Data Modeling to Support Environmental Information Exchange throughout the Supply Chain

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Abstract. With an ever-increasing awareness of the environmental impact of manufacturing, more and more political organizations (countries, states, and unions) are enacting legislation designed to protect the environment. One category of this restrictive legislation is called Extended Producer Responsibilities (EPR). EPR directives place greater responsibility on manufacturers for the environmental impact of their products. These laws shift the focus from the product's origin to the product's final destination and from the process of manufacturing to the product itself. The highest impact of these directives is the Restriction of Hazardous Substances (RoHS) directive, finalized by the European Union in 2003. The RoHS directive restricts imports of new electrical and electronic equipment containing lead and five other hazardous substances. For manufacturers to successfully comply with RoHS and similar legislation, they need the ability to exchange material content information. This information would then propagate through the supply chain from the raw material suppliers all the way to the final producer. While a solution could be generated for any single piece of legislation, the problem is that companies will need to successfully deal with potentially dozens of laws and directives. To deal with this problem, the National Institute of Standards and Technology (NIST) (a US Government Research Laboratory) developed a data model to address the underlying material declaration problem using a software development methodology. This data model was used in the development of IPC's 1752 Material Declaration standard. IPC's 1752 standard helps the electronics industry comply with RoHS by providing a data exchange mechanism by which businesses can declare the presence or absence of the restricted materials. While IPC 1752 was created to deal with EU's RoHS, the data model was designed with the intent that it would be able to support future RoHS-like legislation (China RoHS, California RoHS, etc). Even if different solutions were developed for each piece of Legislation, they can interoperate provided they are based on the same data model. This paper looks at the data model designed for the IPC1752 standard, the methodology that was used to create it, and how it can be adapted to similar RoHS-like laws and directives.

Keywords. RoHS, material composition declaration, data exchange, modeling

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1 Introduction

Countries around the world are creating legislation designed to encourage manufacturing practices that promote human health and environmental protection. Many of these laws are built around a concept called *extended producer responsibilities* (EPR). EPR shifts the responsibility of a product's negative environmental or health impact directly to the producing company. The first major regulation of this type was the EU RoHS directive [1], which went into legislative force in 2006. The RoHS directive restricts imports of new electrical and electronic equipment containing six substances specified in the directive. For manufacturers to successfully comply with RoHS, and similar legislation, they need the ability to exchange material content. This information would then propagate through the supply chain from the raw material suppliers to the final producer. At the time the RoHS directive was developed, there was no standard to support material data exchange through the supply chain. This necessitated the creation of a new data exchange standard. The design of this standard was complicated by the diverse nature of the electronics industry business processes and reporting practices. In fact, the complexity of the reporting requirements meant that traditional *ad hoc* standards development processes would likely fail to produce a viable standard. To overcome this, software development methodologies were chosen to be the basis for the standards development process. After reviewing several design methodologies, simple Uniform Modeling Language (UML) [2] modeling with class diagrams was chosen. The main benefit of using UML being, it offered a relatively high degree of improvement for the development process compared with a relatively low cost of implementation. The UML is one part of a structured design approach that starts with domain experts defining the scope and use requirements which are then developed into a data model.

NIST developed a data model (using UML class diagrams) that described the required underlying material content based on the requirements specified by the IPC 2-18 experts. This data model was used to generate an eXtensible Markup Language (XML) schema that defines the IPC 1752 Material Declaration standard [3]. An important result of this approach is that, while the IPC 1752 standard was developed to support EU RoHS, the data model was designed to be flexible enough that it could be modified to support additional material data from other content regulations (China RoHS, California RoHS, etc) with little effort. The salient point is that, even if different data exchange solutions were developed for every new piece of legislation, as long as they where based on the same data model, the solutions would be interoperable. This paper looks at the data model designed for the IPC1752 standard and how it can be revised for similar laws and directives.

2 Model of Present Material Declaration Exchange

The first step in developing a data exchange standard to support RoHS compliance was to examine the underlying issue of material declarations. In this case, a data model (an abstract representation of how data is represented and used) was developed. Specifically, a UML design model was created to show the different material composition data, associated business information, and the relationships between this information. (see Figure 1).

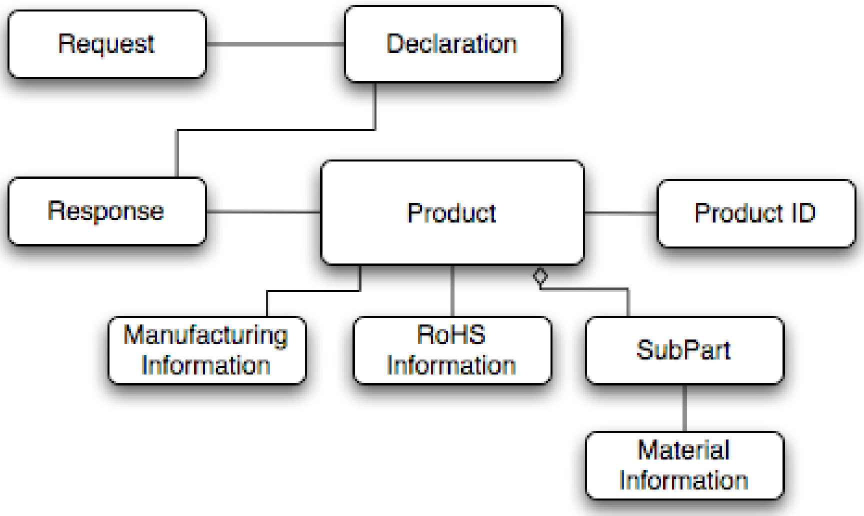

Figure 1. High level view of the original design model

The model contains a business information section including specific information about the requester and the responder needed for a material data exchange transaction. The model also captures material composition information. This is the heart of the declaration, covering regulatory information and the supporting material content data.

The data model captured the following information:

- Company information, contact information, and authorization information for the companies exchanging data. Additionally, business-to-business data needed for automating the data exchange is included here.
- Unique identification information for the part being declared. This information has been difficult to acquire, since non-RoHS and RoHS versions of the same part may have the same product identification. Therefore, manufacturing site, version, and effective date are captured along with the part number and name.
- Support for three basic levels of reporting; the yes/no declaration, substance category reporting (groups of substances), and substance level reporting (where every substance in the product can be reported).

- Information about substances and substance categories from both the request side and response side of the data exchange. This was needed to support specific companies' needs.

3 Limitations of the Present Model

Many of the problems with this current data model can be traced back to the fact that there was only a time window of six months to complete the data standard. This was driven by the small window of opportunity that industry had to understand the issues and implement solutions to meet the impending RoHS deadline of June 1, 2006. Because of the short development window, and the desire to be sensitive to the needs of small electronics suppliers, certain compromises were made.

- No support of multi-level sub-components: Parts can only be broken down one level into subparts. A subpart can not have another subpart. While this approach can work fine for simple declarations, it can not express complex multilevel declarations efficiently.
- Minimal support for multiple part IDs: A part family must be described using a single PartID attribute, and all the parts described must have the same weight. Although it is possible to associate multiple IDs with one product declaration, the IDs are presently squeezed into one attribute/field.
- No support for multiple legislation reporting: Because no other laws or declarations requiring material declaration for the electronics and electrical industry had reached a finished state when the first version of the model was designed, the regulatory information is specific to the EU RoHS and its exemptions.

While these issues could not be resolved for the first implementation of the design model, the IPC standards committee has begun developing version 2.0 of 1752. This presented the opportunity to revise the data model for the next version of the standard and using a software development methodology based around UML means that changes made to the data model can be propagated easily into the new standard.

4 Next Generation Model

This model and information presented here is only a prototype for discussion and is not meant to be final. As other countries around the globe begin to adopt environmental legislation similar to the EU RoHS, a more general container for regulatory information needs to replace the RoHS specific element in 1752 v1.0-1.1. Upcoming regulations, including China RoHS, EU Registration, Evaluation and Authorization of Chemicals Directive (REACH), and EU Energy Using Products (EuP), will require different product declarations. By creating a reusable class that can be used to represent many types of regulatory declarations for a product, multiple regulations may be associated with a single XML instance.

Besides the generalized declaration, there also need to be elements added to hold data specific to each new regulation. A survey of several of the upcoming legislations identified several unique data exchange requirements that are absent from the current model because they were beyond the scope of EU's RoHS. Listed below are several examples of data requirements that have emerged since the publication of the first model:

- China RoHS requires data on the safe use period, in which manufacturers identify the stable shelf life of the product before it leaks into the environment.
- China RoHS grants the producer the ability to report a substance as parts per million (ppm) at the part level instead of at the homogeneous material level for small objects under $4mm^3$.
- EuP requires the tracking of the total energy used in the manufacturing of a product.

One of the easiest requirements to address in the new data model will be the safe use period information requirement in China RoHS. Because of the methodology used to design version 1.0, the structure and attributes already present within the v1.0 design model and schema will require very little modification to support this information, since it can fit within the new generalized declaration.

Another issue that needs to be addressed is the ability to report concentration in ppm of homogeneous materials (as for EU RoHS) or mass (if the mass is under the China RoHS weight limit for small parts). Since the inception of EU RoHS there has been concern about how to report the quantity of a substance. RoHS requires that companies report the mass of substance relative to a homogeneous material, while other legislation and the Joint Industry Guide (JIG) require that a company report mass relative to the entire part (unless specified by a specific regulation), not just the material. Adding an attribute to qualify the reported mass as being reported at the part level or the homogeneous material level resolves this discrepancy.

The EU EuP Directive does not cover materials, but instead covers the energy used during the production and use of a product. Since the directive has not been finalized, it is not clear what information will be required, but it is likely the electronics supply chain will want to track this information in a similar manner to material data. Using a modular design, this additional energy related information may be added by creating a class associated with the product which holds the energy information for the product. Likewise, the manufacturing data will be modularized.

To provide declaration information for the new regulations, the RoHS declaration class will become more generic, which will allow declarations for other regulations. To support products that are shipped to multiple markets, it will support multiple declarations for a single part. Figure 2 shows a high level view of the prototype design model for version 2.0. It does not show the association multiplicity or sequence information. Additional information related to the XML schema has been removed to make the diagram easier to read. Interested parties may contact the authors for more detailed models.

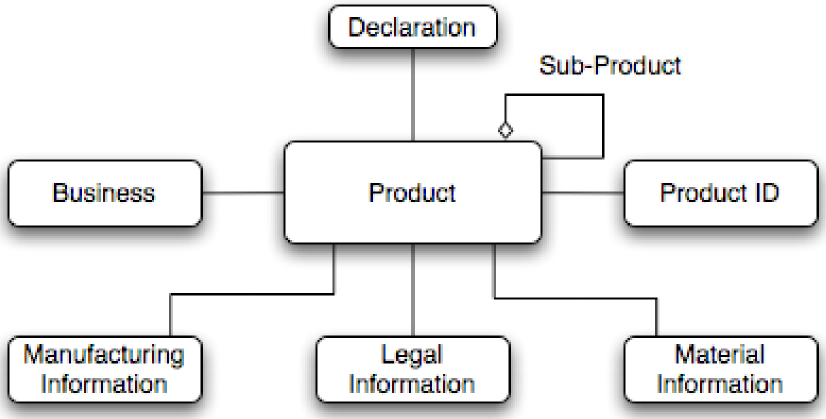

Figure 2. Prototype high level design model for next generation material composition data standard

The prototype proposed for the next generation model has several key classes, which include:

Declaration – defines the basic information for the data transfer, such as an identifier and version for the standard. This class represents the top-level element in the XML implementation.

Business Information – defines the two companies exchanging data, or a single company, to cover the case in which a supplier creates the declaration without a specific customer in mind. This class includes contact and authorization information and additional information needed to automate business-to-business transactions. This class changed little from v1.0, however, its association has been moved from the top-level class to the product class in order to support nesting of product information complete with all business information.

Product class – defines the product or group of products to which the declaration applies. This is the central class in the model. The other main classes are associated with the product class, and the product class is associated with itself as a subclass to allow nesting of product information. Structuring products this way means that an entire product declaration can be wrapped up and easily used as part of another product declaration.

ProductID information – Holds the identifying information for the product being declared. Version 2.0 will support multiple product IDs by allowing multiple ProductID objects to be included within a file. A part family ID may still be used as with v1.0.

Legal Information – includes the regulatory information and any legal language required for the data exchange to happen. This class is flexible so that it can handle legal information for specific regulations. Legal language about the file's data, along with regulation-specific language, is included here.

Material Information – holds the actual material content data. This data can be reported at the product level (e.g., is the product within the limits set by RoHS yes/no), the category level (e.g., JIG substance categories), or the substance level (e.g., JIG substances).

Manufacturing Information – contains manufacturing process information that is specific to the product being declared. This information is important since it is often different for alternate products that replace those with restricted substances.

5 Conclusions

The electronics industry is building advanced manufacturing facilities and supply networks to produce goods that have a complexity only imagined a few years ago. The data exchange standards to support this are equally complex. Creating and implementing these standards is a continuing task. By using simple tools such as those available with UML modeling in a structured development process, robust data exchange standards may be created that are easily modified to meet future requirements. These material declaration models and resultant XML implementations are a good example of how to apply software development methodologies to data exchange standards development.

6 Citations and References

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