omschrijving_Factuur"
requirementTitle = "Correctietekst"

Table 5 SETU results on completeness and relevance for invoice

Standard user	Standard	Completeness	Relevancy
SETU	HR-XML	55/78 = 71 %	55/385 = 14 %
SETU community	SETU invoicing standard	1	74/78 = 95 %
SETU community considering AdditionalRequirement as custom elements	SETU invoicing standard	74/85 = 87 %	74/78 = 95 %

5.3 Completeness and relevance

HR-XML standard contains 385 elements. SETU invoicing standard defined 78 elements, 55 of which are from the HR-XML standard. Considering SETU as the user of the HR-XML standard, the relevancy of HR-XML is 14.29 %, while the completeness is 70.51 % (Table 5).

All invoices in our data collection are specified using elements specified in SETU. For SETU community, most of the 78 SETU elements have been used in invoices. The relevancy of SETU invoicing standard is 94.87 %. All elements used in invoices are defined in SETU invoicing standard, therefore its completeness is 1. However, if the custom fields in AdditionalRequirement are considered as custom elements, the completeness of SETU standard in the context of our data collection is 87.06 %.

5.4 Results of SETU timecard

From the 32 collected timecard implementations, 2 pairs were exactly similar. The results of the validation of the remaining 30 are shown in Appendix. The results are quite similar to those of the validation of the Invoice data: 3 (out of 30; a striking 10 %) are not well formed XML. There are more than 400 validation errors based on the HR-XML schema, and 43 errors based on the SETU business rules. However there is one exception: There is one timecard implementation without errors!

The analysis of the used and unused data elements for the timecard leads to similar results and can be provided upon request.

The calculation of completeness and relevance for the timecard is presented in Table 6.

Table 6 SETU results on completeness and relevance for timecard

Standard user	Standard	Completeness	Relevancy
SETU	HR-XML	1	82/85 = 96 %
SETU community	SETU timecard Standard	59/59 = 1	59/82 = 72 %
SETU community considering AdditionalRequirement as custom elements	SETU timecard Standard	59/68 = 69 %	59/82 = 72 %

Compared with the invoice data, the timecard data shows quite similar results, except that both completeness and relevancy are somewhat lower. It seems that the Customer Reporting Requirements module (Additional Requirement) is used more in practice for timecards. A major difference is the relevancy scores when SETU is seen as a user of HR-XML. It shows that the SETU profile on HR-XML for timecard (96 %) is less deviating than the invoice (14 %). This perfectly shows how difficult it is to find the right balance: The less deviating SETU timecard has a relevance of 72 % in practice with the actual end users, while the more deviated SETU invoice standard has a relevancy of 95 % in practice.

6 Discussion

6.1 Results

I is remarkable that no single implementation of the invoice standard is fully correct, and only one for the timecard standard. This leads us to conclude that standards are used differently in practice than they are envisioned to be used in a standardization process setting.

We have identified several potential causes for this outcome in three categories: product-related, process-related and use-in-practice-related causes, in line with the quality framework for data standards (Folmer 2012).

Although we explore the causes particularly related to the SETU implementations, these causes may very well be valid for other data standards.

6.2 Potential causes of the outcome

The results are highly remarkable and definitely unexpected for SETU. We discussed the outcome with both developers and users of the SETU standard. Based on these discussions we can identify three categories of potential reasons for the sub-par quality of the implementations:

Product, i.e. standard itself

1. Plug-and-play interoperability, the design goal of SETU and similar standards, turns out not to be the outset on a business level. Although plug-and-play interoperability is generally perceived as a goal in e-business (in particular during the era of standards like ebXML), discussion with stakeholders from the staffing companies on a business level indicates that 90 % interoperability is usually preferred over 100 %. This is due to the fact that organizations like to be in contact with the customer and like to tailor their services around the final 10 %. Full plug-and-play interoperability will impact the desired customer contact and will diminish the connection the customer have with the staffing company. So far academia are convinced that 100 % plug and play is a desirable goal, but our research shows that this is doubtful in practice. Validation of the suspected 100 % plug and play requirement from a business perspective is required

2. The flexibility of the standard, especially during the early stages of its life cycle. There is usually debate on how flexible a standard should be and how many changes and version updates are needed to accommodate the community. In general, too much flexibility leads to incompatibility in implementations.

Specific to SETU cases mentioned in this paper, we therefore suggest the following types of changes:

- *Clarification* in order to clarify semantics of the standard, we suggest to clarify the use of SupplierParty, RemitToParty and BillToParty and to clarify the use of Invoice Lines that requires amounts and price per quantity.
- *Removal of elements* in order to avoid doubt and unwanted use of 'bandwidth' the workgroup should consider removal of unused elements. This will make implementations easier.
- *Reduce optionality* in order to enforce common ground in implementations, we suggest to change the cardinality of elements that are always present, to mandatory. Again, this will make implementations easier.

In addition, the SETU workgroup should analyse the results of this study and the results of the use of the customer reporting module.

Process of standardization

3. The early stage of the SETU standard in its life cycle. The SETU standard is relatively new, and implementations have mainly been realized from 2009 onwards. This means that tested implementations are likely to be from the first batch of implementations. It might be expected that during the years both the standard and its implementations have been improved. Follow-up research with repeated validation is required to test this assumption.

Practice of using the standard

4. SETU is occasionally used as a marketing term. Attention to correctness of the implementations seems limited. Especially to staffing companies and system providers it is essential to be able to state SETU compliance. This perception is supported by the fact that even during the early years most companies stated they had implemented SETU, which was highly questionable. In practice, customers will ask for SETU (especially in large government tenders), and failing to state SETU compliance may well mean losing contracts. Since there is no possibility to test implementations for official SETU compliance, issues regarding implementations as shown in this study are created as a result.
5. The standard is used in unforeseen situations. In other words: the scope of the standard is extended in practice. The SETU standard is explicitly designed for situations in which staffing customer and staffing company directly exchange messages with each other. In practice the standard is also used in situations with an intermediary system provider in between parties. The requirements of this particular situation are not taken into account during the SETU standard development and lead to implementation issues.
6. Knowledge availability of implementers, on a technical level. It turns out to be difficult for implementers to fully comprehend the technics and semantics of the

standard, if the implementer has not participated in the development process in the SETU workgroup. This statement holds for technics of the standard, since our study is not focused on semantic errors but rather on technical errors. There may be however even more errors on semantic level then there are on technical level, which means that knowledge availability of implementers may equally be lacking on a semantics (business) level. There is no hard evidence for this lack of semantic knowledge, since errors on a semantic level are hard to find.

7. There may be a mismatch between the technology used in the SETU standard and the technical knowledge and means available to the implementers. Although SETU is using standard XML technology, IT departments of the temporary staffing industry are still in the process of adopting this technology.

6.3 Potential solutions

Based on the results and causes listed, we can identify three possible solutions to the problems perceived:

- Certification (addresses causes 4, 6, 7): certification may be a potential solution to improve the implementations by guaranteeing compliance to a large extent.
- Test/feedback (addresses causes 3, 5): use of test/feedback loop to improve the quality of the standard. After development of the standard, feedback from using the standard in practice should provide insightful information about the scope and applicability of the standard.
- Promote electronic tooling and report results (addresses causes 6, 7): the use of electronic tooling during implementation should aid in reducing errors. Basic syntactic validation limits the number of human-induced errors in the process. It is remarkable to note that we used eValidator in our study, which is accessible through the SETU.NL website. Our results make it doubtful whether this validation tool is used by SETU implementers. We have reason to believe that the quality of the implementations would have been better if the implementers had used the validation service freely available to them.

6.4 Comparison of SETU and XBRL results

Zhu and Wu (2011)'s study finds that for the US-GAAP XBRL user community, the completeness of US-GAAP standard is 32.12 % and the relevancy is 19.29 %. Their study is based on all annual financial reports that have been submitted to US Stock and Exchange Commission as of 2010. SETU invoicing standard seems to have a better fitness for use by the staffing community. As measured by our data collection, SETU invoicing standard's completeness is 87 %, and relevancy is 95 %, and SETU timecard standard scores 69 % for completeness and 72 % on relevance. However, note that if the data collection is larger, such as if we were able to collect all invoices from the staffing community in Netherlands, the completeness of SETU invoicing standard would have been somewhat lower (considering custom fields in AdditionalRequirement as custom elements). Also, financial reports are much more

complex than timesheets and invoices. The US-GAAP standard has more than 12,000 elements and is much more complex than the SETU invoicing standard. The lower fitness for use of US-GAAP XBRL standard, as measured by completeness and relevancy, can be partly attributed to its complexity.

The results show the value of having localizations on top of broader data standards (such as HR-XML), in line with earlier findings that localizations are essential for interoperability (Brutti et al. 2011). The difference in results between the timecard and invoice show the trade-off of designing the localization and its definition of the core standard.

6.5 Discussion of the approach

Although our approach is in line with the intended usage approach of the quality model, and has been carried out with significant efforts, our approach addresses only a small part of the original quality model as presented in Sect. 2.3. Even within quality in practice (one out of three main parts), we have tested 3 out of 15 quality factors. While our approach gives an important view on quality, many other views are possible. Based on the information need in practice an appropriate view has to be selected and created. The view in this research is focused on interoperability on syntax level while testing the completeness and relevancy of the information elements, which fits the information need for SETU. A logical follow-up step would be to dive more in the technical design of the SETU standards, as part of "product quality" in the quality model, for instance by using the measurements suggested in literature in Sect. 2.5

Besides diving deeper in the technical content, we can broaden the quality view, even within the quality in practice part of the quality model. For instance we can analyze the maturity, how many concurrent versions are in use, or cost-effectiveness, etc.

However even more interesting would be to dive into a different interoperability layer: from syntax to the semantic layer. The core of data standards are its semantics, but what we tested so far is only partly related to semantics. In practice, data standards evolve in a fragmented and distributed fashion. To make integration and interoperability more efficient and scalable, the fragmented specifications need to fit into a coherent, semantic model (Kulvatunyou et al. 2008). They need to be logically consistent and contain minimal duplication. Additionally, semantically overlapping data structures should be related or annotated, because every term and data structure should have unique semantics. Although this is product quality and its quality can be checked in the specification document, semantic issues also occur in the implementations of the standard. Therefor semantically correct use of the standard is important to interoperable implementation. Unfortunately semantic issues are difficult to test in practice, as we have to ask people what their meaning is of their data and compare that with the intended meaning of the standard. For instance when "Erwin" is used as LastName and "Folmer" is used as FirstName, we might get the feeling that this is not correct, but we don't know for sure unless we start asking the people involved.

During our analysis of the dataset we encountered some usage errors that are semantical "suspects". These need further investigation, but our first impression is that these are relatively easy semantic errors, such as mixing up two elements (such as FirstName and LastName). Although it will be difficult to prove, we expect that SETU does a good job in achieving semantic interoperability.

7 Conclusions

This paper has shown an analysis of the implementations of a data standard. This section will answer the research questions.

What is the quality of the SETU *standard in practice*?

The quality of SETU implementations is somewhat questionable since no invoice and only one single timecard instance proved to be a correct implementation. The quality of SETU standard in general, related to completeness and relevance, seems to be fine however, compared to other electronic standards such as the US-GAAP XBRL standard in financial reporting. This comparison is questionable though considering the diverse characteristics of both standards.

Theoretical contribution To our knowledge this is the first study that tries to measure quality of data standard based on real transactional data in a rather objective way. This study gives evidence to the conclusion that standards can be improved, and there is difference between the quality of the specification (the product) and its implementation, as evident in the SETU case.

In particular does the SETU standard lead to interoperability?

The SETU standard and its wide implementations certainly lead to a certain level of interoperability. But since the implementations are technically incorrect, it will lead to lower-than-expected interoperability on the technical layer. However there are ways to improve the quality of the implementations. We have provided valuable results to the SETU standards organization, in two ways:

1. The low quality of implementations raises the question what the SETU organization can do to improve the quality of implementations. Education, mandatory validation, or even certification might be solutions.
2. This analysis has been used to support a improvement initiative within SETU. The analysis of frequency of element use and the two groups of frequent errors might lead to changes in new version of the standard.

Theoretical contribution Although current research on data standard is mainly positivist view on the value of these data standards, this research shows that having a data standard does not necessarily mean that (technical) interoperability will be achieved. Our research also shows that a quality analysis results in valuable outcome for improving the data standard. In the end that might lead to improved interoperability. Finally it shows the emphasis of extant literature on data standard adoption as major barrier for interoperability might need reconsideration.

Is this quality measuring approach useful?

For SETU this approach has led to valuable results in two ways: First it leads to improvement suggestions, and second SETU will have a much better view of the quality of the standard and achieved interoperability results so far.

But our study also shows that it is insufficient to have a single view on standard quality, especially when studying the interoperability effect of standards. SETU scores almost perfectly on completeness and relevance, but interoperability is still questionable due to low quality of implementations. The other way around could be said for other standards. An interoperability achievement study should at least include a study of:

- Completeness and relevance of the standard
- Validity of standard implementations

It is remarkable to notice that there are no data standardization organizations that use aforementioned measures to improve their standards, or any other quality measurement approaches for that matter (Folmer et al. 2011). Based on our research we strongly advise all data standardization workgroups to perform such analysis and improve the standards or set up policies to improve implementations.

Theoretical contribution We have provided supporting evidence to earlier claims that localizations for data standards are needed to achieve interoperability. This study proves that our quality model and approach work fine for SETU, which might indicate that they will also lead to interesting results for other data standards. An important contribution is that this research shows that quality is tangible and can be objectively measured, which is an important step in achieving evidence-based interoperability in the future.

Appendix: Validation results timecard data

See Table 7.

Table 7 SETU validation results for timecard

#	Usage scenario (timecard type)	Structure errors	Schema errors	Rule errors	Total errors
1	StafOrg1-Timecard1	No	0	4	4
2	StafOrg1-Timecard2	Yes	–*	–*	–*
3	StafOrg1-Timecard3	No	0	1	1
4	StafOrg1-Timecard4	No	44	0	44
5	StafOrg1-Timecard5	Yes	–*	–*	–*
6	StafOrg2-StafCust2	No	1	0	1
7	StafOrg2-StafCust5	No	0	1	1
8	StafOrg2-StafCust6	No	1	1	2
9	StafOrg2-StafCust7	Yes	–*	–*	–*
10	StafOrg3-StafCust1	No	1	0	1

Table 7 continued

#	Usage scenario (timecard type)	Structure errors	Schema errors	Rule errors	Total errors
11	StafOrg3-StafCust2	No	70	0	70
12	StafOrg4-StafCust4	No	0	17	17
13	StafOrg4-StafCust5	No	1	0	1
14	StafOrg4-StafCust6	No	0	1	1
15	StafOrg4-StafCust7	No	61	0	61
16	System1-StafOrg1-StafCust1	No	0	0	0
17	System1-StafOrg3-StafCust6	No	0	2	2
18	System1-StafOrg4-StafCust5	No	3	1	4
19	System1-StafOrg5-StafCust6	No	0	1	1
20	System1-StafOrg6-StafCust7	No	0	3	3
21	System2-Timecard-A-1	No	28	1	29
22	System2-Timecard-B-1	No	0	1	1
23	System2-Timecard-B-3	No	0	1	1
24	System2-Timecard-B-4	No	0	1	1
25	System3-System1-Timecard1	No	0	3	3
26	System3-System1-Timecard2	No	0	1	1
27	System3-System1-Timecard3	No	0	1	1
28	System3-System2-Timecard1	No	38	0	38
29	System3-System2-Timecard2	No	45	0	45
30	System3-System2-Timecard3	No	80	0	80
	TimecardErrors		401	43	

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