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Chapter 6

PLM for Supply Chain Optimization

Imane Bouhaddou

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.81272

Abstract

Technological advances in science and technology information and communication in recent years have completely changed the way the enterprise functions. It works toward a collaborative relationship between the different partners of its supply chain. Thus, enterprises need to exploit the benefits of integrating supply chain actors and information sharing to improve their performances. This has led to the development of a collaborative product lifecycle management commonly known as PLM. The objective of this chapter is to propose a decision support tool based on PLM for supply chain optimization. Through this work, we conciliate two scientific communities: the one dedicated to PLM and the one relating to the problems relating to supply chain optimization.

Keywords: product lifecycle management (PLM), product design, supply chain design, optimization mathematical models, integrated logistics

1. Introduction

It is recognized that competition is shifting from "firm versus firm" perspective to "supply chain versus supply chain" perspective. Therefore, the ability to optimize the supply chain is becoming the critical issue for companies to win the competitive advantage [1].

Today, it is essential for firms to exploit the benefits associated with supply chain integration and information sharing to improve their supply chain performance [2, 3]. More efficiency can be achieved if this integration is done early in product life cycle particularly in product development process [4].

This has led to the development of systems to manage the technical data of the engineering process. It is in this context that the concept of product lifecycle management (PLM) was

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born [5]. We propose a methodology based on PLM to design simultaneously the product and its optimized supply chain. The description of the mathematical models optimizing each element of the supply chain is not the object of this chapter. First, we define the concept of PLM. In Section 2, we explain the need of an interface integration design, production, and supply chain. In Section 3, we present our methodology of designing the product and its supply chain. In the last section, we modeled using unified modeling language (UML) and PLM, our decision support tool for supply chain optimization.

2. Concept of PLM

PLM is above all a business strategy. It can be defined as an approach collaborative management of product information throughout its life cycle [6].

We also adopt the vision of Francis Bernard, co-founder of Dassault Systemes and creator of CATIA computer-aided design software that considers PLM is a business solution that allows simulating virtually the reality of the digital product: the complete life of the product and its environment, integrating all partners in a collaborative mode [7].

A PLM system automates and simplifies the process of developing new products. This system manages critical product information, product life cycle, and value chain. PLM systems maximize development efforts of new products and significantly increase the company's performance [8].

PLM connects employees to enable them to collaborate and centralize the process of the development of new products. It simplifies the steps by which one must pass for design and manufacture and support the products offered by the company. A PLM system organizes the development from the point of view of customer constraints, production costs, sales history, or other information about the existing products in the business [9].

3. The interface design/production/supply chain

Paviot [10] illustrated a parallel between design and production; we will add a third activity that is very useful in optimizing the costs; it is associated to the management of the supply chain; they are all activities to transform resources into products (**Figure 1**):

- During the design phase, designers must have production data (production system) and supply chain data (means and equipment available). Design teams, in order to successfully integrate all the supply chain partners in the design phase, must be able to integrate all their constraints.
- During production activities, the physical product is created from physical resources (raw materials, energy, and purchased components) and the virtual product from the design

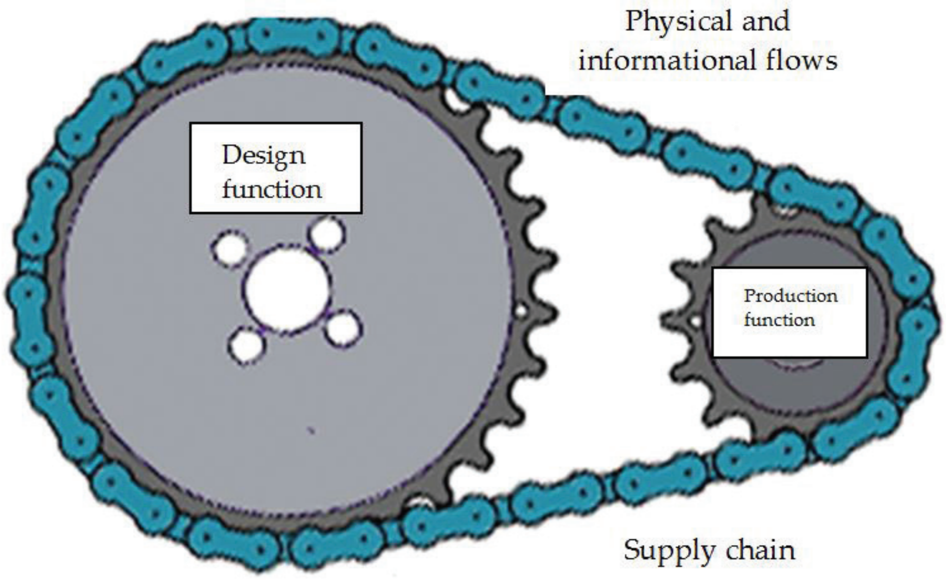

Figure 1. Design/production/supply chain interface.

(digital mockup). The production function generates knowledge that must be brought to the attention of design teams.

- During the supply chain management phase, the physical product is procured, stored, transported, and distributed using the supply chain actors (suppliers, warehouse, transport, etc.).

4. Methodology of designing the product and its supply chain

We will exploit the PLM approach in our methodology by:

- Integration of supply chain constraints into the design phase; these constraints are information flows relating to the production site, customers, suppliers, warehouses, and transport providers.
- Collaboration of all the actors of the extended enterprise (the different partners of the supply chain).
- Simultaneous design of the product and its supply chain:
- Capitalization and archiving of all data.
- Ability to make changes and modifications whenever there are changes in the general environment since a supply chain strategy based on flexibility and agility is the best approach to manage the growing pressure of supply chains [11].

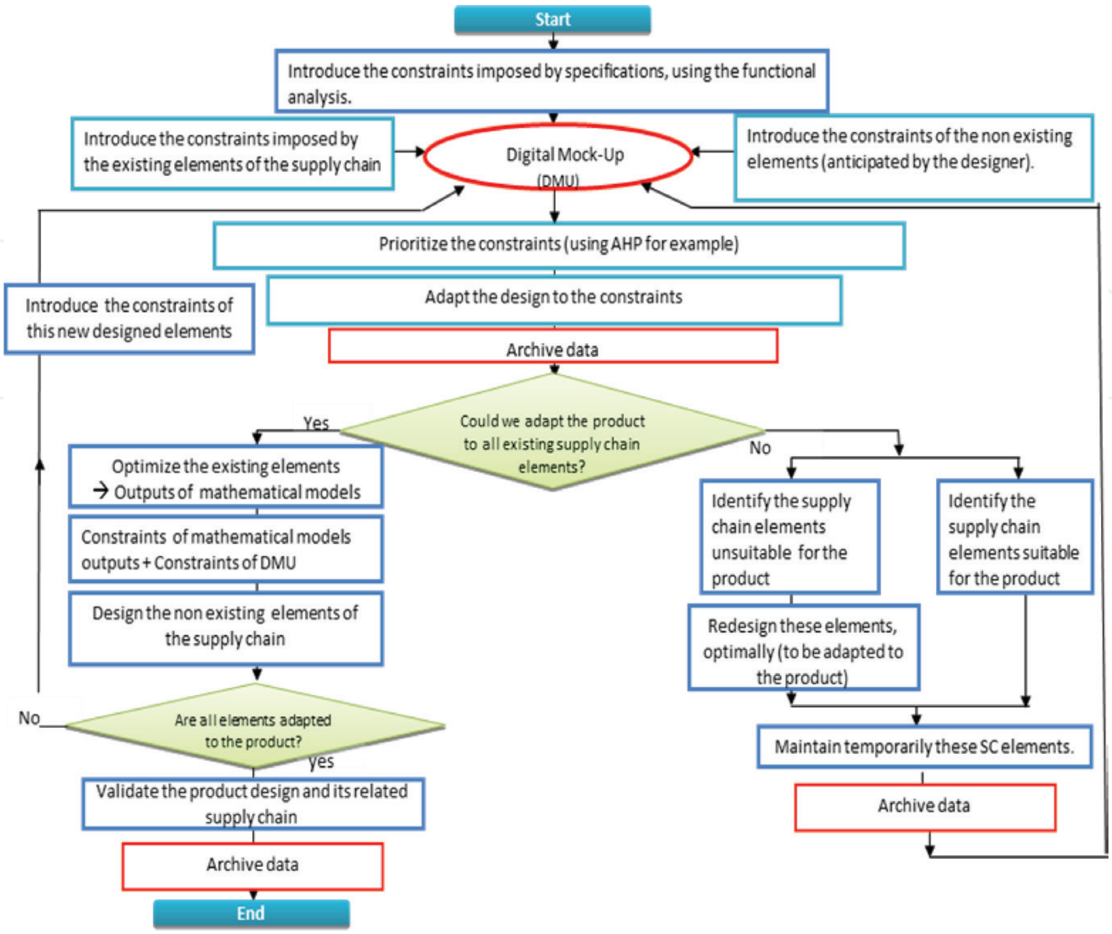

Figure 2. Flowchart of the proposed methodology.

We present in **Figure 2**, the flowchart of our methodology. As the digital mockup is the heart of PLM, it is the center of our proposed methodology flowchart, and all the operations are made around it. First, the designer receives constraints from the existing elements of the supply chain and from the customer specifications. The designer must also anticipate the constraints of the nonexisting elements (e.g., the designer should think about the transportability of the product by optimizing volume, shape, etc. even if the transporter is not yet determined). The purpose of the proposed methodology is to better adapt the product to the existing elements of the supply chain and design the rest of the supply chain optimally.

5. PLM decision support tool for supply chain optimization

5.1. Functional specifications of the tool

The proposed tool helps decision-makers with decisions about supply chain design in the product development phase [12].

We model the expected characteristics of the tool using the unified modeling language (UML) that allows the conceptualization, construction, and manipulation of data. The tool must maintain the PLM approach focused on the product; it must allow to:

http://dx.doi.org/10.5772/intechopen.81272

- Establish the state of the links, as well as their nature.
- Visualize the product and the supply chain and use mathematical optimization results.
- Check the relevance of each decision (objective cost respected).
- Ensure an iterative process.

The tool consists essentially of three modules that represent the main methodological steps proposed in the previous section (**Figure 3**).

Product design module: An interface must be implemented between the tool and computer-aided design (CAD) software. The designer imports a CAD file to retrieve data relating to the digital model (product nomenclature, component characteristics (physical, geometrical, etc.)).

- Supply chain design module: This module is used to represent the data relating to the various links in the supply chain. It includes fields relating to each link (supplier, manufacturer, transport, warehouse, and customer). This module allows adding or removing a link in the supply chain. It also makes it possible to visualize the succession of the links.
- Supply chain optimization module: This module is linked to an optimization software; in our case, we use CPLEX optimization software; it allows to visualize the different results of the mathematical model optimization. It will calculate the optimal product cost throughout its supply chain. This module generates the fields including the following results:
- Supplier: cost of supply and optimal quantity to supply
- Production site: cost of production, optimal quantity to produce, stock level of raw materials, and semifinished products.

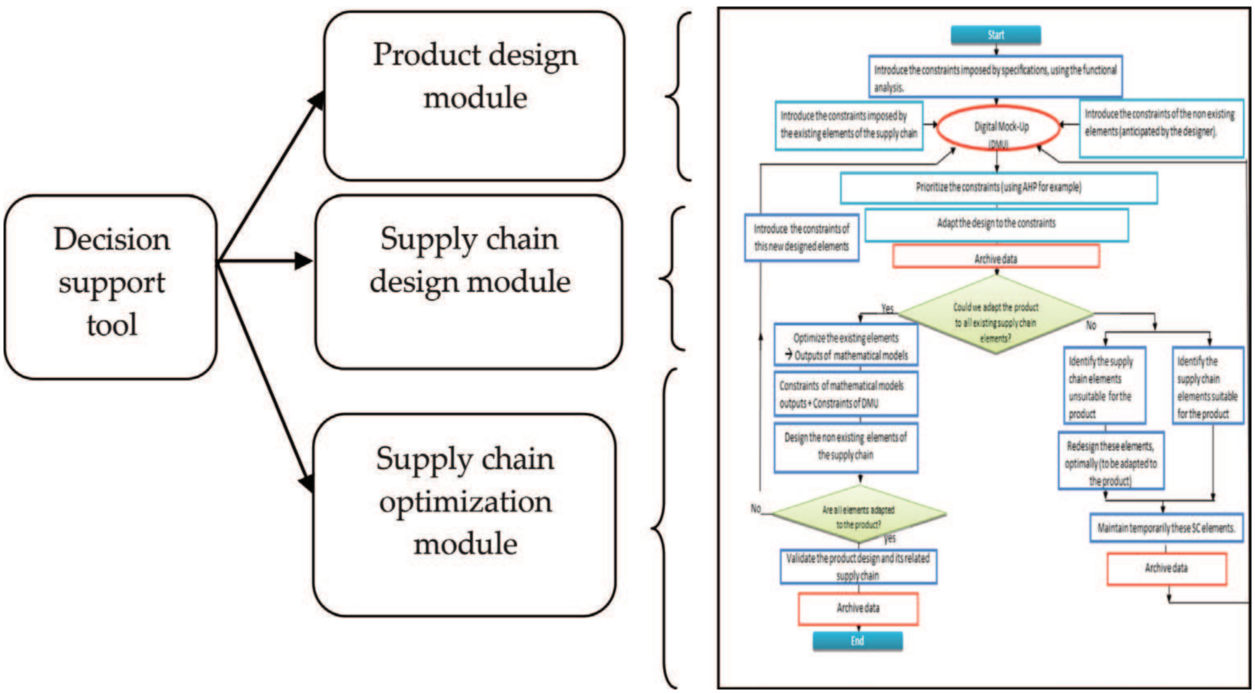

Figure 3. The three modules that make up our decision support tool.

- Transport: transport cost and optimal quantity to transport (from the production site to the warehouse and from the warehouse to the customer).
- Warehouse: cost of storage and optimal quantity to store in each warehouse.

The criteria for stopping the optimization process will be the cost of the product along the supply chain. A check with an objective cost will validate or not each design. This work is done by the decision-maker or the project manager. This person will feed the database and will be able to correctly fill in the information related to the product and the supply chain.

5.2. UML modeling

5.2.1. Use case diagrams

The use case diagram for modeling the product architecture describes the procedure for introducing all product components and their properties (**Figure 4**).

During the design phase of the supply chain, the decision-maker identifies the existing links in the chain as well as the new links to be determined. It defines the link of succession of the different links which will make it possible to specify the order in which the optimization of the supply chain will be done point by point (**Figure 5**).

Optimizing the cost of each link in the supply chain involves introducing the data relating to each link, necessary for the mathematical resolution on the CPLEX software. Once the optimization results are obtained, the cost of the product throughout its supply chain is calculated and compared to an objective reference cost. Finally, the decision-maker validates the design of the product/supply chain pair or decides to modify some links in the supply chain or to act on the product design (digital model) as shown in **Figure 6**.

5.2.2. Class diagram

This class diagram is based on our proposed methodology for the simultaneous design of product and its supply chain; it integrates the variables of the optimization mathematical models relating to each link (ou element) of the supply chain [13] (**Figure 7**).

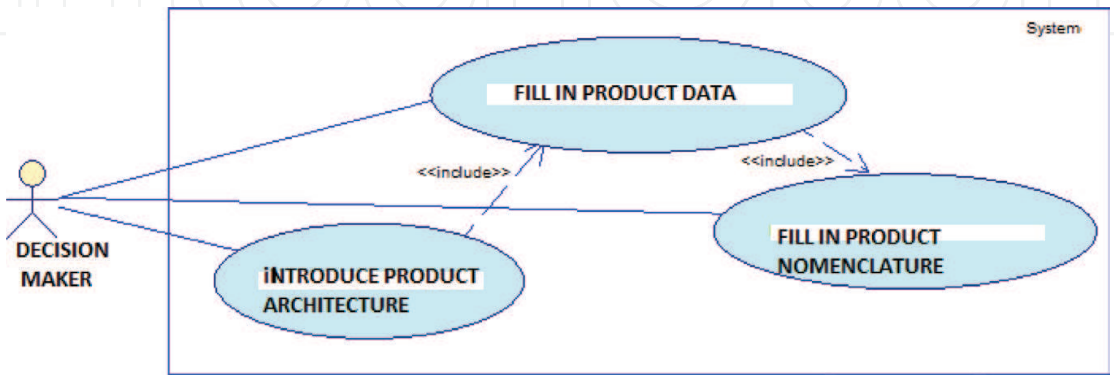

Figure 4. Use case diagram-Product architecture modeling.

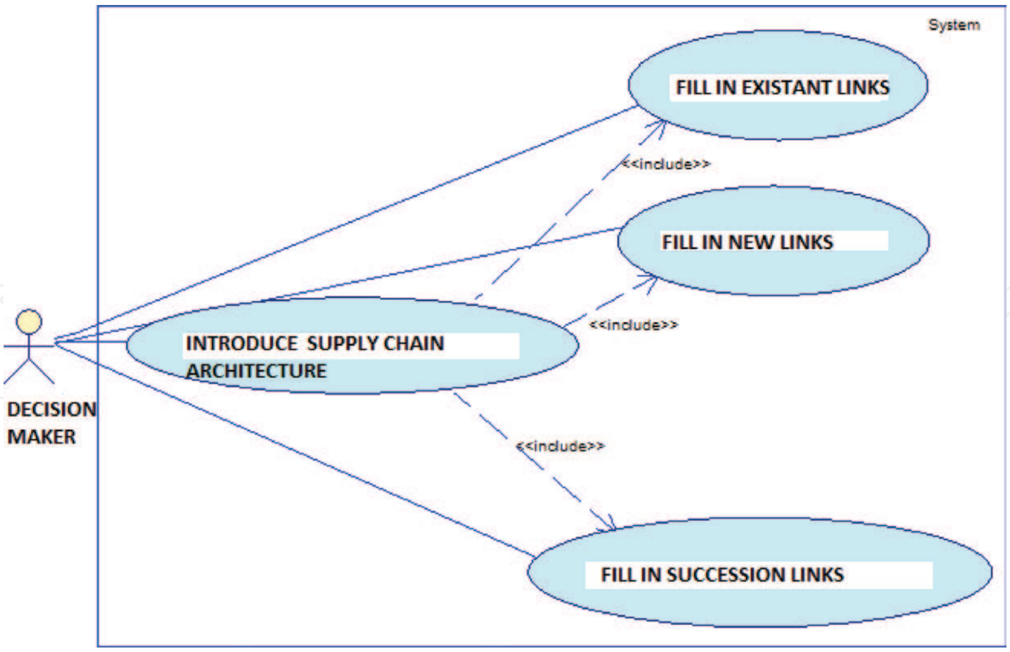

Figure 5. Use case diagram-Supply chain structure modeling.

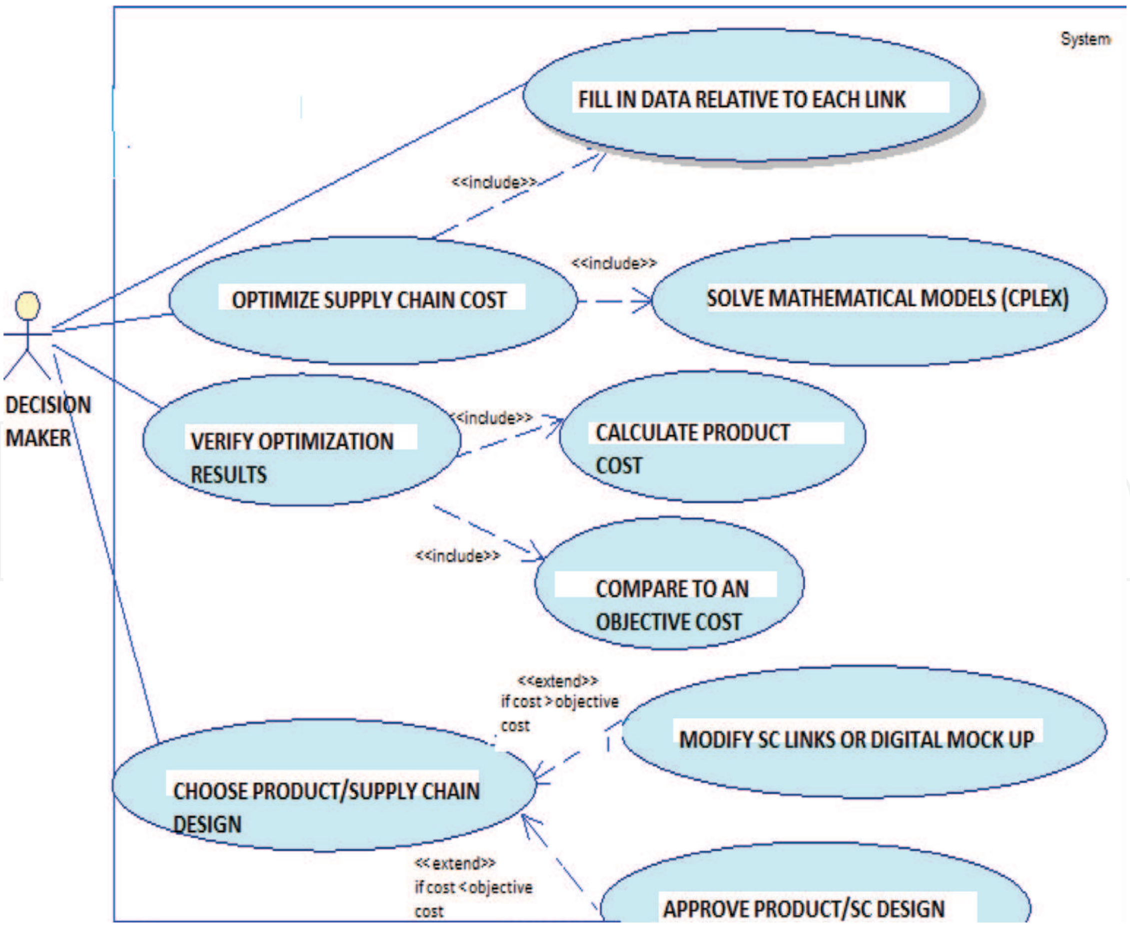

Figure 6. Use case diagram—Supply chain optimization.

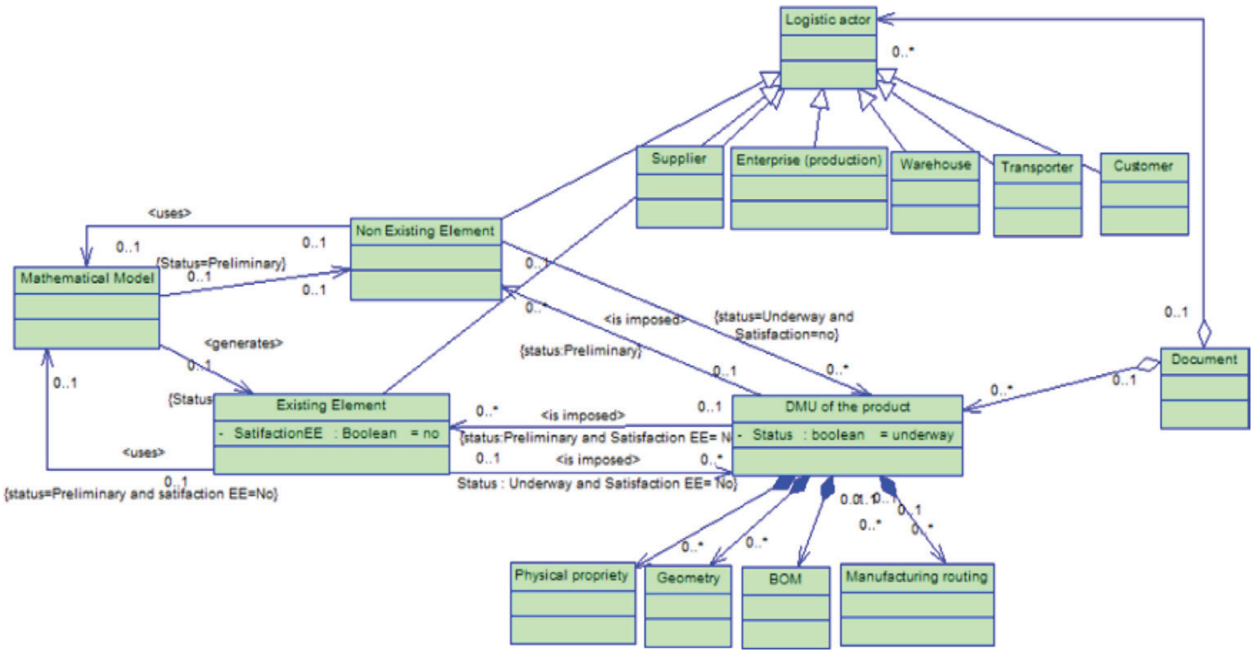

Figure 7. UML class diagram modeling the proposed methodology.

6. Conclusion

The competitiveness of a product on the market no longer depends on the company that assembles or sells it, but to all companies involved in the manufacturing process of this product and thus its entire supply chain. Therefore, the complex management of supply chains has increased the need for information exchange, sharing, and archiving.

Our work contributes to the field of integrated engineering, specifically the integrated logistics in the early stages of the product life cycle using PLM. Concretely, PLM enables a supply chain to become much more competitive by an effective collaboration among customers, developers, suppliers, and manufacturers at various lifecycle stages of a product.

In this chapter, we proposed a framework combining PLM and mathematical models to design the product and its related supply chain.

In our work, we defend the idea that the structure of the supply chain must be defined at the level of the product design that is to say at the level of the digital mockup. We then proposed a methodology based on the PLM approach for product design and its optimized supply chain.

Our approach takes into consideration, as a first step, the supply chain elements that already exist; their constraints must be integrated into the digital mockup. In a second step, designing new links must satisfy the digital mockup and the existing logistics network.

This approach combining PLM and mathematical models is based on three aspects:

- Organizational through the integration of the constraints of all the supply chain partners, responsible for main stages of the product life cycle.

- Technological by bringing together all the actors around the digital mockup; it structures the supply chain design.
- Mathematical by optimizing the costs of the different supply chain partners.

In our future work, we will implement the proposed methodology in two types of industries with different specifications: the agro-food packaging industry and the automotive industry.

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