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# Concepts for Modeling Hybrid Products in the Construction Industry

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**Abstract.** Methods for modeling products need to be extended or integrated with other methods when moving from products, i.e., tangible goods, to hybrid products. This paper investigates such modeling methods from a method-engineering perspective. In particular, we consider the construction industry which is increasingly subject of hybrid product strategies as a mean of differentiation. The contribution is that we (1) reconstruct core modeling concepts from six modeling methods and (2) integrate those into a meta model. The analysis shows that the so called result dimension is still dominating, thus what hybrid products provide whereas both the process and resource dimension lack attention and dedicated modeling concepts.

**Keywords**: Hybrid Products, Meta Modeling, Modeling Methods, Product Models, Product Data Management, Reference Models

## 1 Introduction

Product Data Management (PDM) offers a comprehensive set of integrated methods for modeling products ranging from parts and components to highly complex products. These methods are widely used in practice and implemented in respective information systems. The methods, however have to face the *problem* of hybrid products. Such products represent integrated bundles of both tangible goods and services, and therefore require considering the resource, process and result dimensions. Hybrid products can exemplarily be studied in the construction industry. Due to increasing price competition in this industry, hybrid products as value-adding solutions to specific customer requirements, have attracted many firms as a mean of differentiation. In addition, this industry has yielded specific modeling methods for products which need to be studied whether they can be extended towards hybrid products.

This paper *investigates* methods for modeling products and services. Such methods have emerged independently and successively from each other and thus differ not only in their underlying design paradigms but also with regard to process model, modeling concepts and notation. We take a *method engineering perspective* which allows for (1) conducting a systematic analysis of syntactically diverse modeling methods and (2) constructing a domain-specific modeling method for hybrid products. The contribution is that we (1) reconstruct core modeling concepts from six modeling methods and (2) integrate those into a meta model. This is made possible by language-based meta modeling as the underlying research method [1]. This research method requires the following four steps: (1) definition of the meta model language, (2) specification of the meta models of each modeling method, (3) identification of common and different modeling concepts and (4) specification of an integrated meta model.

The present work contributes to a research framework which concerns *logistics systems under customization*. Logistics systems provide services which transform goods with regard to location, time, and quantity. The goal of this research framework is to make logistics massively customizable by means of information systems. Customization is a major trend [2] and is in particular observable in the construction industry. Customers demand not single, standardized products which can be bought off-the-shelf, but complex ones which (1) are tailored to their specific needs (e.g., usage and location of the building, preferences regarding architecture, style, interior etc.) and (2) necessarily require services such as consulting, planning, supervision, and building activities. Such customized hybrid products impose also new requirements on logistics in the construction industry. The current work addresses hybrid products which are subject of a set of inter-related logistics services. We study the means how firms in the supply chain of the construction industry model and thus describe such products.

The remainder of this paper is structured as follows. Section 2 reviews related work. In section 3, we design our research approach. In section 4, we present modeling methods for products and services which will be analyzed. In section 5, we perform the model synthesis. The final section draws conclusion and outlines future work.

## 2 Related Work

The related work can be grouped into product and service modeling respectively.

**Product modeling** is an essential task of product data management. The resulting models define product data in such a way that respective information systems can be designed and product data can be exchanged. The concept of an integrated product model is closely connected with the standard ISO 10303 (STEP standard for the exchange of product model data) [3].

*Technical product models* represent physical product properties and are described by for instance, geometry, kinematics, flow, and deformation models. These models focus on the product structure and features. STEP allows creating such models by means of data models which can be specified using the data definition language EXPRESS.

In contrast to technical product models, *commercial product models* are used in enterprise information systems such as ERP systems. They contain product data for the functional business areas such as procurement, manufacturing, and distribution. These models can be described by means of standardized data exchange formats and product classification systems. The latter are also known as product ontologies and can, for instance, be specified using ontology languages of the Semantic Web [4].

Regarding hybrid products, the above mentioned methods do not provide concepts for modeling original aspects of hybrid products [5]. Very often, such methods are used for describing services or even hybrid products which results in product models that do not reflect essential characteristics of services or hybrid products (e.g. in [6]).

In terms of comparative studies of modeling methods, approaches based on requirements engineering dominate which compare methods on the basis of empirical or theoretically derived requirements (e.g., [7]).

### 2.2 Service Modeling

Service modeling is an essential task of service engineering. Service engineering refers to systematically developing new services based on a methodological approach, similarly to the development of products. A service model is the representation of the service to be provided.

Services can be characterized by their constituent properties immateriality and customer integration (so called contact services). Thus, for contact services, the customer interaction has to be part of the service model. A fundamental difference to product modeling gets obvious: Service modeling does not only address the result but primarily the process. Consequently, many service modeling approaches are based on general process modeling methods:

– Service Blue Printing is an early method for the graphical representation of service processes [8]. It is used for service development and does not make a direct contribution to the service representation in information systems. This also applies to extensions of this method such as [9].
– Grieble et al. [10] distinguish three service dimensions: resource, process, and result. For the process dimension, they propose to use EPC method (event driven process chains).
– Schneider and Thomas suggest an extension of the EPC method due covering the customer integration [11].
– In contrast to that, [12] adopt conventional PDM product modeling methods for service modeling and show this approach for education and training services.

Modeling methods from service engineering still suffer from diverse deficits. In particular, the development, deployment, and validation of a universal modeling method is hindered by the fact that real service models differ significantly depending of the respective service industry (e.g., financial vs. training services). These observations suggest that service models are more domain-specific and can only partially be specified using a domain-independent method.

## 3 Research Approach

In this section, we design our research approach based on meta modeling.

### 3.1 Meta Modeling Process

The diversity and heterogeneity of approaches for modeling product and services as identified in the previous section provide an obstacle for the move from products and services modeling to hybrid product modeling.

To compare syntactically differing modeling methods, we employ language-based meta modeling. This allows for capturing a method's concepts (analysis) and extracting the constitutive concepts for modeling hybrid products (synthesis). Meta modeling as a research method for comparing methods can be found, e.g., in [13]. This approach requires the following four steps:

1. Determination of the meta model language: Requirements for a suitable meta model language are semantic expressiveness and determination. Semantic expressiveness describes how precise and differentiated the language can be used. Determination requires the absence of design freedom. Situations should be avoided in which different, though semantically equivalent modeling alternatives can be chosen for representing the same concept.
2. Specification of meta models: For each modeling method, the meta model has to be specified. The terminology of the original has to be kept. Generally, three cases can be distinguished: (a) Modeling method with an explicit meta model: The meta model can be taken and, if necessary, converted to the chosen meta model language. (b) Modeling method with no explicit meta model: The meta model needs to be reconstructed. (c) Reference data models: At first, relevant concepts have to be typecasted. Afterwards, these can be extracted and compared to the modeling concepts of 2a and 2b.
3. Identification of common and different concepts: Due to a common language, the specified meta models are syntactically comparable. Nevertheless, when comparing conceptual models, three sorts of model conflicts need to be considered and solved: type, naming and structural conflicts. Naming and structural conflicts are caused by a heterogeneous usage of the domain language in the conceptual model. Type conflicts, however, can be traced to a different representation of reality on the level of the modeling language.
4. Specification of an integrated meta model: In this step, the identified *relevant* modeling concepts will be consolidated and integrated into a single meta model for hybrid products.

### 3.2 Meta Model Language and Modeling Conventions

We use the UML diagram type *class diagram* as meta model language. This language fulfills the requirement of semantic expressiveness, since it provides a large number of modeling concepts such as classes, attributes, generalization / specialization, aggregation, association, and association classes. It is worth noting that class diagrams do not fully comply with the requirement of determination [14]. Therefore, further modeling restrictions on the degree of freedom are necessary (modeling conventions):

1. Vertically, classes will be arranged according to structure. Specialized classes are placed below more general classes.

2. Horizontally, classes are arranged from left to right whether they depend on the existence of other classes

These rules materialize in the layout shown in figure 1.

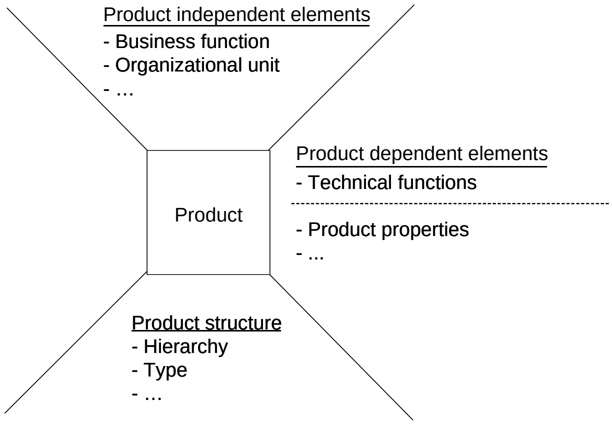


**Fig. 1.** Layout of Meta Models

The product structure is placed below the central product class. Product independent elements such as organizational unit related to products can be found in the upper part of the model. Product dependent elements such as functions and properties are subject of the right hand area.

As already mentioned, the original terminology of each modeling methods will be retained as far as possible. To increase clarity, attribute lists will not be included in the class symbols. Due to diverse focus of some modeling methods, the respective meta models can not be covered completely. This is especially valid for those methods that provide highly detailed concepts for areas such as product prices.

## 4 Analysis

In this section 4, we present modeling methods for products and services which will be analyzed.

### 4.1 Overview

Subject of investigation are six selected modeling methods (see table 1) which represent the most relevant methods due to maturity and adoption by industry. With regard to the method engineering perspective, the methods form two groups:

– Conceptual modeling methods: For each method the meta model needs to be adopted, adapted, or reconstructed (here: ARIS and ISO 10303).

– Reference data models: The model elements have to be typecasted respectively conceptualized at first. Eventually, they can be used for comparison (here: ISO 13584, Y-CIM reference models as well as GAEB DA XML 3.0 and bau:class).

While ISO 10303 and ISO 13584 address the modeling of products, ARIS and Y-CIM are not limited to tangible goods. GAEB DA XML 3.0 and bau:class represent specific modeling methods used in the German construction industry.

**Table 1.** Product Modeling Methods.

| Name | Reference | Type | Notation | Meta model construction |
|---|---|---|---|---|
| ARIS | [15] | product model language | custom | adoption |
| ISO 10303 | [3] | data definition language | custom | reconstruction |
| ISO 13584 | [16] | reference data model | EXPRESS | |
| Y-CIM | [17] | reference data model | ERM | typecasting and |
| GAEB DA XML 3.0 | [18] | reference data model | XML Schema | reconstruction |
| bau:class | [19] | reference data model | Database schema | |

### 4.2 ARIS

ARIS provides concepts for modeling goods and services [15], which are essential inputs and outputs for business processes. Following other industrial approaches, products in ARIS are hierarchically structured. Furthermore, products can be attributed with a type of costs and cost rates. In [15], the product meta model is already modeled by means of class diagrams. Compared to other PDM-oriented product modeling methods, ARIS focuses product structures and refers for a detailed representation of product features to other concepts, such as industrial product catalogs [17].

### 4.3 ISO 10303

ISO 10303 [3] provides concepts for modeling products by means of the EXPRESS language [20]. EXPRESS combines concepts of relational and object-oriented modeling and is supported by the semi-formal method EXPRESS-G. The concepts include entities, which represent classes of objects with some same properties, and typed relationships between entities. Attributes describe entities and can be atomic or structured. Schemes summarize several entities that furthermore can be referenced from other, external schemes.

### 4.4 ISO 13584

ISO 13584 concerns the standardization of product classes and technical product properties. For this purpose, it defines a reference data model [16]. As a complementary standard to ISO 10303, it uses both EXPRESS and EXPRESS-G for specifying this model. An UML-based representation of this model can be found in [21].

### 4.5 Y-CIM

The Y-CIM reference model for industrial business processes is used for structuring and describing business and technical tasks in industrial enterprises. The reference model is based on ARIS family of methods. However, unlike ARIS, product modeling is subject of the data view [17], because it is based on an earlier version of ARIS which does not provide a specific product view. Products are referred to as parts, which can be structured hierarchically and described by means of properties. Further concepts are principles and technical features as well as functional structures and relationships between properties.

### 4.6 GAEB DA XML 3.0

GAEB DA XML 3.0 [26] is a standard for the exchange of data in the German construction industry. The respective reference data model is specified using XML Schema. This model covers all phases of construction from planning to execution. Products in the construction industry are characterized by pre-defined attributes and textual descriptions. A product description includes an explanation of work and optional documents. The work can be hierarchically structured and divided in so called lots of number (e.g., buildings 1, 2, 3, etc.) and content (such as earthwork, carpentry etc.).

### 4.7 bau:class

bau:class is a classification system (or taxonomy) for products and services in the German construction industry [19]. The classification includes about 5,000 definitions. Products and services classes are described by means of property lists. Such classes may represent complex products though such a product structure is not explicitly described.

## 5 Synthesis

In this section, we report about the results of the synthesis of all meta models.

### 5.1 Model Elements and Scope

The method analysis and synthesis calls for a systematic comparison of the modeling concepts found in the respective methods. Therefore, the original language has to be retained to compare the semantic. The comparison includes only those elements that are explicitly contained in the method's meta model by means of classes or associations. The attribute level is not considered here. Table 2 shows which elements the methods contain and how they are entitled.

**Table 2.** Comparison of Meta Model Elements and Terminology

| ARIS | ISO 10303 | ISO 13584 | Y-CIM | GAEB DA XML 3.0 | bau:class |
|---|---|---|---|---|---|
| **Product** | | | | | |
| Product | Entity | Product class | Part | Building product | Product |
| Good<br>Service<br>Information service<br>Miscellaneous service | | | | | |
| **Product structure** | | | | | |
| Product structure | Relation | | Part structure | Product structure | |
| | Pattern, Relation | | | Lot | |
| | | | | | Subject area |
| **Product-dependant elements** | | | | | |
| Attribute | Attribute | Property | Part property | Attribute | Description property |
| | | | | | Property list |
| | | | | Product description | |
| | Synonym | | | | Keyword |
| | | | Technical function | | |
| | | Domain | | | |
| | | Value | | | Characteristic |
| **Product-independent elements** | | | | | |
| Type of costs | | | | | |
| Cost rate | | | | | |
| | | | Solution principle | | |
| | | Supplier, Identification | | | |

Reviewing the table above, the following interim conclusions can be drawn:

- ARIS distinguishes products in the sense of products and services and embeds product modeling in enterprise modeling.
- In Y-CIM, relations to manufacturing processes can be described by means of technical functions and solution principles. These two concepts are missing in all other methods.
- All considered methods describe products by means of properties. ISO 13584 presents the most comprehensive property concept and allows dependencies between properties.
- ISO 13584 and bau:class consider only atomic products, whereas the other methods allow for modeling complex products by means of hierarchical structures.
- Product bundles can only be described in ISO 10303 and GAEB.

### 5.2 Integrated Meta Model

The aim of an integrated meta model is to consolidate the relevant concepts for modeling hybrid products. It is not just a superset of the individual meta models.

For integrating the identified concepts and systematically constructing the model, we adopt the object-type approach which provides the four operations subsumption, subordination, composition, and reduction (a detailed explanation can be found in [2]).

The meta model shown in figure 2 is based on the results of the previous analysis and comparison:

- Products are distinguished in tangible goods, services, and hybrid products.
- Product characteristics are described by means of properties. The property model is based on ISO 13584. Textual descriptions, as they are made explicit in GAEB, are represented by properties.
- According to Y-CIM and to take into account the customer integration, the concept of customer function has been considered. These functions can have a hierarchical structure.

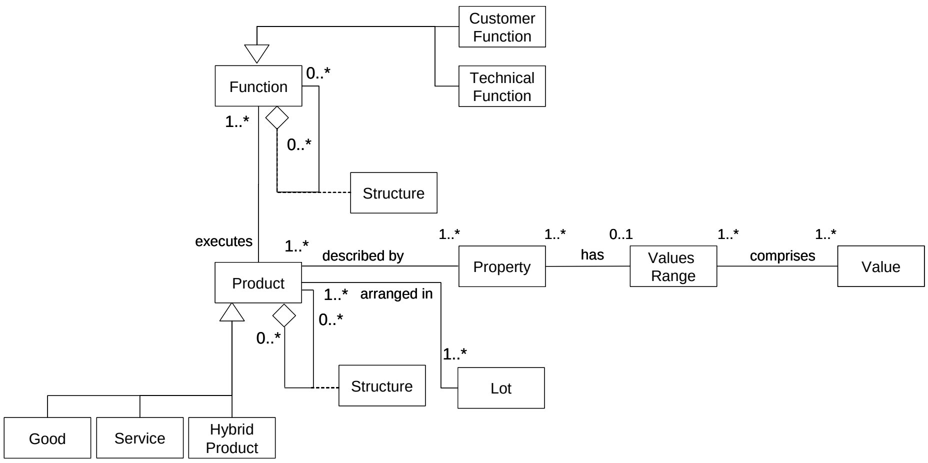


**Fig. 2.** Integrated Meta Model

## 6 Conclusions

In this paper, methods for modeling products and services were investigated. In doing so the question should be answered, to what extent the considered methods provide concepts for modeling hybrid products. For this purpose, we adopted a method engineering perspective, which allowed by means of language-based meta modeling a systematic analysis of syntactically diverse modeling methods. As a result an integrated meta model was constructed.

The contribution is that we (1) reconstruct core modeling concepts from six modeling methods and (2) integrate those into a meta model. The analysis shows that the so called result dimension is still dominating, thus what hybrid products provide whereas both the process and resource dimension lack attention and dedicated modeling concepts.

With regard to the research framework of *logistics systems under customization*, we studied the means how firms in supply chains of the construction industry could model and thus describe hybrid products. The analysis, however, indicates that such means are hardly available. The conclusion is that interactions between customers and suppliers with the purpose of matching customer requirements with supplier capabilities require additional modeling concepts and more suitable methods. Thus the current methods in the construction industry do not cater for individualization whereas they focus rather standardized, less complex products.

The considered methods originate predominantly from product modeling in the sense of goods, even if they sometimes allow a differentiation between goods and services. It can be stated, however, that modeling concepts for the customer integration in particular, hardly exist. This way the methods address the result dimension only.

Relating to the process dimension of hybrid products, dedicated concepts are hardly recognizable. The example of the construction industry presents a pragmatic approach for representing hybrid products. The modeling approach is based on just a few constructs, the formal semantics is limited.

Since the current meta model focuses primarily result-oriented aspects, future work has to aim at integrating the resource and process dimension, which are required for a clear understanding of hybrid product modeling.

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