# Product data model for PLM system

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**Abstract:** Product lifecycle management (PLM) is a new business strategy for enterprise's product R&D. A PLM system holds and maintaining the integrity of the product data produced throughout its entire lifecycle. There is, therefore, a need to build a safe and effective product data model to support PLM system. The paper proposes a domain-based product data model for PLM. The domain modeling method is introduced, including the domain concept and its defining standard along the product evolution process. The product data model in every domain is explained, and the mapping rules among these models are discussed. Mapped successively among these models, product data can be successfully realized the dynamic evolution and the historical traceability in PLM system.

**Keywords:** data model, domain, data mapping, data traceability, PLM

## 1. Introduction

With the emergence of the networked firm and the networked economy, Product Life cycle Management (PLM) has become a new business strategy for global manufacturing. As a management paradigm, PLM support entails the modeling, capturing, manipulating, exchanging and using of information in all product life cycle decision-making processes, across all application domains [1]. PLM emphasizes the collaboration of product data driven by the process collaboration, which is process-centric. These data is an important basis of PLM, which generated from all phases of a product's lifecycle, and engineers/managers/technicians inside an organization, as well as suppliers and customers [2].

In the context of PLM, evolution of product is a phased and hierarchical running mode, which is across multi-dimensional coordination. Product data in PLM have various formats, such as figures, reports, tables, files and data sets. With evolution of product, product data are changing and evolutional in their structures and attributes. Data modeling is a key concern in PLM. Product data model should be setup to describe, categorize, analyze, store, trace and transit all product data in PLM. For different users in PLM system, they have not the same rights to visit the product data. So, creating a safe and effective data model to support PLM is a major challenge for implementing PLM system in a company. In order to ensure to send the right data to the right person in the right time, product data model should have integrality, consistency, safety, diversity, share, activity, traceability and other characteristics.

To address this issue, this paper emphasizes the importance of defining, managing safe data, and exploiting their relationships between different product data representations. The goal is to manage effectively and reuse the dynamic data generated from product lifecycle. The paper proposes a domain-based data modeling approach to the management of these data in product lifecycle. The modeling approach relies on domain natures and proven mapping rules between product data. As a closed space, domain is a safe and effective data carrier, and achieves the right mapping between product data by its intelligent interface.

The body of this paper is organized as follows: It begins with a short review on product data modeling in Section 2. Section 3 introduces the concept product data domain and defines many data domain along product lifecycle stage. Section 4 builds a domain-based data model. In this section, the product data information embodied in every data domain is exploited. In section 5, the evolution of product data in its lifecycle is described in detail, including the data dynamic evolution and historical data trace. Section 6 presents an illustrative example of this modeling approach for PLM system, and the last section

summarizes the key elements.

# 2. Related work

Different product data modeling techniques are proposed in lots of literatures. Bellatreche et al. [3] and Fu et al. [4] discussed the ontology-based data modeling. Zhang [5] discussed product data meta-model and the product data integration and created a product composing model and a product data classification model. Zhang et al. [6] discussed a feature-hierarchy product modeling method based on assembly unit, which support the data consistency in product design process. Ghang et al. [7] described a data modeling case based on the Georgia Tech Process to Product Modeling (GTPPM).The method was initially developed in response to the need to integrate multiple use-cases with differing data definitions from different companies. Yang et al. [8] proposed the architecture of integrated product lifecycle model and described the building process for product lifecycle model from fives dimension as lifecycle dimension, product level dimension, version status dimension, attribute type dimension and collaborative control dimension.

However, these citing product data models based different modeling methods are deficient in describing and managing all data information throughout the whole lifecycle. Their disadvantages and limitations are summarized as follows:

(1)They only consider product data, but do not pay attention to the resources information related to product in product evolution process. The resources information is important in PLM environment, which needs to be managed.

(2) They only manage static product data, but do not consider dynamic product data information throughout the product evolution chain.

(3) Product lifecycle unified model tries to express all product information through the whole lifecycle by using a single model. However, product unified model proposed may be static model, which does not describe dynamic data and process information. Or, it is dynamic and multi-dimension, but it can't be implemented for their complex structures.

(4) They only guarantee single product data source, but they have deficiency of managing data integrity, security and traceability.

In our research, product development and evolution is divided into a multi-stage, multi-layer and cross tridimensional running mode in all product lifecycles. At the same time, these product stage data model can be integrated seamless by the data domain.

# 3. Data domain definition and representation

## 3.1. Data domain representation

Definition1. Data domain is a closed unit management entity, which encapsulates the tools, data, models, methods and other resource objects in a knowledge domain or a lifecycle stage, in order to manage and share varied heterogeneous data during collaborative product development processes.

Data domain can be described as the following formula:

**D=P×DM×R×I**

Here, **P** is the product data manipulator, they are the users who visit data domain, and they are limited by R. **DM** is denoted as the product data model in data domain. It is an information set including product data, product metadata, processes information, data domain environment information, etc. **R** is defined rule set, include data access control rules, the define rules of data structure relationship, metadata mapping rules and other rules. By **R**, data domain can control product data model. **I,** intelligent interface, denoted to express the intelligent agent between data domain and outside, in order to achieve various resources sharing during product development.

Fig.1 shows a product data model in every data domain consists of product data information model, process information model and environment information. Product data information model describes the complete information of product data in a dynamic change period, which has complete structure, attributes and life cycle status. Process information model refers to the process information related to product data change and evolution. Environment information is the domain-specific product-related resource information.

Fig.1 illustrates the data models between data domains are relatively independent of each other, and they can establish mapping, achieve data resources sharing through the intelligent interface of data domain. The associated domains not only express and manage effectively all product-related information, but also ensure a single product data source and source. As can be seen from fig.1, the mapping between data domains is achieved through the collaborative process.

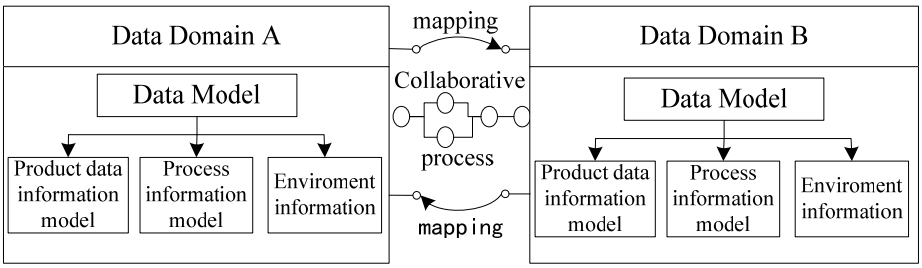


Fig.1 Data model in data domain and their mapping based collaborative process

## 3.2. Data domain definition in product lifecycle

In theory, in order to accurately describe and manage product data and information, numerous data domains can be established following the product lifecycle axis. However, in practice, taking into account the granularity of the data management and the difficulty on their implementation, the number of data domains is limited. Thus, in the early stages of the data domain definition, these two concepts are mentioned as:

Data domain breadth: it refers to the horizontal expansion extent of data domain on the product lifecycle stages. The optimal number of data domains can be defined along product lifecycle stages, according to the managed product data grain size.

Data domain depth: the concept of data domain depth refers to the vertical expansion extent of data domain-level division. Facilitating to control the operation access of the data information in data domain, a data domain can be divided into multiple sub-domains.

Generally speaking, modern complex product starts with collecting and analyzing customers' requirements, and market analysis, and ends with recycle & disposal. Based on this, the paper defines many basic data domains including concept design domain, structure design domain, detailed design domain, process planning domain, manufacturing domain, sales & service domain, as shown in fig.2.

The content and controlling rules of the data model in different data domains are different. However, all the data domains are established in accordance with the uniform definition standards, following the development process. Fig.2 shows these domains have the similar definition method and package similar content type, including data model, data operators, intelligent interface and rules. Therefore, the paper only introduces the definition of the detailed design domain as an example. It can be described as:

Detailed design domain: it is a unit domain with rules and intelligent interface, which includes all resource objects in detailed design stage, such as, design tools, designers, product data model, parts data models, the structures information and attributes of product part, and the association between these objects.

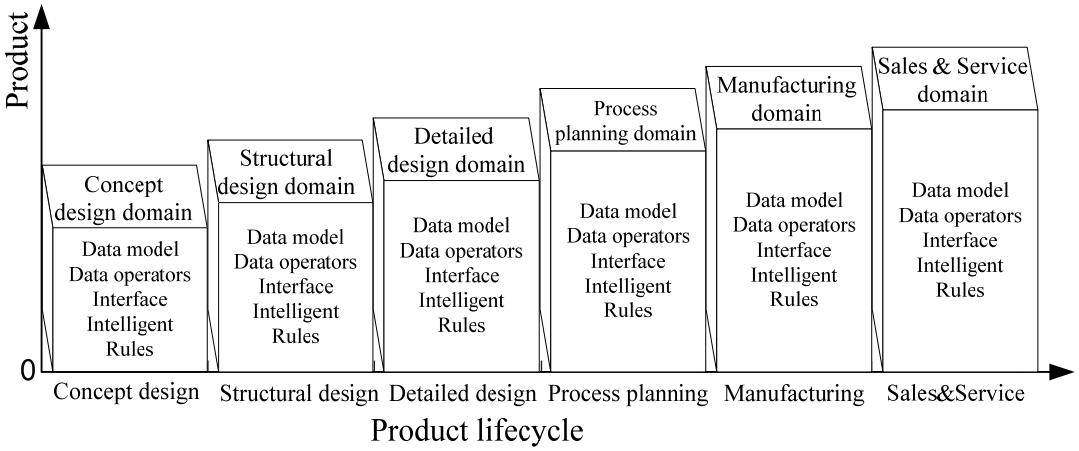


Fig.2. a few basic data domains in product lifecycle

# 4. Product data model in data domain

Fig.3 shows the product data model in every data domain built in the previous section. In support of the Collaborative processes, these product stage data models establish their mapping links by the intelligent interfaces, and product lifecycle data model is formed in PLM environment. These specific data models in basic data domains are described as follows:

The data model packaged in the concept design domain is product function data model [9]. It mainly describes product should meet the functions and the capabilities to achieve the physical and chemical principles, methods and role of the product functions, including function hierarchy delineation and function information definition. Function layer is a tree structure, which can be divided into multi-layer, sub-functions, basic function. The basic function is no longer a breakdown. The final leaf node is the basic function, which is not only the key to build product function data model, but also the importance to pass product function information to downstream data domain.

Structure design domain is the successor of concept design. The data model in structure design domain reflects the specific results of product concept design, namely, each basic entity function in product. Therefore, the data model packaged in structure design domain is product assembly structure model, which includes the structure and function characteristic information, product structure layers information, the overall assembly constraint information and property characteristics information.

Detailed design domain has the role of nexus, which the key to pass data information between the upstream domains and middle and lower domains. The upstream domains are concept design domain, structure design domain, and the middle and lower domains include process planning domain, manufacturing domain and sales & service domain. The data model which is packaged in detailed design domain is parts data model, including product part function information, product part characteristics information and its attributes information.

Process planning domain and manufacturing domain package the data models for product manufacturing. The data model in process planning domain is parts data model and product process data model. Here, parts data model describes the parts assembly sequence, craft parts definition and the assembly relations between them. Process data model includes craft parts information and parts manufacturing methods. The data model in manufacturing domain mainly describes the manufacturing information of parts, such as parts materials information, geometrical characteristics, processing equipments, parts batch and parts numbers.

The model packaged in sales & service domain is product service model, which is built by product sales plan and customer demands. The service model mainly records final product sales, part sales, as well as

user service information.

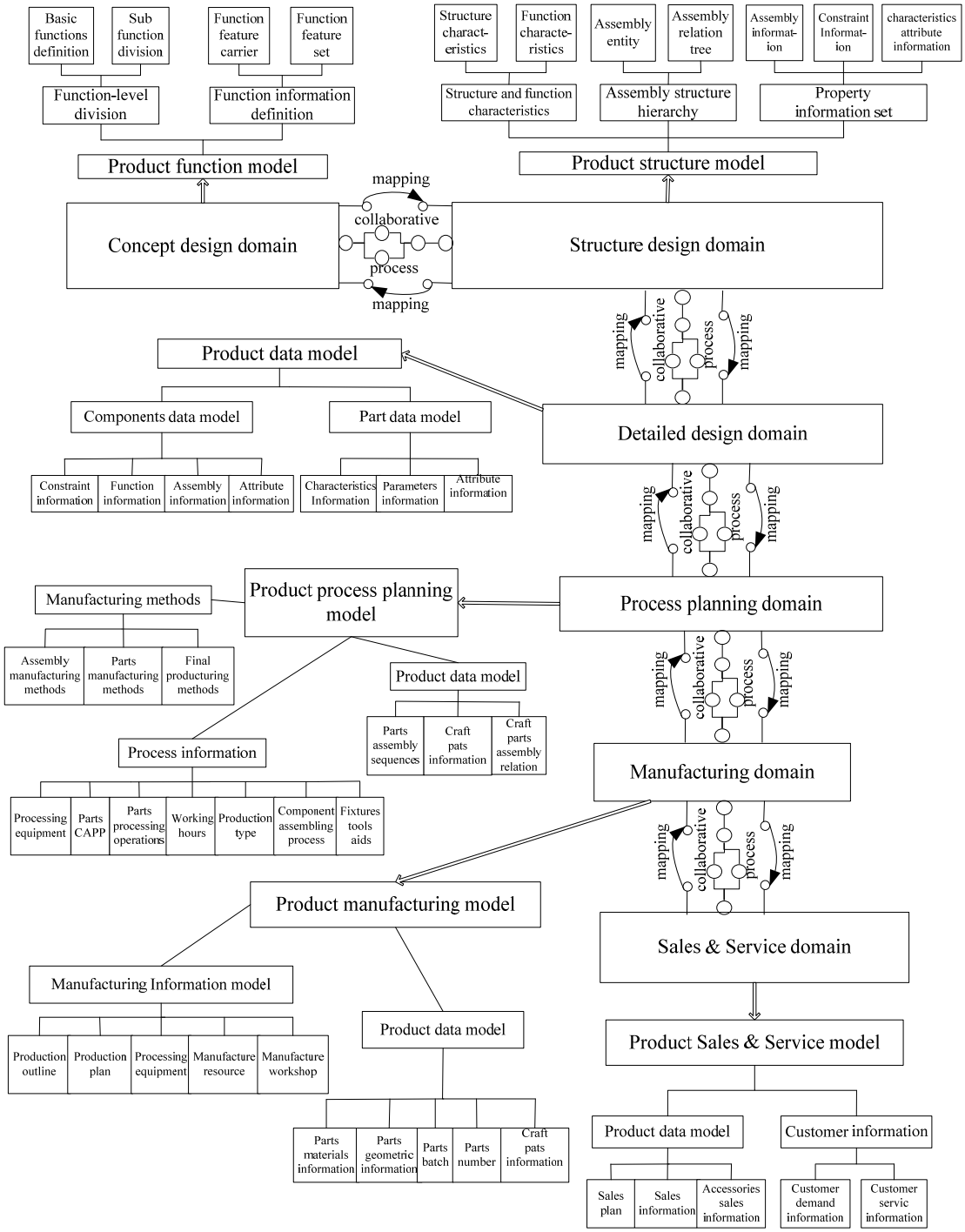


Fig.3. product data model in every data domain

# 5. The mapping between product data models

Product data models can be established the mapping contact by the intelligent interface of the data domain in the collaborative process's supporting of PLM. Product data in all the lifecycle can be share and transmitted each other through the data models mapping between data domains. The mapping has two main roles:

(1) It achieves the dynamic evolution of product data information throughout product lifecycle.

(2) By the mapping between product data models, product data is implemented positive predictive tracking and reverse historical data traceability.

## 5.1. Dynamic evolution in product data

In the dynamic evolution process, product data objects will bring the qualitative change and quantitative change, that is, the change in product data structure and its attributes.

### 5.1.1. The change in product data structure

Product data structure describes the structure relationship between product materials. In different data domains, the classification criteria for product data structures are different. For example, in detailed design domain, product data structure is defined according to its function structure; in manufacturing domain, product data structure is divided in accordance with parts processing and assembly sequence. Therefore, the product data structures must be regulated when the product data models between two data domains map to switch themselves.

The change in product data structure is that the changing in product materials types and their assembly numbers. From the perspective of product manufacturing, the materials constituting product data structures are mainly distributed in detailed design domain, process planning domain and manufacturing domain, specifically divided into six types: dummy parts [10], craft parts, key parts, subcontractor parts, outsourcing parts, and generic parts.

Fig.4 illustrates the conversion processes and rules of these materials types in different data domains. Here, the six kinds of products are firstly explained.

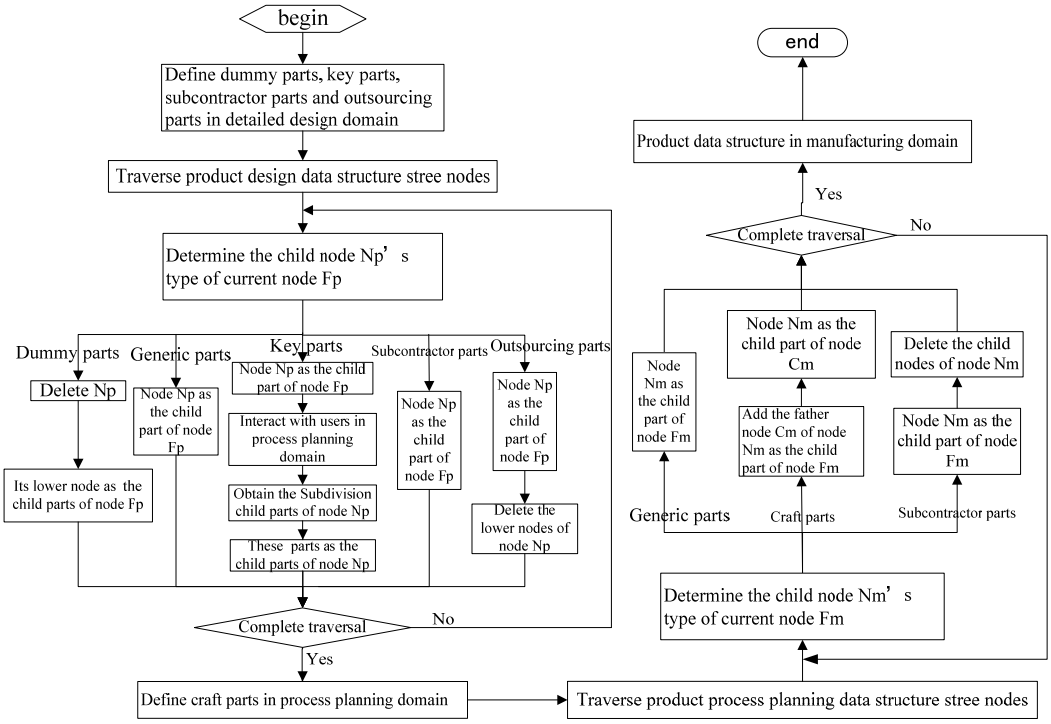


Fig.4 the changing process of product data structure among detailed design domain, process planning domain and manufacturing domain

In detailed design domain, dummy parts, key parts, subcontractor parts and outsourcing parts are defined. Dummy parts are only recorded in detailed design domain, are not manufactured and stored in the actual production. Key parts appear along with parts craft separation. Key parts are the parts that they are generated from the parts subdivision in detailed design domain in parts craft decomposing process. Subcontractor parts are those parts that they and their child parts need to be manufactured by subcontractors. These parts will don't exist in manufacturing domain. Outsourcing parts are the parts that they and their child parts need to be outsourced, and these parts don't appears in process planning domain and manufacturing domain.

Craft parts will be manufactured and stored in actual production since parts craft plan needs. Craft parts

are defined in process planning domain, and added in manufacturing domain. At the same time, some parts will be downgraded the child parts of craft parts. These downgraded parts are called craft child parts. Through these craft child parts treatment, parts manufacturing work will be serial. Thereby they are saved to use on the context of limited resources.

In addition to above five kinds of materials, those parts are called generic parts. Generic parts are the same in every data domain.

Fig.4 shows that these materials have different conversion processes and rules. For example, dummy parts, key parts and outsourcing parts will treated when product data structure conversion between detailed design domain and process planning domain. However, craft parts and subcontractor parts will be treated in the mapping process of product data structure between process planning domain and manufacturing domain.

### 5.1.2 The mapping between product data attributes

Product data attributes are called product metadata objects, are used for describing product data objects. For a data domain, product data attributes are a complete description for all the product data objects in the data domain. However, from the perspective of object-oriented technology, product data attributes are integrated by the data subset of product data models in every domain. So when different data models in different data domain begin to map, the mapping relation is in their data attributes.

The mapping between product data attributes includes attributes items mapping and attributes values mapping. The mapping process reflects the data integration requirements in product development process. Generally, product data attributes mapping types include genetic mapping, derivative mapping, reduced mapping, aggregation mapping, separation mapping, educed mapping and domain distribution mapping. These mapping types are explained as following:

When genetic mapping occurs, the product data attributes don't have any change before mapping and after mapping. For example, those public attributes, such as material ID, are the same in every data domain.

If there is a derivative mapping, the product data attributes in target data domain will add new data attributes on the basis of the corresponding data attributes in source data domain. Reduced mapping is opposite from derivative mapping.

Aggregation mapping is a complex mapping type. When it occurs, the product data attributes in the other data domains will be combined to form a new data attribute describing product data in the target data domain.

Separation mapping is partly opposite for aggregation mapping. When it occurs, several product data attributes in target data domain are from one product data attribute in source data domain.

Educed mapping is the mapping that the product data attributes in the other data domains are calculated to form a new data attribute in the target data domain.

Domain distribution mapping means each data domain has its own unique data attributes according to the management needs for data domain.

In practical applications, the mapping between product data attributes in different data domains is often the synthetic maps of above seven mapping types. For example, product public attributes, such as material ID, name, are the same when product data structure conversion between process planning domain and manufacturing domain. This kind of mapping is generic mapping. The mapping between the product material attribute, weight attribute in process planning domain and the manufacturing resource attribute in manufacturing domain is called derivative mapping. Product numbers attribute in manufacturing domain is calculated from the product numbers attribute and production plan attribute in process planning domain. The kind of mapping is aggregation mapping. The manufacturing workshop attribute in manufacturing domain is decided by the production type attribute in process planning domain.

The kind of mapping is educed mapping.

## 5.2 Product data traceability based data domain

In the context of PLM, product traceability not only traces the sources of raw materials and parts, but involves product all lifecycles. According to enterprise's demands, the traceable contents are processes, product, batch, and parts, which make product traceability complicated. The product data model proposed in the paper can manage product all lifecycles and provide the full traceable sources.

The paper simplified the product lifecycle development processes and established product data traceability model based data domain as shown in Fig.5. Fig.5 illustrated that product historical data can be traced through several ways. For example, if designer in detailed design domain found some design problems in version 1 of part P, he can search all processes information related to the version through part P number. In the supporting of all the processes, designer can search and found its process methods, manufacturing methods, raw materials and production equipments in process planning domain. Then in manufacturing domain, the designer can trace its production lines, production time and so on by searching its process planning information. Eventually, the problem part is recalled. Otherwise, if a problem product is found in the final assembly or the sales & service, all information related to the product, including production equipments, batch, raw materials, process methods, design drawing number, etc, can be traced in manufacturing domain, process planning domain and detailed design domain. Finally, the matter source can be found and the changes can be fixed on by analyzing the disqualification reasons of the product.

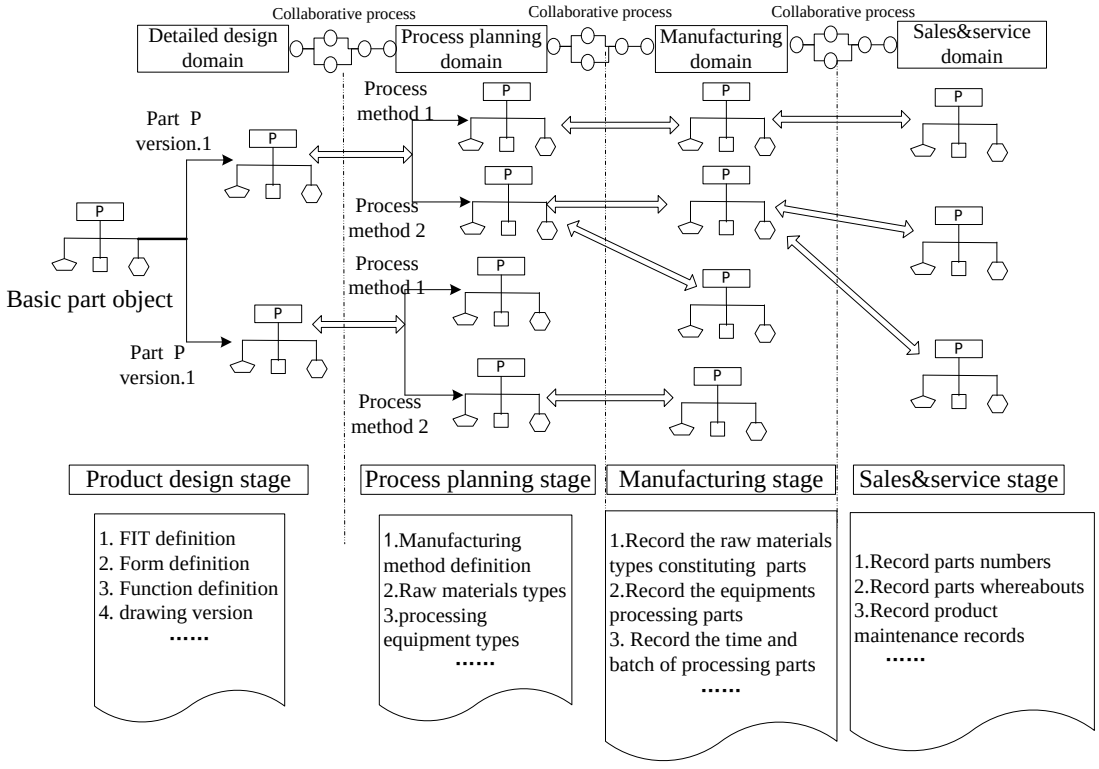


Fig.5 product data traceability model

# 6. Instance

Based on the methodology research, a web-based PLM system (IntePLM) has been developed in National CAD Support Software Engineering Research Center of Huazhong University of Science and Technology (HUST). The software and hardware environment is as follows:

Operating system: Microsoft Windows 2000 Server. Web Server: IIS6.0.

Database Management System: Oracle 10g. Programming language: VC++ 2005.

Modeling tool: Rational Rose 2000. Developing tool: VC++ builder 2005.

This system provides fine-grained access to all the product data whenever and wherever it is recorded. The applications of above product data model can be expressed in many ways in IntePLM system. Because of the complexity of this system, the multi-view BOM management is selected as an example. Its implementation steps are described in the section.

1. Establish BOM domain

According to the methodology research, BOM domain is established in IntePLM system. In order to meeting enterprise's management needs for the multi-view BOM , BOM domain type in IntePLM includes Design BOM domain, Process planning BOM domain, Manufacturing BOM domain, Assembly BOM domain, Quality BOM domain, Cost BOM domain, Sales BOM domain, etc.

2. Domain-based user login

When user enters IntePLM system, he must first choose a domain to login. The selected domain restricts the range of user's activities, and the security risks induced by the illegal users are eliminated.

3. Establish Design BOM view

The engineer in Design BOM domain can import design BOM view of a product from CAD environment to IntePLM system. The user can modify the design BOM view and create different BOM view versions by business needs.

4. Establish and maintain the other BOM views

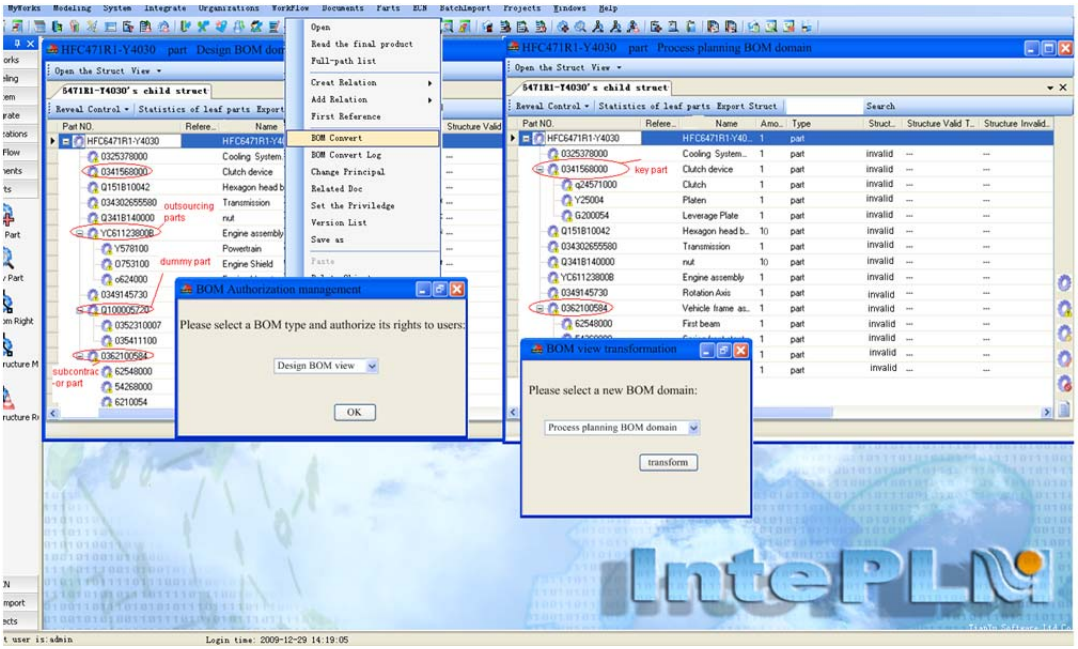


Fig.6. the establishment and maintenance of Process planning BOM view in IntePLM

The other BOM views can be transformed from the Design BOM view through the mapping relation between the above BOM domains. Fig.6 shows the establishment and maintenance of the Process planning BOM view. Firstly the engineer in Process planning BOM domain must obtain the right to visit the Design BOM view; Secondly he choose Design BOM domain as the source domain by the BOM view transformation function in IntePLM system; Thirdly he uses the transformation rules of BOM view structures to deal with these parts structures transformation, including generic parts, dummy parts, key parts ,subcontractor parts and outsourcing parts; And he uses the data attributes mapping rules of BOM views to obtain all types data information, such as genetic data, derivative data, reduced data, aggregation data, separation data, educed data; Finally the Process planning BOM view is finished. The engineer can modify it for the process needs and production needs. For example, he may subdivide key parts, define

craft parts, etc.

Using the similar operation way, the users in the other BOM domains can establish and maintain the corresponding BOM views. Since these BOM views are transformed from a same data source, and the transformation process is restricted and protected by the BOM domain, product data is ensured the uniqueness, integrity and safety throughout all stages.

5. BOM view data traceability

Based the proposed data traceability method in the paper, the users in different departments can trace the historical data information in all BOM views by product data attributes values.

# 7. Conclusions

Product data model is the key core to support PLM system, and it also is the basic for collaborative data and process. Product data model for PLM system organizes all data information throughout the whole life of a product effectively and efficiently. As a solution, a domain-based product data model is here proposed on the base of the advantage of domain management and analysis of dynamic and changeful data information in product lifecycle. This model does not only guarantee the manageability, integrality, consistency, security and traceability of product data in all lifecycles but can share various and dynamic data information from product evolution chain. The mapping processes between product data models in all data domains provide a feasible approach for data conversion in its structure and attributes.

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