A Reference Model of an Instrument for Quality Measurement of Semantic IS Standards

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This study describes the design of a reference model for an instrument to measure quality of semantic Information System (IS) standards. This design satisfies requirements gathered among potential users, in a previous study. The reference model features three layers: concerned with quality, semantic IS standards, and the instrumentation, respectively. It serves as a basis for implementation of a quality measuring instrument.

Introduction & Research approach

Given the evidence for the need of an instrument to measure the quality of semantic IS standards (Folmer, Oude Luttighuis, & van Hillegersberg, 2011), and based on requirements for this instrument (Folmer, Krukkert, Oude Luttighuis, & Van Hillegersberg, 2010), this study presents an overall reference model for an instrument for quality measurement of semantic IS standards. It will not present the instrument itself, but rather the overall model and concepts needed for developing it. The following research question is the central theme for this paper:

"What constitutes an instrument for the Quality Measurement of Semantic Standards (iQMSS)?"

The answer to this question lays out the core elements of the instrument. These elements and their relations form the model of the iQMSS. In terms of design science research (Hevner, March, Park, & Ram, 2004), the reference model of the iQMSS is a design artefact. Evaluation will be done in later stages. An iterative design approach, involving several experts, has been chosen to execute this design science research.

As a starting point, design constraints have been set up based on existing knowledge and the requirements gathered (Folmer et al., 2010) for the iQMSS. We use meta-modelling techniques and MDA (Model Driven Architecture) (Kleppe, Warmer, & Bast, 2003) for the clustering of design artifacts, and UML (Unified Modelling Language) (Fowler, 2004) for the method description.

Design constraints of the iQMSS

ISO (ISO/IEC, 1984) defines an measuring instrument as "*a device intended to make a measurement, alone or in conjunction with other equipment*". Wikipedia describes instrumentation engineering as "*the engineering specialization focused on the principle and operation of measuring instruments which are used in design and configuration of automated systems in electrical, pneumatic domains etc.*" (Wikipedia, 2011). In our context, however, neither the measured objects nor the instrument itself is predominantly physical. Therefore, we turn to the definition from Websters (Merriam-Webster, 2011): a measuring device for determining the present value of a quantity under observation.

The SEMIC.EU project of the European Government provides a quality framework for so-called interoperability assets, and corresponding artefacts, that are useful within e-government interoperability projects (Nentwig et al., 2008). It contains amongst others (Nentwig et al., 2008):

- Requirements for the definition of quality criteria for assets and their artefacts.
- An appropriate structure and representation of these quality criteria assigning these quality criteria to assets and their artefacts according to stakeholder requirements.
- Requirements for assessing, preferably measuring the quality of assets and their artefacts.
  Although the SEMIC.EU requirements are useful, it is important to involve potential users as well. The requirements for iQMSS result from a requirements engineering study (Folmer et al., 2010), in which the top goal is defined as "to support semantic Standard Development Organizations (SDO's) in developing high-quality standards". This requirement restricts the usability of the intended instrument to standard developers. This implies that, for instance, the selection of standards by standards users is taken to be out of scope for iQMSS. This goal has been decomposed into three level-two goals, which all have been further decomposed, grouped and reformulated into five main requirements:

A. Usefulness for different semantic SDO's.

- REQ1: Accommodate the differences between semantic IS standards.

B. Efficiency of use.

- REQ2: Focusing on the quality needs/question of a specific SDO.
- REQ3: Implementation of the instrument in easy to use tools.

C. Usable results.

- REQ4: High-quality outcome based on grounded quality model
- REQ5: Output report as fundament for improvement project.

Quality terminology

Terminology about quality is characterized by huge diversity and even conflicting definitions. SEMIC.EU defines and uses the term quality factor, criteria and indicator in a hierarchical way (figure 1) (Nentwig et al., 2008). In our work we use the terminology from the Software Measurement Ontology (SMO) since it is it combines the most appropriate definitions from different sources, for use in the software engineering discipline (García et al., 2006; Garcia et al., 2009).

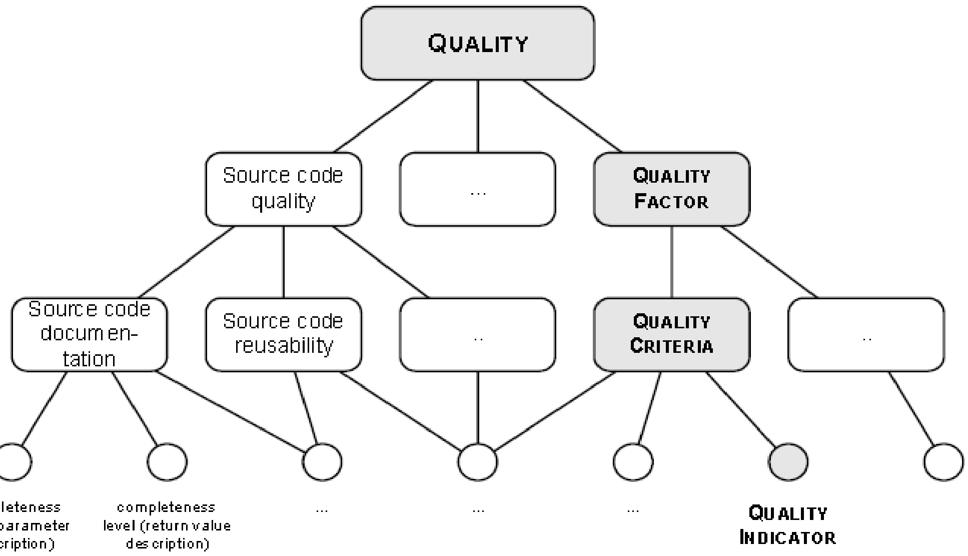

Figure 1. *Relations between concepts used by SEMIC.EU (Nentwig et al., 2008)*

The measurable concepts (figure 2) stem from the quality model and are the concepts that we want to know (the information needs). Attributes of the semantic standard, the object of measurement, that are related to the measurable concepts can be measured by combining the use of indicators and base and derived measures.

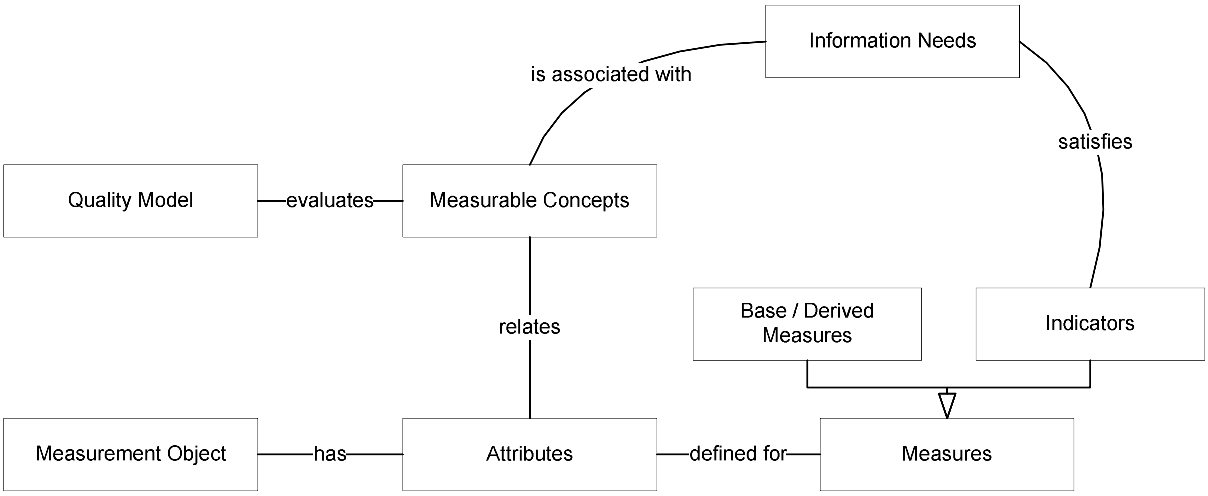

Figure 2. *Simplified version of terminology used in SMO (Adapted from (Garcia et al., 2009))*

iQMSS Use Case

This section will describe use cases and identify the main actors and constructs of the iQMMS. The modelling notation used in the use cases and package diagram is conforming to the UML definition. We identify four actors:

- Initiator: Expert with in-depth knowledge of the iQMSS, knowing how to customize it for application for a specific standard.
- Principal: Expert with knowledge about applying the iQMSS and semantic standards in general. The principal has the lead in carrying out the measurement.
- Client: The client has an information need regarding the quality of a specific semantic standard and basic understanding about that semantic standard.
- Standard Developer: The standard developer has detailed knowledge regarding the semantic standard. This knowledge is needed during the process of quality measurement.

In practice, the initiator and the principal may be one person. The same holds for the client and standard developer. This use case diagram (figure 3) shows the actors and their activities during and preceding the measurement.

Because semantic standards are diverse and will have different attributes, the measured concepts defined in the iQMSS have to be adapted before they can be used in the measurement process of a specific semantic standard. Together with the client, the initiator selects the measurable concepts to be used in the measurement, based on client's information needs, and adapt these concepts to the specific situation for the semantic standard at hand. Based on the generic iQMSS, the initiator is responsible for the customization of the tools to the specific quality information needs and specific semantic standard under subject. After customization, the actual measurement of the standard can be executed.

The measurement process is performed by the principal. He or she performs the measurements and reports the results of the measurement to the client. These results are also evaluated by the standard developer. The latter should be able to interpret the results for the semantic standard, and to define quality improvement actions when needed.

The principal uses the customized iQMSS, in two basic steps, each presented as a lower-level use case. First, he gathers detailed information about the semantic standard at hand. The standard developer serves as the major source for this information. Second, the quality model needs to be initiated based on the gathered information resulting in an outcome that will be analysed and documented.

Alternatively, a fifth actor may be imagined: an analyst who is equipped to analyse the overall results of several measurements of different semantic standards. After this analysis, the results of a measurement can be compared to other results and the quality measurement of a particular semantic standard can be positioned against other results.

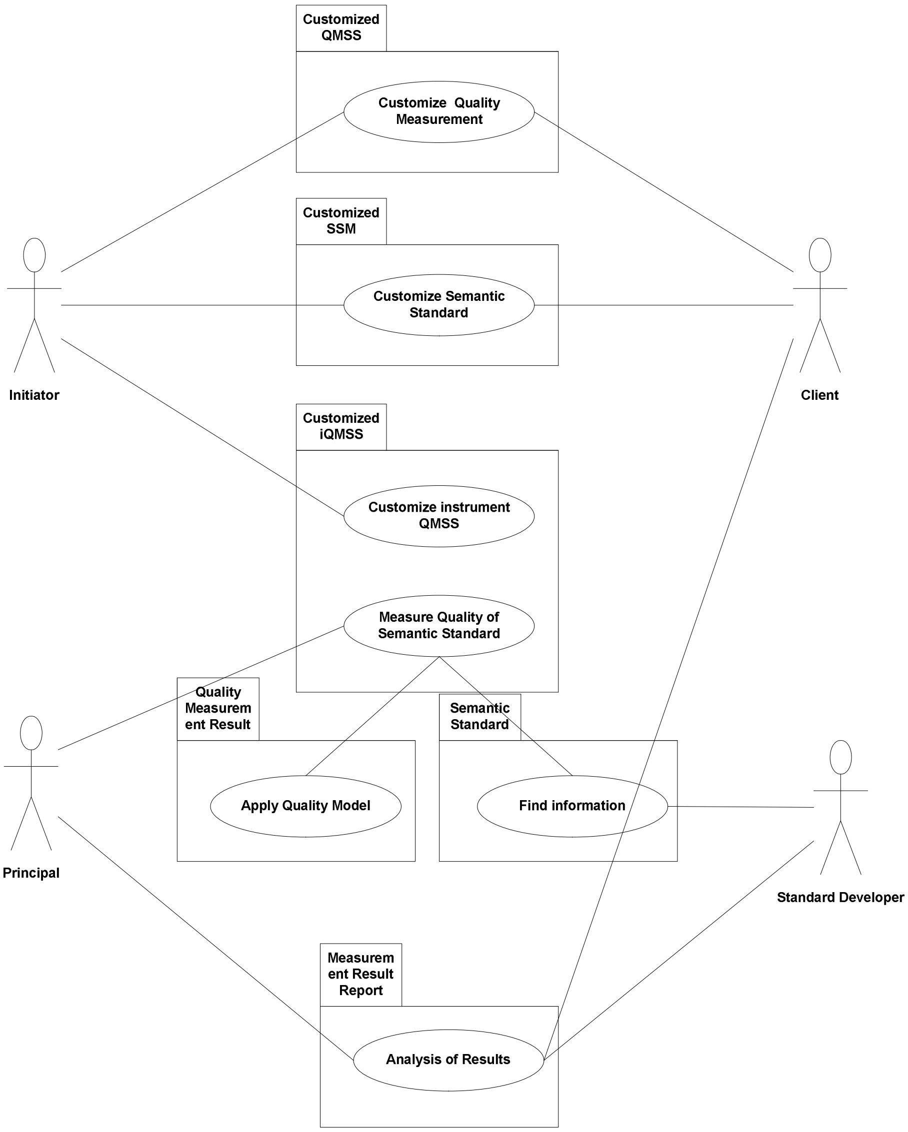

Figure 3. *Use case diagram iQMSS*

Design of model of iQMSS

When measuring, the initiator has to match what the information need) with what is measurable (the attributes of the measurement object). It makes no sense to measure things the client does not want to know, and if the client wants to know things that are not measurable makes no sense as well. This distinction between the measurement object and the quality model is also inline with the selected SMO model for terminology (figure 2). This leads to the first design rule in which the measurement subject and "what we want to know" are separated as different perspectives:

- The first perspective is from what we want to know which in our case is related to quality. The information needs from the end users will be part of what we call the quality model for semantic standards (QMSS).
- The second perspective contains the semantic IS standard as measuring object, in a broad sense, covering more than just the specification of the semantic standard, and including the broad context (including implementations, etc.) of the semantic standard.

- A third perspective is added to visualize that in the end we need an implementation of the artefacts in some kind of tooling: the instrument itself.

Each perspective contains different artefacts on different abstraction levels. Our second design rule is the distinction between different levels:

- In terms of MDA (Kleppe et al., 2003) we have three levels of each artefact: The model (M1) is expressed in a language (M2), and the model is instantiated (M0)
- Based on our requirements (REQ1, 2, 4) we have to make a generalization-customization separation of concerns. A general model needs to be customized based on the context. The relation between the generic and customized version is a subset relation type. The customized version is a subset of the generic version, customized to the specific context of the instance of the semantic standard as subject.

This leads to the following reference model for iQMSS, based on the design constraints mentioned. The three perspectives are captured on the horizontal axis, the abstraction levels on the vertical axis. Emphasized in bold is the development core of the instrument: the generic elements of the iQMSS.

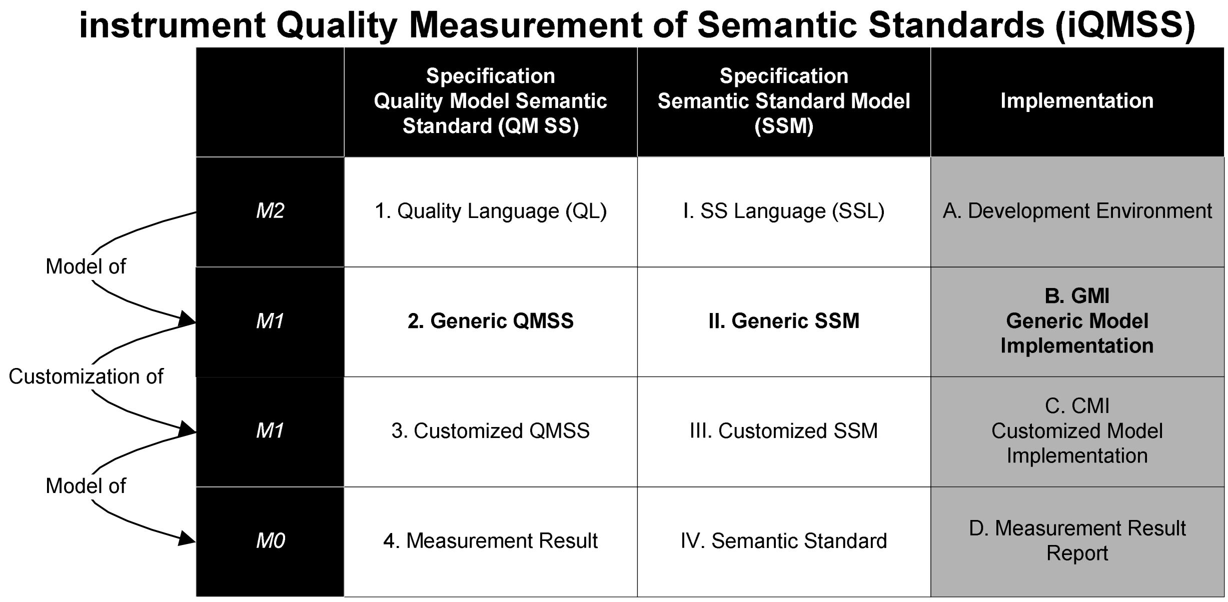

Figure 4. *The model of iQMSS*

This model contains a total of twelve constructs. The table below contains definitions of the three columns and the overall model of iQMSS.

Term	**Definition**
Model of iQMSS	The overall model of the instrument for Quality Measurement of Semantic Standards.
Specification QMSS	Specification on all levels related to the Quality Model for Semantic Standards (What we want to measure).
Specification SSM	Specification on all levels related to the Semantic Standard Model (What we are able to measure).
Implementation	The implementation is related to practical tooling; the output of the tools, the generic and customized version of the tools, and the development environment for the development of the tools. The tools are supporting the QMSS and SMM.

Table 1. *Definitions overall iQMSS*

The twelve constructs from the iQMSS model are listed in the next table.

	Term	Definition
1.	Quality Language (QL)	The language in which the QMSS is expressed, consisting of defining constructs and their relations.
2.	Generic QMSS	The generic version of the Quality Model of Semantic Standards using the QL to express the aspects within the model.
3.	Customized QMSS	A specialized version of the QMSS adapted to the characteristics of the semantic standard.
4.	Measurement Result	The result of a quality measurement on a specific standard with use of the QMSS.
I.	SS Language (SSL)	The model of the SSM, consisting of a language in which the constructs are defined.
II.	Generic SSM	The generic model of a semantic standard expressed in concepts from the SSL.
III.	Customized SSM	A customized version of the generic model of the semantic standard, customized to be fit for a specific standard.
IV.	Semantic Standard	The instance of a semantic standard as subject for measurement.
A.	Development Environment	The components useful for building tools.
B.	Generic Model Implementation (GMI) (generic iQMSS)	The generic version of tooling making the QMSS instrumental of nature. The tooling should support the measure process.
C.	Customized Model Implementation (CMI) (customized iQMSS)	A customized version of the tooling based on the characteristics of the specific semantic standard.
D.	Measurement Result Report	The output (report) of the tooling when performing the measurement.

Table 2. *Definitions iQMSS constructs*

The implementation level (the fourth column) applies to implementations in the broadest sense; this might consist of software tools, questionnaires, instruction document, or any other physical or digital tool for performing the measurement. It should guide and assist the initiator and principal of the iQMSS in effectively and efficiently making use of the iQMSS leading to useful results in the measurement result report.

There are more relations between the artifacts than figure 4 shows. This section takes a closer look at the relations between the artifacts in the model. Most important is the relation between the QMSS (quality model) and the SSM (semantic standard model). The SSM defines the measure points that can be used by the QMSS.

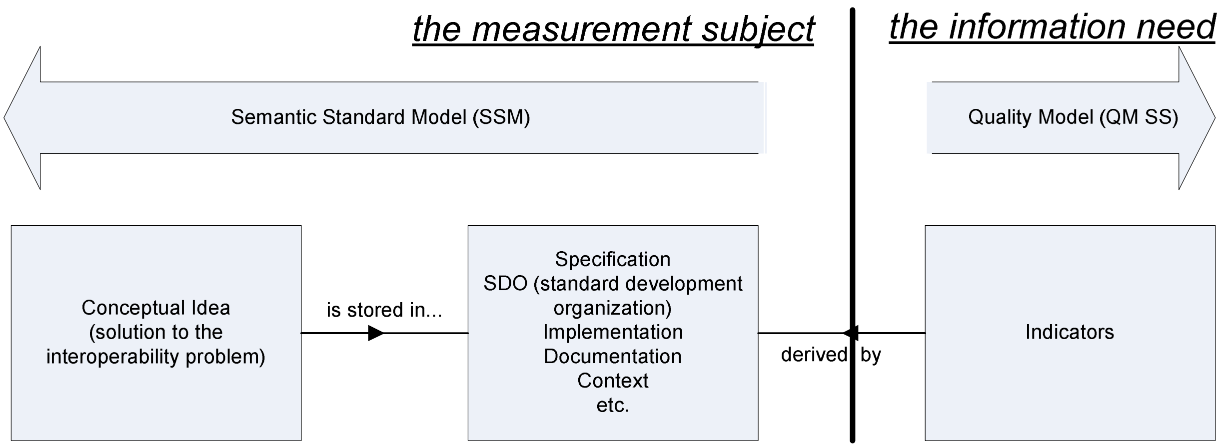

Figure 5 – The link between the measurement subject and the information need.

The modelling notation used in the following package diagram is from the UML specification (Fowler, 2004). Three types of dependencies are used. Each of the dependency between the packages is labelled:

- *uses:* Indicates that one package element in the client requires another package element from the supplier for its full implementation or operation.

- *specialize:* Relates two package elements, or sets of elements, that represent the same concept at different levels of abstraction, or from different viewpoints.
- *realize:* Indicates that the client model element is an implementation of the supplier model element, and the supplier model element is the specification.

Figure 6 shows the packages from the model and position these packages to each other. The type of dependency defines what type of relation is identified between the packages. Most of the associations are of the <<use>> type.

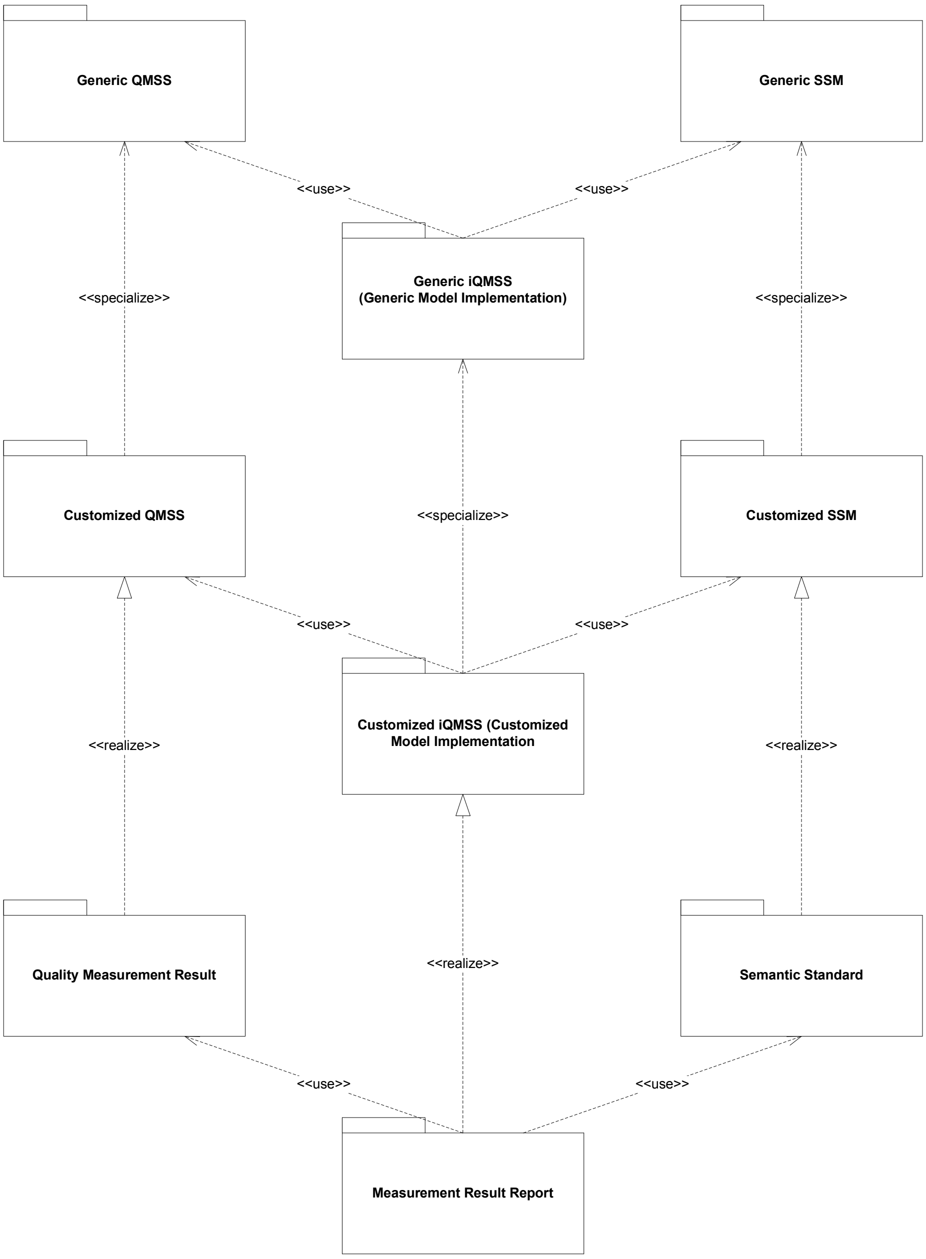

Figure 6. *Package model iQMSS*

This UML representation (figure 6) of figure 4 shows also some refinements. The three horizontal and vertical layers are recognizable: from a generic instrument, to a customized instrument that is initiated and leads to the result, and the distinction between the quality model constructs (left side), the semantic standard constructs (right side) and the instrumentalization in the middle. On each of the three layers, the instrument is the central element and is built upon the notion of the quality model and the semantic standard.

The previous figures show how the customized iQMSS links the semantic standard to the quality model. Figure 7 is an example of how this could work in practice; the crosses in the grid are the matches between what we want to know and what we are able to measure. A combination of crosses is an indicator for the value of the measurable concept for the semantic standard (based on a formula). The general information need for our research is the quality of semantic IS standards. However in practice users will be interested in more detailed information needs like what is the quality of the functionality of the standard. These information needs are an aggregation of measureable concepts. Examples of measurable concepts might be functionality, usability, implementability, etc. Information needs might consist of multiple measurable concepts, and measurable concepts might be decomposed into other measurable concepts.

The (grouped) attributes of the semantic standard are measures for the measurable concept. This relation is described by the indicator which has become the linking pin between the semantic standard and the quality model. This potential relation is shown in the next figure.

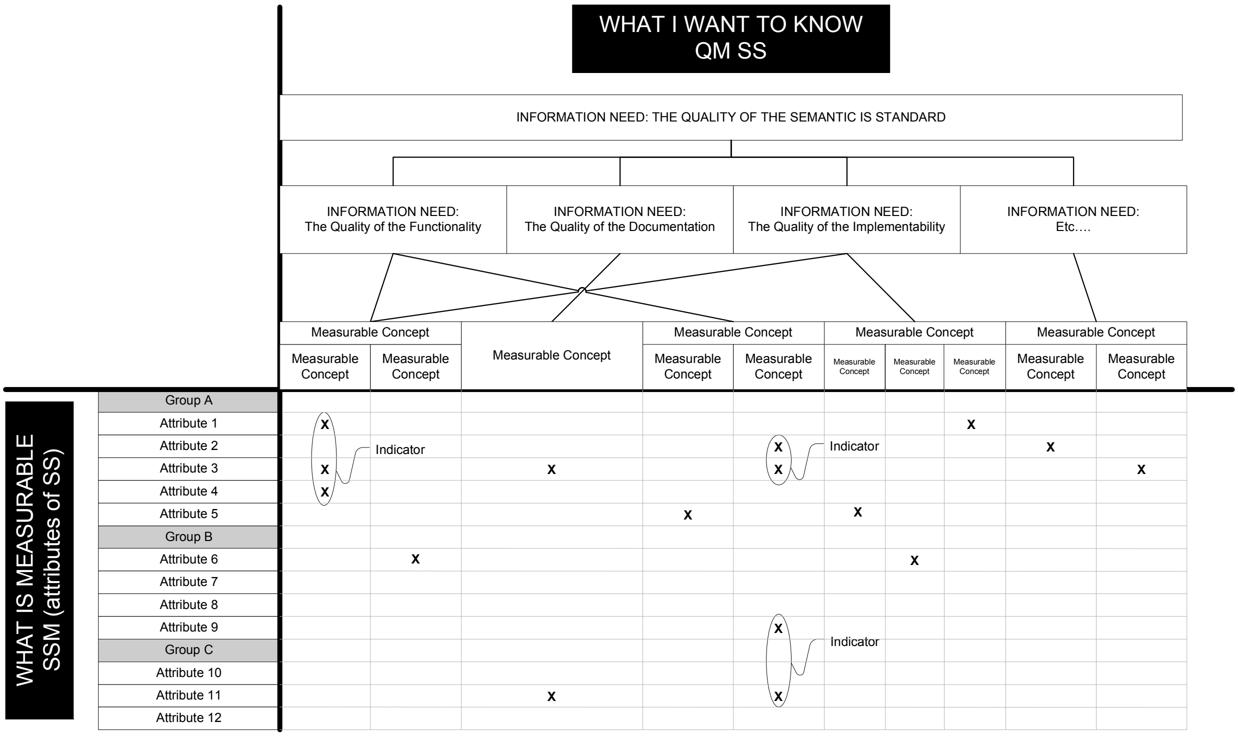

Figure 7. *The potential relation between QMSS and SSM in practice*

Conclusion & Next steps

Based on the design constraints, the instrument should contain several artifacts, including a quality model, a model of a semantic standard, and an implementation as instrument. To accommodate the differences between semantic IS standards, a distinction is necessary between generic and customized artifacts. To be more specific, table 3 summarizes how the requirements are met in the iQMSS reference model.

Other potential use of iQMSS is benchmarking of semantic IS standards. However due to the flexibility of customization, the results of the measurement are not by default comparable with the results of other measurements of other standards. For this reason, specific knowledge is needed to interpret the results before comparison can be done. However comparison was not mentioned as requirement by potential users; the users are more interested in suggestions for improvements. In practice benchmarking might be done by using the same customized iQMSS for a group of standards.

This paper has presented a reference model for a quality measuring instrument for semantic IS standards. In follow-up work, the reference model should be detailed, especially concerning the two uppermost levels. That is, appropriate languages for QL and SSL should be selected, as well as appropriate implementation platforms. Within the context these provide, a generic QMSS, a generic SSM, and a generic instrument should be developed, which will be validated in case studies.

Nr.	Requirement	Accommodated
1	Accommodate the differences between semantic IS standards	By initiating the model of a semantic IS standard knowledge is gathered about the measurement object. Only attributes of the specific semantic standard that have been included in the initiation of the model might be included in the measurement.
2	Focusing on the quality needs/question of a specific SDO.	This implies that dynamic selection of measures and partly measures need to be accommodated. In our model this requirement is satisfied by the introduction of a generic quality model that will be customized for every specific need from a client.
3	Implementation of the instrument in easy-to-use tools	This is implemented by the “implementation” level in our model. This will focus on the development of appropriate tools that support the quality measurement.
4	High-quality outcome based on grounded quality model	By having a generic QMSS based on existing theory.
5	Output report as fundament for improvement project.	Our model includes the measurement result report. However the content of the report will determine if it is useful for an improvement project.

Table 3. *Summary of requirements and how these have been accommodated within the design*

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