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# PRODUCT DATA MODELING WITHIN PLM

**Dr Prof. Amol D Lokhande** Principal, Sanghavi College of Engineering, Mhasrul, Warvandi Road, Nashik-422202, Maharashtra, India :amollokhande3@gmail.com
**Jaykumar Yoga Mule** PhD Sholar, Mechanical Engineering, School of Engineering and Technology, Sandip University Trambakeshwar Rd, Nashik, 422213 Maharashtra : mulejai@gmail.com

**Abstract:** Supporting Product Lifecycle Management (PLM) is a primary goal of the new breed of product modelling concepts and applications; specifically, they aim to facilitate the generation, utilization, storage, and dissemination of product data across the entire product lifecycle, from inception to disposal. The modelling, recording, manipulating, exchanging, and using of information in all decision-making processes across the product life cycle is what is meant by "PLM support," and it applies to all application areas. Data generated at any point in a product's lifecycle can be safely stored and managed in a PLM system. Therefore, it is important to construct a reliable product data model to underpin PLM systems. Data integration is another issue that must be addressed in a PLM strategy. That is, how to seamlessly incorporate product data from inception to decommissioning, covering every step of the product's lifecycle from design to production to operation. The significance of identifying and managing secure data, as well as utilizing the relationships between their various product data representations, cannot be overstated. All product lifecycles may be broken down into distinct phases that each serve different functions. In the same breath, the data domain can easily incorporate various product-stage data models.

**Keyword:** *Product Lifecycle Management*; *Product data Modeling, Data Domain, Product Data Mapping*

## • INTRODUCTION

The Center for Information and Management (CIM) defines a PLM system as "a strategic business approach that applies a consistent set of business solutions in support of the collaborative creation, management, dissemination, and use of product definition information across the extended enterprise from concept to end of life-integrating people, processes, and business systems and information." As a result, PLM systems are becoming increasingly popular for handling data from product inception to retirement. The modelling, recording, manipulating, exchanging, and using of information in all decision-making processes across the product life cycle is what is meant by "PLM support," and it applies to all application areas. The information created by engineers, managers, and technicians within an organization, as well as external parties such as suppliers and customers, is crucial to the success of any product lifecycle management (PLM) system. Product data refers to all these details, and product data modelling is the process by which they are organized and made accessible at the right time and to the right people [1].

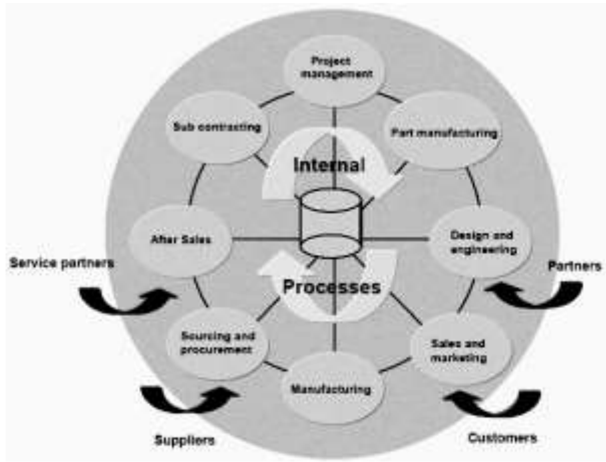


Fig 1: PLM system function and properties [1]

Within product lifecycle management (PLM) systems, product data modelling is a relatively new but critically significant topic. Figures, reports, tables, files, and data sets are just a few of the many ways that PLM stores information on its products. Product data, like the products themselves, are dynamic and ever-evolving in their structures and attributes as time goes on. PLM requires a product data model to be built up in order to correctly characterize, classify, analyses, store, trace, and transmit all product data. Users of the PLM system do not all have the same access to the product database. Making sure the data model you use to support PLM is secure and efficient is a significant obstacle when introducing PLM to a business. Integrity, consistency, safety, variety, sharing, activity, traceability, and other qualities of the product data model are necessary for sending the correct information to the right person at the right time [1].

PLM systems, located at the pinnacle of an organization's software pyramid, rely on lower-level systems for the collection and transmission of granular data. Product Lifecycle Management (PLM) software typically employs a separate system, known as Product Data Management (PDM), to handle the product's descriptive data. Furthermore, in many businesses, PDM systems rely on CAD systems for managing product descriptions because only the geometric description of objects provided by CAD systems is controlled directly.[2]

To effectively manage and reuse the dynamic data generated from the product lifecycle, it is crucial to define, manage, and exploit the links between the various product data representations. In this article, a data model based on domain expertise is investigated. Application support for conceptual design, design engineering, manufacturing planning, service and maintenance are all provided by PLM. Customer Relationship Management (CRM), Supply Chain Management (SCM), and Enterprise Resource Planning (ERP) are just a few of the processes that it is built to integrate with and handle (ERP). When all the elements are incorporated into a PLM system, it may function at peak efficiency. In object-based systems, tracking and tracing serve as representations of accumulated data on objects' attributes over time. Thus, it is crucial in providing safety, precision, simplicity, and dependability.

Integrity of data generated for a product is preserved by a PLM system over its duration. In order to efficiently manage and utilize the dynamic data generated during the product lifetime, it is necessary to construct a reliable product data model to enable PLM systems.[2]

Additionally, there is a demand-

- To solve the problem of data integration in a Product Lifecycle Management vision and to emphasize the importance of defining, managing safe data, and exploiting their relationships between different product data representations.
- To obtain the required information within information quality factors like accuracy, timeliness, sufficiency, easiness, reliability, and meaningfulness i.e., traceability.

## • HISTORICAL BACKGROUND

The history of most significant events that gave birth to PLM is given below:
The 50s and 60s: These were golden years for manufacturing industry. Demand exceeded production capability. Computer Aided Design (CAD) systems were in their infancy.
The 70s and 80s: Companies in the West were worried by the increasing presence of high-quality, low-cost Asian products. Computer Aided Design and Manufacturing (CAD/CAM) systems were no longer centralized. Product Data Management (PDM) appeared.
The 90s: Globalization hit. Production was outsourced to low-cost countries. Concurrent engineering morphed into collaborative development. CAD functionality became a commodity. Customer focus became a buzzword. Product Lifecycle Management appeared.
2001: Governments and consumers are forcing manufacturers to focus on the entire product lifecycle right through to recycling.
Now a days: New PLM software and newer versions of existing software's are emerging. PLM system integration with other systems becoming new research objectives. [4]

## • PRODUCT DATA

Product data refers to the data related to product throughout its lifecycle. Product development data is the most valuable innovation asset of an organization. These records contain not only the facts about the product but also all the insights gained via its creation rather than keeping track of multiple data models, businesses should centrally handle product data. [4,6]

## • PRODUCT DATA MODELING WITHIN PLM

PLM, or Product Lifecycle Management, is a group of programmes used to coordinate the entire product development process from the initial idea through the final disposal of the product. The product data model is the central hub for all product-related data. Any PLM system will struggle without a thorough product data model to guide its operations. During the first step of developing a PLM strategy, you must determine what data will be needed and generated at each stage of the product development process, then organize and map that data. Some benefits of product data modelling include mapping, integration, consistency, safety, diversity, sharing, activity, and traceability of data. Another major perk is confidence that the right data will get to the right people at the right time. [4,6]

## • DATA MODELING TECHNIQUES

Many different approaches to modelling product data, such as an ontology-based data model, a product data meta model, and a feature hierarchy product modelling approach, are presented. Data models based on these cited modelling approaches fail to adequately describe or manage data across the product lifecycle.
Their disadvantages are:
• In the product evolution process, they focus exclusively on product data and ignore information about the product's underlying resources.

Industrial Engineering Journal
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• Throughout the lifecycle of the product, they simply manage static product data without taking into account information about dynamic product data.
• A unified model for the entire product lifecycle is the goal of the product lifecycle unified model. However, the proposed product unified model can be a static model that cannot account for changing data and processes. It may be dynamic and multi-dimensional, but their intricate architecture prevents it from being executed.
They lack the ability to manage data integrity, security, and traceability, and can only guarantee a single product data source.
Given the aforementioned drawbacks of more traditional approaches to data modelling, a domain-based data modelling strategy is being seriously studied. The modelling strategy makes use of existing mapping rules between product data and domain natures. Domain is an enclosed environment that provides a secure data carrier and an efficient interface for correctly mapping product data. [4,6]

## • DATA DOMAIN

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.

It can be described as, $D=P\times DM\times R\times I$

Where,
Data domain users (they) are P, who manipulates product data, and are constrained by R.
The data model (DM) refers to the product data model in the data domain. It's a collection of data that covers a wide range of topics, from product details to metadata to process flows to the context of the data domain itself.
R is a rule set, which may include, but is not limited to, rules for controlling access to data, defining the relationships between data structures, mapping metadata, and so on.
I is intelligent interface, which stands for the expression of the intelligent agent between the data domain and the outside world in order to accomplish the sharing of diverse resources throughout the development of a product.
There is a product data information model, a process information model, and an environment information model for every data domain. As shown in Fig.1, data models across data domains can be treated as autonomous entities; by utilising the intelligent interface, mappings can be established, and data resources can be shared. All product-related information is properly expressed and managed inside the associated domains, which also serves to guarantee a unified product data set. Figure 1 shows how a group effort results in a consistent mapping across data types. [4,6]

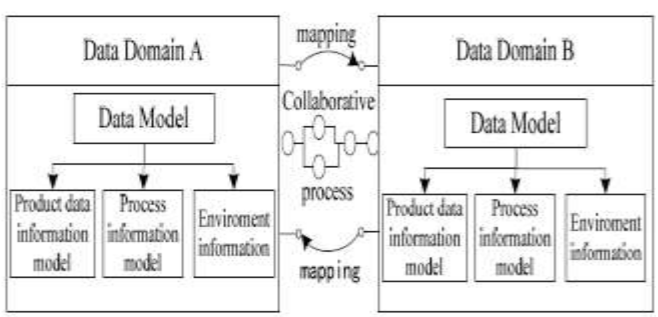

Fig 2: Data model in data domain and their mapping based collaborative process [4,6]

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 8, No. 5, August : 2023

Although multiple data domains can be established to precisely describe and manage product data and information, the number of data domains is limited by the granularity of data management and the difficulty of their implementation. The horizontal expansion of a data domain over the various product lifecycle phases constitutes its breadth. The vertical breadth of a data domain's subdivision level is its depth.

In spite of potential differences in data model content and governing rules between data domains, all data domains are constructed using the same set of definitional standards. Each of these domains has its own set of components, but they all share the same definitions and packaging for things like the data model, data operators, intelligent interface, and rules.

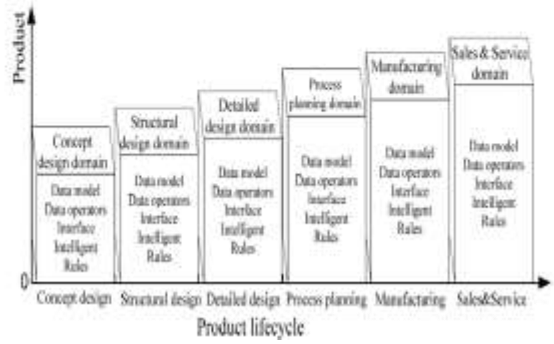


Fig 3: A few basic data domains in product lifecycle [4,6]

- **DATA INTEGRATION**

In order to effectively manage a product over its entire lifecycle, product lifecycle management (PLM) necessitates detailed modelling of all applicable application systems, data, processes, methodologies, and skill sets. it is important to merge the various file formats and data types employed by these applications, from text documents to geometric computer-aided design (CAD) files, simulation data, and organizational records. Techniques to properly organize, store, access, transform, and interchange this data for its users are necessary for its successful incorporation into a PLM concept. Our principal interest is in learning more about how the PLM system promotes productive interaction amongst its numerous users. Three alternative approaches are used to illustrate the collaborative solution presented in this article [5,6,7]

1)The Meta data approach
2)The features approach
3)The ontological approach.


Fig 4: Collaboration as a mechanism for integration. [5]

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 8, No. 5, August : 2023

- ***The Meta data approach***

A meta-data approach relies on a means to represent the data being transferred, transform it into a common format (the meta-data), and guarantee that it is exchanged correctly between parties so that it may be read and processed without difficulty. To get there, you need a strategy that can adapt to the here and now while also expanding to meet the demands of the future. The World Wide Web Consortium developed a language called Extensible Markup Language (XML) as a portable, open-source system for secure data transmission. The 3/3 architecture, Enterprise Java Beans (EJBs), and the XML interchange standard are crucial to the success of this method. Structure is composed of a series of layers or levels:

Client-side designers of all stripes have their own layer at the top of the stack called the User Interface layer. The information gathered at this level is converted to XML before being transmitted to the next level. Inversely, data received from higher levels are in XML format and must be converted back before being used.

Level two, the Multi-view Interface Layer, is a collection of server-side programmes powered by Java technology that regulate database-client communication.

Data is exported to the clients from a remote common database on the server side, which is in the third tier, the Database layer.

The failure of this strategy lies in the fact that it is limited to exchanging data or information syntax while ignoring its semantic content. This forces users to manually handle the semantic components of the data, which is inefficient. [5,6,7,8]

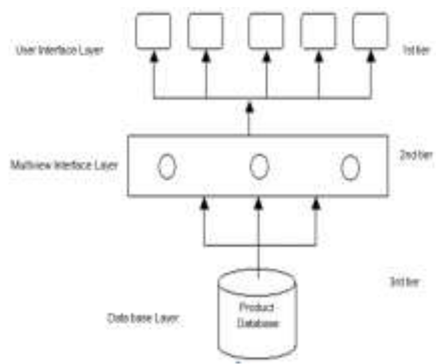


**Fig 5: Architecture for the meta-data approach [6]**

- ***The Feature Approach***

A feature is a fundamental object that connects the geometric specifics of a product to their interpretation from a specific vantage point.

There are four techniques to obtain a feature model:

In the case of automatic feature recognition, a geometric model is used to extract features (often those associated with manufacturing) (generally a Boundary representation B-rep).

•Feature-based design: During the design process, parameterized libraries of features are used to add basic functionalities.

• Feature conversion takes as input an existing feature model from one view and outputs a model of another view based on the input features. Indeed, this is one of the most convenient methods for multi-perspective collaborative settings to coexist.

• Hybrid methods combine elements from multiple approaches, typically due to the limitations of a single method.

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 8, No. 5, August : 2023

The assumption underlying the feature-based approach to multi-view integration is that several applications share a common geometry, which is then translated into a set of features that are interpreted differently depending on the perspective. The product model is an amalgamation of the several feature-based actors' models, each of which represents the actor's perspective on the product lifecycle. In this approach, a semantic analyzer is used to link geometric data with different product semantics through the use of composition and abstraction techniques. However, the various stages of a product's lifecycle are not only concerned with the product's geometric data, but also comprise numerous other forms of information, especially during simulation, maintenance, etc. The feature approach addresses the issue of data integration across CAD/CAM disciplines as a collection of geometric entities endowed with meaning.

- ***The Ontological Approach***

The ontological method rests on the assumption that all points of view share some underlying body of information or meaning. The philosophical term "ontology" refers to a comprehensive analysis of the nature of things as they actually are. Everything that can be represented exists in artificial intelligence. A concept's ontology is its formal description. Ontologies are currently the state-of-the-art when it comes to representing knowledge. Concepts, relations, properties, examples, and axioms are the main parts of an ontology.

A higher level of abstraction allows for the semantic component of an ontological approach, which is the technique's primary advantage. This compromises our ability to abstract the information semantics involved in the ever-evolving phases of product lifecycle management. [6,7,13,15]

## • PRODUCT DATA MODEL IN DATA DOMAIN

The specific data models in basic data domains are described as follows:
The product function data model is utilized as the conceptual design domain to define the physical and chemical principles, methods, roles, and information about the product's functions. The realm of structural design has succeeded that of concept design. Each component of a product's core functionality is reflected in the data model for the structural design domain. This means that the product assembly structure model is the pre-configured data model for the structure design domain. The detailed design domain acts as a hub, transmitting data and instructions between higher-level "upstream" domains and lower-level "downstream" domains. Data models used during production product creation are bundled together from the process planning domain and the manufacturing domain. Parts' material information, geometrical qualities, processing equipments, batch numbers, and component numbers are all examples of the types of data that make up the data model in the manufacturing domain. Product service models are bundled in the sales and service area, and they are created based on product sales strategies and client needs. In the service model, data on sales of both completed products and individual components, as well as data on user service, are kept. In a PLM setting, a product lifecycle data model is produced as a result of mapping linkages between data models at various stages of the product's development. [4,6,7,13]

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 8, No. 5, August : 2023

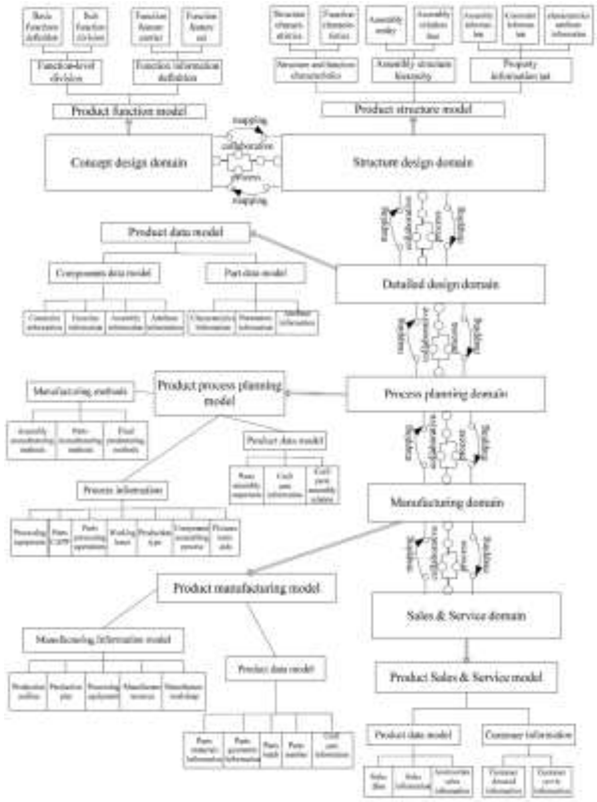


Fig 6: Product data model in every data domain [3,5, 13,19]

- **PRODUCT MULTI-POINT OF VIEW MODELING**

Configurations are used to organize technical data in PLM software. With an ever-increasing number of PLM application users, an ever-increasing volume of technical data, and a variety of evolutions associated with these data, it is crucial to control and check the consistency and safety of the exchanged technical data, as well as to consider data evolutions and all their effects on the product and its components. The technical details are helpful for developing, producing, maintaining, recycling, and marketing the product. The building blocks of a product's configuration are laid out in a configuration model. This model specifies all the possible components that will go into the product's ultimate shape. The rules for how these parts can be combined are also part of the configuration model. This setup is in accordance with the flexible nature of manufacturing lines as they've evolved throughout time. Functional view, technical view, industrial view, etc.—each employee in the organization is responsible for a specialized perspective on the product that caters to his unique demands. We incorporated member feedback into the product model primarily through two methods: Integration of Data from Multiple Sources and Models. [5,19]

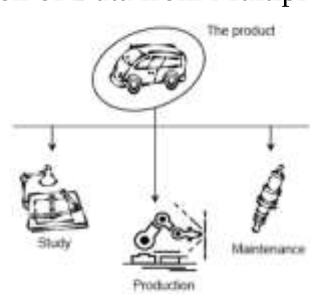

Fig 7: Various business views associated with a product. [3,6,8,9]

The idea behind the multi-view technique is to build a unified model from several vantage points. Many perspectives can be applied to this one-of-a-kind model. If you change something in one of the smaller models, you will see those changes echoed everywhere else. Because there is just one model to maintain, inconsistencies caused by the separation of data between the several partial models are eliminated, and the process of managing and sharing information between parties is simplified. Due to the fixed nature of the models handled by the various elements, the resulting product representation is static. The multi-model strategy involves building a model that reflects the perspective of each team member. Controlling the interdependencies between these models necessitates a set of coherence rules that are universally applicable. It is considerably more challenging to maintain these kinds of connections. The Multi-model's method provides a framework for organizing data according to models tailored to various product-related perspectives. Researching a collection of reference models by industry or profession is a great way to build familiarity with industry standards and generic models. This reveals two distinct tiers of commercial interaction:

A. Generic level: Here, someone oversees developing generic models by learning from the experiences of others and the reference models that have been developed for similar situations. Models can be improved by adding generic specifics that have not been utilized before but will help with what came before.

B. Specific Level: At this stage, a person is narrowing in on the specifics of the model they want to buy or sell. The parts of the specification were used to fine-tune this model. For this reason, this individual will simply need to finish this basic model to provide the model to be applied in the organization, saving time overall. This general model accounts for technical object configuration specifications. Helping PLM solution integrators and developers by getting rid of generic models according to industry or profession. Generic modelling alters object setups and, by extension, the related product architecture. The product's assembly numbers and the materials it is made from are both subject to change as a result of the new data structure. The methods and principles for converting between these materials in various data domains are depicted in Fig. Different types of components are distinguished in the design domain, including fake components, important components, subcontractor components, and outsourced components. While the detailed design domain is where dummy components are recorded, the manufacturing domain is where real parts are made and stored. The critical pieces are derived from the parts subdivision in the detailed design domain during the decomposition process of parts craft. They, too, will have to hire outside help to produce some parts for both themselves and their progeny. They and their progeny need to have these items manufactured elsewhere.

Various components will be mass-produced and stocked to meet the needs of the craft's production schedule.

Various conversion methods and guidelines exist for these parts. Dummy parts, critical components, and outsourced parts will be treated differently, for example, when moving product data structures from the detailed design domain to the process planning domain. However, both hand-made and outsourced parts will be considered in the mapping process of product data structure between the process planning domain and the manufacturing domain. [5,6,13,19]

## • PRODUCT DATA MAPPING

Product data objects are described by product metadata objects, which detail the characteristics of product data. Product data allows for a mapping of items and values between its many attributes. Different methods of mapping product data attributes include genetic mapping, derivative mapping, reduction mapping, aggregation mapping, separation mapping, educed mapping, and domain distribution mapping. Pre- and

post-genetic mapping, no significant changes occur in the product data's defining characteristics. Material identifiers, for instance, are accepted everywhere.
In derivative mapping, additional characteristics are added to the product data characteristics in the target data domain that go beyond the characteristics already present in the source data domain. Materials and weights are two examples of attributes. In reduced mapping, source and target data domain properties for a given product are compared and any non-essential ones are removed from the target data domain. Aggregation mapping involves consolidating many attributes of product data from different data domains into a single attribute in the target data domain. It's possible to derive the product numbers attribute from the production plan attribute in the manufacturing domain and the product numbers property in the process planning domain. One attribute in the source data domain can be separated out into several target data domain product attributes via separation mapping. In an educed mapping, one property of the target domain's data is derived from the properties of products in other domains, as the name suggests. The attribute manufacturing workshop in the manufacturing domain is based on the production type attribute in the process planning domain. Domain distribution mapping indicates that each data domain will have its own set of data attributes based on management needs. [6,13,20]

## • PRODUCT DATA TRACEABILITY

In object-oriented systems, tracking and tracing are metaphors for the persistent representation of contextualized data on object attributes. The term "traceability" refers to a product's ability to maintain its original identity, as well as its original purpose and context. The goal of any tracking system is to collect the necessary details while adhering to established standards of quality in areas like accuracy, timeliness, sufficiency, ease of use, reliability, and significance. It has long been a major topic in production control to establish a Tracing system that takes into account relevant details such as product features, manufacturing system, and requirements. Traceability is useful in many contexts beyond only recollection, proof-of-quality, proof-of-originality, etc. The traceability system is of critical importance in assisting with root-cause analysis, corrective action planning, and ongoing quality improvement. In this regard, information sharing is crucial, especially for tracking and tracing purposes. All stages of a product's lifespan are considered in the process of establishing its provenance, not just its raw material and component suppliers. Traceability is difficult because processes, products, batches, and parts all need to be tracked to meet the needs of different businesses. When it comes to the infrastructure of information and communication in the supply chain, models of reference are crucial for tracing. [6,13,20]

## • MODELING FOR TRACEABILITY

Information on the layout of a traceability system's database can be modelled conceptually. One of the first steps in conceptual modelling is figuring out what kind of traceability you'll need and why. In this step, we catalogue all of the key use cases for the traceability system that will be taken into account later in the modelling process. The subsequent stage is to determine the entities involved in the traceability requirements and the connections between them. How two or more entities are connected is captured by the relationships between them. Then, a conceptual model of the system is built utilizing the specifications established in the earlier processes. In this way, the framework of a traceability system for a given domain of application can be represented. After that, the physical modelling is utilized to describe the actual process of data storage in a storage medium. Every part of the database—tables, columns, relationships, and properties—must be represented in the physical model. The comprehensive description of the traceability system is formed by merging the conceptual model, the logical model, and the physical model. To develop a computerized traceability system that dynamically manipulates data to maintain information

Industrial Engineering Journal
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Volume : 52, Issue 8, No. 5, August : 2023

up to date and guarantees a reliable report producing system for various traceability applications, the resulting three models (i.e., conceptual, logical, and physical) are used.

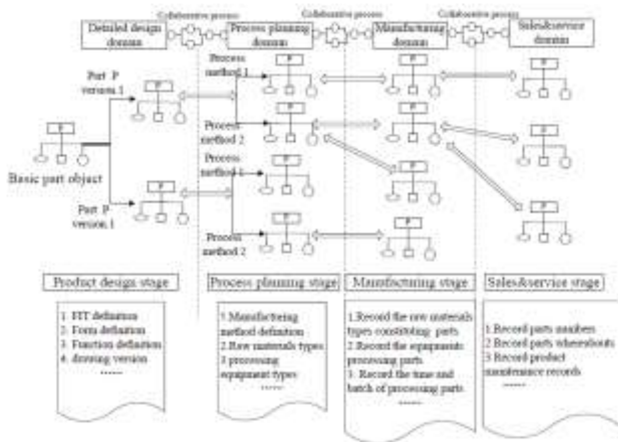


Fig 8: Product data traceability model [6,13,20]

## CONCLUSION

PLM revolves around the product data model. PLM, or product lifecycle management, is an information system that handles all the details of a product's existence. An effective product data model is required for the efficient handling of this data throughout their existence. It also serves as the foundation for shared information and procedures. Product data is any and all information gathered about a product throughout its entire lifecycle, and product data modelling is the process by which this information is organised and made accessible when and where it is needed. The data integration issues are addressed by the product data model. In this article, the product data model in the data domain is unveiled, guaranteeing the controllability, consistency, security, and traceability of product data throughout its many iterations. Since many divisions may have varying perspectives on the same product data, a product data map might be useful in bridging these gaps. By facilitating the transformation of product data structure and its properties, product data mapping allows for dynamic evolution of product data information across the product lifecycle. An entire history of product information can be tracked down with the help of this model. Implementing a traceability model facilitates the tracking of product and process variations and the evaluation of their effects.

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