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A framework of concurrent design of the product, its manufacturing process and its supply chain

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Abstract— This article tends to model simultaneously the product design, its manufacturing process and its Supply Chain (SC) in a Concurrent Engineering Environment (CEE). It comes to seek for adequate methodology and the appropriate modelling of three design dimensions that will be applicable in a collaborative environment. This study consists in a first step to perform a literature review in order to explore the different integration types of two Design's Dimensions Integration (2-DDI). In a second step, a conceptual model formalizing three Design's Dimensions Integration, (3-DDI), has been considered. The proposed concurrent integration requires a general idea coupling all three dimensions of design, refined by the use of a Product Development Team (PDT) and a Collaborative Product Development (CPD) approaches. In the end, an illustrative scenario is suggested for the proposed model.

Index Terms—Concurrent Engineering, Manufacturing process design, Product design, Product Life-cycle Management (PLM) System, Supply chain design, Three design's dimensions integration (3-DDI).

1 Introduction

Competitiveness in an industrial world requires companies to innovate, to respond quickly and with less error to customer's needs. In order to guarantee its market share, companies must change its traditional product development mode, its manufacturing process and its Supply Chain Management (SCM) organization. Thus, we must act on whole those three design dimensions that are Product Design (PD), Manufacturing Process Design (MPD) and Supply Chain Design (SCD). These three dimensions are traditionally processed independently and sequentially.

Nowadays companies have understood that collaborative work has become the inevitable trend in product development. In fact, some complex products are made jointly by several enterprises. So, the SC and all the manufacturing process can be distributed all over the world. This requires wide and strong collaboration, communication, product data and knowledge sharing between actors implied in all Product Development Process (PDP). To reduce errors and development time while improving product quality, the product, its manufacturing process and its SC must be designed simultinously. Thereby, the success key for companies seems to be the integration of these three design dimensions in a CEE.

In a concurrent engineering (CE) framework, the three design dimensions are generally integrated in pairs in most research works, but rarely all of them at the same time. In this article, first of all, we are going to figure all types of 2-DDI and we are going to represent results of most related studies. Thereafter, we will present some recent 3-DDI studies. In the second part, we will present a 3-DDI model in a CEE. Finally, to validate the proposed model, an illustrative scenario is suggested.

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2 Two Design's Dimensions Integration, 2-DDI

2.1 Product Design (PD) and Manufacturing Process Design (MPD) integration

The design activity is more and more related to other product development phases, including the MPD and PD phases [32]. The product and its manufacturing process are often designed simultaneously. Manufacturing process and product designers must communicate, exchange and share information concurrently. Hence, both teams take into account constraints of each other during the product-process design activities. Actors involved in MPD make sure that production times are short and the means used are inexpensive. For their part, designers try to reach a product more reliable and efficient. Simultaneous product-process design allows optimization of cost, time, resources, etc. taking into account the constraints of each side at an early stage. Indeed, the product-design process reduces the development time.

The product integration concept and process engineering functions are more than simply accommodate two functions under one organizational roof [31]. It is also more than just connecting all project stakeholders electronically. Integration means sharing common resources for making progress toward common goals, from equal positions of powers within the company.

To support the PD integration and manufacturing process, Singh [30] develops a mathematical modelling methodology in the operational research domain. He explores a min-max approach to obtain optimal design's tolerances and manufacturing processes in a generalized multi-objective framework. He affects an objective function to the problem under constraints having the form of linear inequalities and tries to maximize profit or minimize costs. This modelling approach takes into account various design and manufacturing factors at an early stage of the product design cycle.

Methodologies from integrated PD and MPD are based on the principles of decomposition [4]: the decomposition of product into systems, subsystems, the process decomposition into tasks, sub-tasks, etc. However, the decomposition is not sufficient because there is also a need for sub-systems integration to subtasks after assessing the technical concordance (synergy). This integration is done with links made between project actors (PD and MPD actors) at the communication interfaces between different disciplines. Designing mainly involves creating, maintaining and activating these links, and requires knowledge exchange.

Eversheim et al. [10] have developed an algorithm that transmits information from PD to manufacturing process planning in the preliminary stages. This algorithm allows passing information from the PD to the design process. Data and information are transmitted in the form of a correlation matrix between the PD and the MPD. This algorithm guarantees quick start activities in the manufacturing process, although the design process is not fully completed. However, Martín and Martínez [25] present a methodology for the simultaneous process and product design applied to performance products. They claim that the use of mathematical programming techniques for designing the optimal formulation of detergents is a powerful technique that allows simultaneously, including process, legal and performance constraints to the typical pooling problem constraints for the design of economical and environmentally friendly formulations.

According to Feng and Song [11], PD-MPD integration is carried out between the two preliminary phases of these two processes (preliminary PD and preliminary MPD). The basis of this integration is the information movement and communication between the two processes. Furthermore, to realise a successful product development, it is vital to emphasise the importance and capture the representation of relationships between parts and sub-assemblies of a product. This provides the basis to promote and control information flow among lifecycle phases in a proactive and intelligent manner. In this framework, Demoly et al. [5] propose a new concept, called 'Bill Of Relation' (BOR), that allows the control of information flow and exchange. The concept of bill of X (BOX) – such as used in PDM (eBOM), CAD (CADBOM) and MPM (mBOM) systems – allows for capturing the state of the product or the assembly process at defined time in the product development process. Consequently, the concept of BOR provides a complementary view on the state of both domains (product and assembly process). In such way, the role of BOR is to facilitate information propagation by establishing the relationship between BOX in PLM systems.

2.2 Integration of Product Design (PD) and Supply Chain Design (SCD)

The costs of managing the entire SC affect the total cost of a product. Indeed, the product quality depends both on its delivery and after-sales service relationship. The time does not depend only on the design time and time to market, but also on SC delays in management, procurement, production and the product delivering [2].

On the one hand, integrated PD-SCD consists to take into account strategic needs, tactical and operational logistics constraints into design projects in order to easily reach the desired industrial performance levels. On the other hand, it is to adapt a PD that is already done to the specificity of the logistics' organization [9]. This is done while respecting constraints of cost, quality and time.

The SC constraints integration in PD as well as taking into account the products specificities in the logistics network design are both the key tools for an integrated PD-SCD [2], [15]. In this framework, Hashemi, Butcher and Chhetri [18] propose a modelling framework for the analysis of supply chain complexity using product design and demand characteristics. They identify some PD characteristics that are considered critical to supply chain strategy and complexity. These characteristics are innovativeness, structure complexity, product modularity, structure compatibility and lead time to produce.

For Shahzad and Hadj-Hamou [29], PD and SCD share four goals: reducing time, mastering diversity, improving quality and reducing costs. They proposed a conceptual model to move from a sequential organization with separation between tasks to an integrated model by an overlap between the PD and the SCD processes. Moreover, Nepal, Monplaisir and Famuyiwa [26] propose a three-step process to match the product architecture with SC design. The first step is selection of product architecture and its corresponding supply chain networks. The second step is the compatibility evaluation of potential members of SC. The third and final step is the matching of product architecture to optimize SC configuration.

Dawlatshahi [8] studied the logistics involvement in the early phases of design and product development. This study focused on facilitating the interface and the collaboration between designers and logisticians. A set of design rules and suggestions for each area are proposed and intended to be general to allow designers and logisticians to meet their own particular case. Furthermore, Gokhan, Needy and Norman [16], in their approach that uses not only customer, marketing, and management requirements necessary for the product design, but it also incorporates supplier information. With this approach, the cyclic procedure of designing a product, generating and evaluating the SC and redesigning the product is reduced in many cases to a single iteration.

2.3 Integration of Manufacturing Process Design (MPD) and Supply Chain Design (SCD)

The literature review shows that few studies have focused on the integration of MPD and SCD. Even existing studies were superficial at the level of the integration discussion.

There is no explicit definition for simultaneous MPD and SCD. However, some researchers suggest that these two processes affect each other and their integration is important. Integrating SCD and MPD can be defined as the simultaneous development of both processes. SC designs have to fill features of the manufacturing process and where this process has to match with the requirements of an existing or feasible SC.

Gunasekaran [17] proposed an integration framework that links facility design and manufacturing processes with functions that may affect it. Among these functions, surrounding the processes and installations design, he named some functions that represent SC processes such as distribution, production and purchasing.

According to Qiao, Lv and Ge [27] the integration process is mainly done throughout integrating MPD information in the whole of related SCD. Furthermore by specifying production and procurement plans and optimizing the SC based on the manufacturing process information. This integration is accomplished with a feedback from SCD to the MPD. This facilitates the MPD in a reasonable and optimized manner. To ensure a unified organization and expression method to describe the information involved in the integration process and the SCD, authors used a method of Unified Process Manufacturing.

Each type of 2-DDI was represented. The examination of these integrations authorized us to enumerate and nominate the importance of 3-DDI and its goals.

3 Goals Of Three Design's Dimensions Integration, 3-DDI

The 3-DDI realization, is based on principally four Goals:

1. Design optimization (time/cost): the elimination of repetitive calculation and reworking same tasks reduce the time cycle. So, the whole design is optimized and more money is saved.
2. Increase product quality: when the information is shared, designers and engineers get optimal solutions quickly. So, the error risk will be reduced.
3. Increase the product portfolio in the industry: Once the product development time is reduced, engineers can start thinking about the next product development. That will give them the impulse to think about innovation and creativity.
4. Make the company more competitive: as a consequence of the previous point, any company will become more competitive and will have more profits.

4 Importance Of 3-DDI In Industrial And Research Domains

In literature, several researchers have stressed design integration importance and interest. According to Agard and Penz [1], the two main reasons to adopt an integration of these three dimensions are:

1. The importance of the PD integration simultaneously with their SC, as the production and the distribution are highly influenced by PD.
2. The importance of the simultaneous PD and MPD: such approach seems to be very important by the volume of its presence in the literature.

Many authors such as [21], [28] emphasized the importance of coordination and alignment of decisions along the three dimensions.

According to Qiao, Lv and Ge [27] the characteristics generated during the PD process (like product structure, components, its size, coordination, tolerances and materials) affect significantly the assembly method and the choice of materials and parts. In other words, they affect the manufacturing process. Therefore, the total final cost of products, production and movement throughout the SC depends on the design. It is then necessary to take into account the manufacturing process and SCD information in an early stage of PD, to make a potential benefit of the final product as a whole. However, Huang, Zhang and Liang [19], using and extending the concept of Generic Bills of Materials (GBOM) of a product family as a unified framework for qualitatively capturing and representing the structure of its supply chain, they proposed that PD, MPD and SCD integration can be set by three stages. The first set includes the most upstream stages and is defined as procurement stages. The second set includes all the most downstream stages; it represents market demands and is defined as demand stages. The third set includes intermediate stages with both up- and down-stream stages. They denote internal manufacturing / assembling processes and are defined as assembly stages.

For Marsillac and Roh [24] many companies and even government agencies such as the U.S. Ministry of Defense have highlighted the importance of PD integration and process selection. They also encouraged horizontal cooperation between business sectors, marketing, finance and engineering.

5 The 3-DDI Propositions And Limits

As already mentioned, the literature does not offer many proposals for integrated product design, MPD and SCD. In fact, they are usually integrated in pairs, but not really all of the three dimensions at once [1]. The idea is recent. Most of processed jobs were an essay for decisions alignment of the three processes. In fact, if several contradictory decisions must be maked, decisions alignment is trying to minimize the impacts of contradicting decisions to take at the end. Some other propositions have been developed in the domain of operational research by assigning mathematical models to problems in order to solve them (an objective function is assigned to the problem under constraints in the form of inequalities). Thus, the found solutions are numeric variables helping to make optimal or near-optimal decisions for each case and they are not generalized.

The study of the PD, MPD and SCD integration has drawn the attention of managers and researchers when Fine [12] proposed the term "three-Dimensional Concurrent Engineering (3-DCE)". Each one of the three dimensions (products, manufacturing processes and SC) has its own architecture. The reconciliation between these architectures is the key to the 3-DCE success. It is argued that a methodology for evaluating the product architecture can be used to link various decisions in the product life cycle phases and can also serve as a collaborative decision-making. Fine, Golany and Naseraldin [13] proposed a 3-DCE formulation through a modelling technique of "a weighted goal programming" and provided an optimization method of compromise for different objectives, such as cost, time, etc. The technique is a mathematical model satisfying several objectives simultaneously.

In the same context, Agard and Penz [1] worked on the identification of sub-assemblies (modules) to manufacture and the manufacture place in the context of synchronous delivery. The model is a linear programming based on real industrial case. It takes into account the minimization of cost, production and transportation capacity constraints in production locations and time of the final assembly. The limit of their proposed mathematical model is the integration of the three di-

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mensions without taking into account the whole product manufacturing process. In fact, only the assembly process was regarded as a manufacturing process.

Blackhurst, Wu and O'Grady [3] have developed a PCDM (Product Chain Decision Model) based on the network to describe the SC operation while examining decisions related to PD and MPD and their impact on the SC. The usefulness of the PCDM is the coordination of decisions through PD, MPD and SCD (decision alignments). The use of this model is a bit complicated for complex systems. Especially when it comes to build a network of nodes connected with arcs for which algorithms are associated.

Fixon [14] proposed a multidimensional framework for comprehensive reviews of the product architecture. This framework is based on the product characteristic concepts such as the standardization of components, platforms, products, and product scalability. He positions the product architecture as a mechanism for coordinating decisions in three-dimensional design. The product architecture is defined as wel as the other information about the product. Author proposed only functional product architecture. His task is to decompose dimensions into functions. The coordination is achieved by reconciling all these functions from several dimensions.

6 Model Proposal Of 3-DDI In A CEE

6.1 General idea

The basic idea of the simultaneous design of the three dimensions (product, manufacturing process and SC) is to connect and make them work jointly in a CE framework. In this context, an integration model will help organizations to cope with market recent demands. The purpose is to surround the project by the three dimensions of design.

These three dimensions must communicate together and deploy their engineering work simultaneously in a collaborative framework (Figure 1).

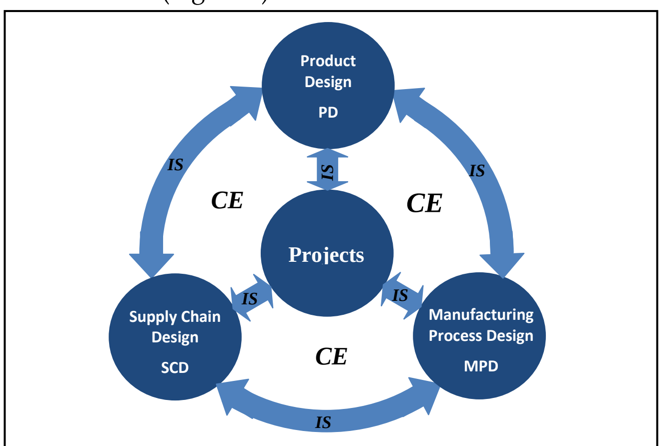

Fig. 1. The 3-dimensional integration principle

Data exchanged between the three dimensions are often structural and / or functional and are shared / exchanged through an Information System (IS).

6.2 Team Product Development (TPD)

The realization of an integrated framework in a cooperative environment, helps organizations to achieve their integrated design goals [22]. The integration system should focus on software and resources involved in the design process while collaborating with all the design teams. This will require the various functional domains integrations of an organization on a common platform. To support product development, the company is moving towards the simultaneous PD, its MPD and its SCD. Hence, the TPD is a way to address this complexity. It is organizing skills and resources on the basis of a support team with product development in a spirit of highly interactive and parallel collaboration. This offers a multifunctional perspective and facilitates integrated and simultaneous PD, MPD and SCD.

Figure 2 models a project development team. Each team element can be composed by several actors. Besides the engineering designers, the end-customers and suppliers must be taken into accountto ensure the satisfaction of their requirements [7], [20]. Indeed, the team must include a customer relationship manager and a product life-cycle manager. However, those needs and requirements influence, especially the PD, which in turn affect the manufacturing and the SC processes. It is also very important to consider the supplier involvement in the TPD, represented by the procurement manager. Moreover the presence of SC manager will help decisions making about product distribution, transport, flow management during production and the return process. Thus, throughout the PD and development scenarios, interactions among all actors are very important.

6.3 Collaborative Product Development (CPD)

The resulting work from TPD is called Collaborative Product

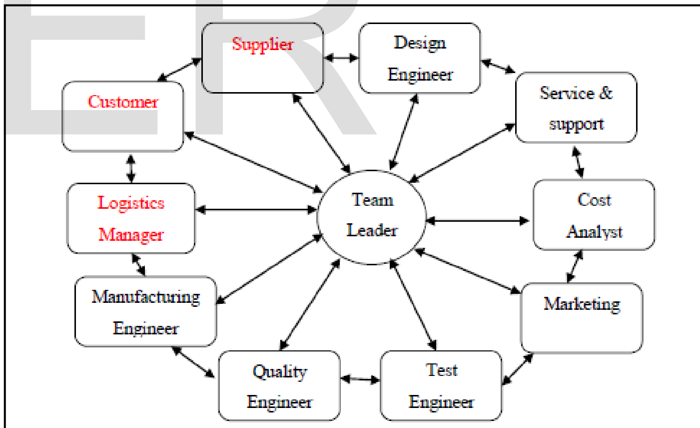

Fig. 2. Product Development Team TPD oriented 3-DDI in a concurrent engineering

Development (CPD) [22]. This is the ideal environment for cooperative product development in a field of 3-DDI CE. The expertise coming from different domains is considered essential at every stage of the development process.

In an integrated and collaborative design environment, designers interact by sharing product information and knowledge. This results a considerable reduction in re-engineering problems. In this context, an information system facilitating the integration is desirable for reducing the design cycle time and achieve optimal results.

6.4 Development of the proposal of joint integration model

The early involvement of the different domains and disciplines results in a complete understanding of all stakeholder requirements and is considered as a consensual approach to design the product, the related manufacturing process and the SC. The TPD encourage an open discussion with innovative thinking that provides high quality products, more efficient manufacturing processes and advanced logistic chains in order to satisfy customers.

For an effective distribution of activities between TPD, the use of a structured approach that gives its consistency, its reliability and its strength is highly recommended. This can be held in a mixed environment of CE and system engineering.

The first step towards an effective CPD is the understanding and the management of customer's needs and requirements. That should to be evaluated and improved given the time-to-market and product quality. The early involvement of all employees participating in product development provides a multifunctional perspective. Even so, the most important task in the TPD work is grasping and sharing information. Data and information exchange needs to be ensured by a reliable information system, understandable and adaptable to different resources of the product life cycle such as PLM systems. This helps to reduce and/or eliminate data redundancy and reduce problems related to manufacturing, logistics, transportability, procurement, scheduling, etc. The following step consists to clarify the model while highlighting the importance of product architecture (structural or functional), the difference between components types and information role coming from the manufacturing process and the SC.

6.5 3-DDI CE model

There are complex links between the PD, its manufacturing process and its SC. Their integration requires collaborative work. To achieve this collaboration in a CEE, it is agreed to forward the information flow between different processes correctly and in real time. That is the reason why all information and all necessary decisions must be coordinated in each design dimension.

6.5.1. Product architecture: an essential key to development

The product architecture is considered as a link for the decisions, coordination throughout PD, MPD and SCD. Indeed, this architecture is the source of all information that will be useful in the product development. It is obvious that information related to MPD and SCD are vital to a product in order to acquire good manufacturing and logistics performance.

To achieve an effective and comprehensive integration of design's three dimensions, the architectural information definition must be provided since the early phases of PD in order to support the integration in downstream phases. Such information affects significantly the manufacturing process (the machinery and tool selection as well as the machining and assembly method). The total cost of production is conditioned by the workflow and the products movement fluidity throughout the SC. This material flow depends mainly on the complexity of components architecture decided at PD. Therefore, it is necessary to take into consideration information of both the manufacturing process and the SC in an early stage of PD.

It is essential after establishing structural and functional product architecture, to classify the product components and assemblies and to determine the passage of their associated information flow.

6.5.2. Components to outsource / components to manufacture

The resulting information and detailed definition of the PD (product architecture) is the information source for the design of both the manufacturing process and the SC. For example, from the designed product nomenclature and its digital mock up, decisions can be taken to split components, assemblies and semi-finished products into two main parts:

1. Standard components and semi-finished products or product to outsource: they are sent directly to the SCD process for selecting suppliers, preparing supplies and make decisions concerning the logistical rules.
2. Components, tooling and machining fixtures to manufacture internally (once designed): these components are sent first of all towards the MPD, to define their specific ranges of manufacturing, their specific ranges of assembly, to do calculations and simulations, to prepare the programs of the digitally operated machines, etc. Ones ready, they will be sent towards the SCD process to realize raw material supplying, stock management, etc.

This methodology helps to reduce project implementation time and enrich the product portfolio. This will give designers an impetus to think about innovation and subsequently improve product quality, efficiency, productivity by the opportunities of reducing product returns on labor and conflict reduction and litigation. Therefore improve the company's competitiveness and generate great profits.

6.5.3. Information in the MPD and SCD: the system feedback

Information flow corresponding to both the MPD and the SCD processes generates an important information feedback to check the decision’s validity taken in upstream processes. This will contribute also to the optimization of the PD processes. Optimized PD may result from support all phases of its life cycle through the feedback evaluation. In particular, those from the SC and manufacturing process by applying the methods of integrated design DFX (Design For X).

Chiu and Okudan [6] categorize DfX approaches in methods with:

1. Product scope: design for quality (DfQ), reliability (DfRe), assembly (DfA), manufacture (DfM) etc.
2. System scope: design for logistics (DfL), supply chain (DfSC) etc.
3. Eco-system scope: design for sustainability (DfS) etc.

Furthermore, standardization plays a key role within the approaches, see DfL: standardization of parts, products and processes. It is the most effective way and can be seen as embodiment of DfX-compliance. The challenge is to enable a large variety of products and at the same time minimal internal complexity of all business processes [23].

6.5.4. Integration process

In a collaborative PD environment, design activities are supported by the link with the requirements of both the manufacturing process and SC. There are four key issues that must be addressed in conducting interoperability:

1. The need to build a unified PD model for information's

expression of whole its life cycle, in particular information relating to manufacturing process and SC. This model will be applied at all product development stages to ensure consistency and completeness of the information flows.

2. The use of efficient design methodologies facilitating analysis feedback (design for manufacture, for assembly, for SC, etc.).
3. The use of computer based tools for calculation, analysis, simulation, design and engineering simultaneously for PD, MPD and SCD. The model can be extended to digital and virtual factory concepts. The goal is to integrate all the manufacturing and assembly processes earlier in PD phases and optimize the manufacturing jobs ergonomics, production times and physical flow trajectories. We speak here about the product development digital chain.
4. Developing a collaborative design system platform to support interoperable information flows. The information integration systems are important tools to support collaboration between PD, MPD and SCD.
5. This digital data stream will be managed by a PLM solution for project management, teams and roles management, data sharing, process definition (Workflow), etc. The unified PD model and modelling approach of its development is shown in figure 3.

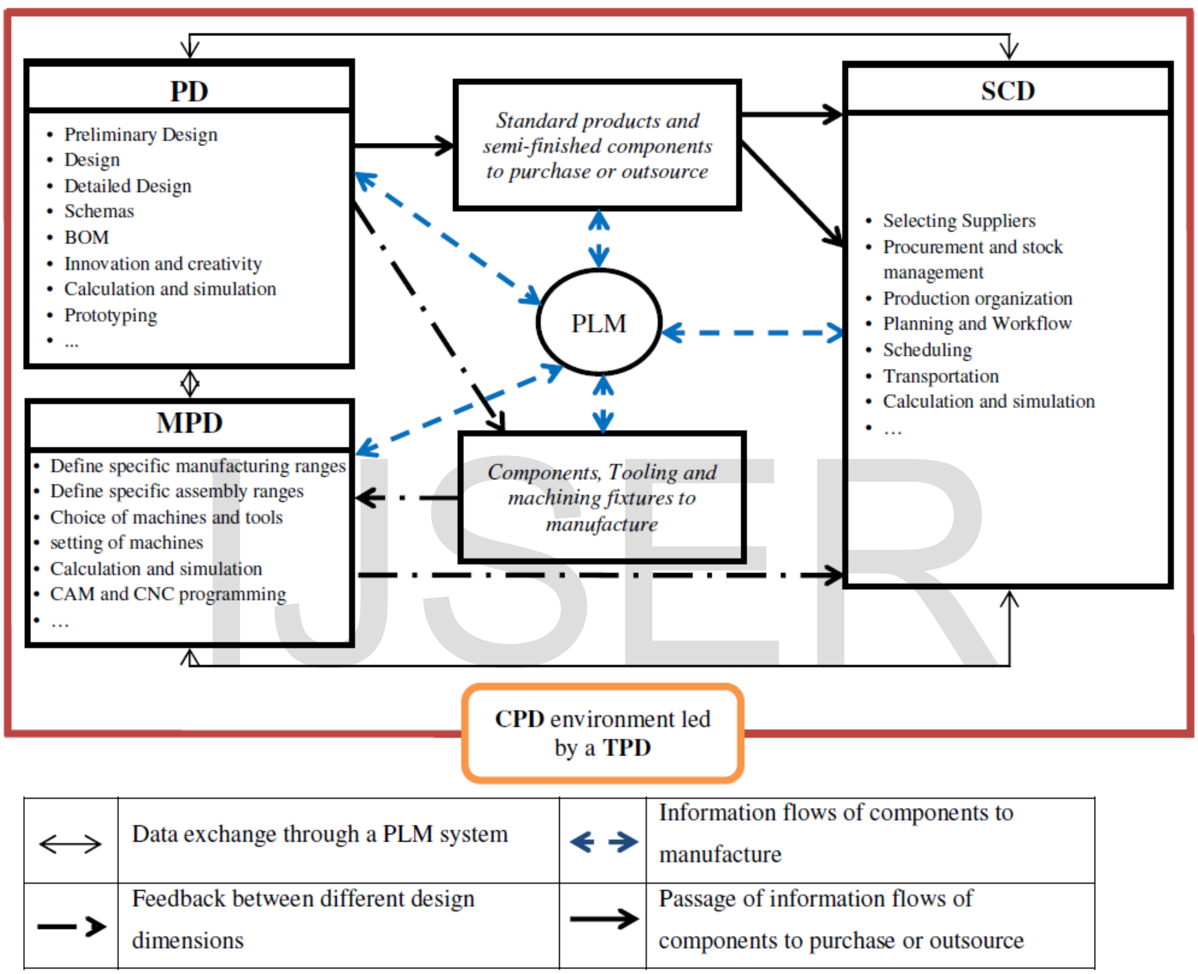

Fig. 3. 3-DDI CE approach conceptual model

7 Illustrative Scenario

For a manufactured product, we consider that the basic tasks of each design dimension (PDP, MPD and SCDP) are as follows:

The Product Design Process PDP

(1). Preliminary design (needs analysis and feasibility study);
(2). Design draft,
(3). Calculation and simulation
(4). Detailed design

The Manufacturing Process Design MPD

(1). Ranges of machining and assembly
(2). Phase contracts
(3). CNC Machine program
(4). Completion time
(5). Calculation and simulation
(6). Control sheet, follower plug...

The Supply Chain Design Process SCDP

A strategic decisions:

(1). Choose to do or to outsource
(2). Select suppliers
(3). Location of production facilities
(4). Location of assembly plant
(5). Production sites and their capabilities
(6). Transport and distribution

B Tactical decisions

(7). Customers and sales forecast
(8). Products allocation to production sites
(9). Plan the production process and associated transport
(10). Storage sites allocation
(11). Define transport policy

C Operational decisions

(12). Delivery program
(13). Allocation of transport means
(14). Assign resources to tasks
(15). Calculation and simulation

If we consider the design processes and their tasks proposed above (relative numbers (x)), the concurrent PD, its manufacturing process and its SC (3-DDI) can be conducted as following:

1st step: The commercial agents identify the production rate, according to the market survey. The sales forecast and customer predetermination can be studied too. At this preliminary level we integrate PD and SCD (see table 1).

TABLE 1
1st step of the simultaneous integration 3-DDI

1st step	
PD	**SCD**
(1) Preliminary design: •Statement of need •Validation need •FPS (Functional Performance Specification)	(7) Customers and sales forecast • **Production rate determination**.

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2nd Step: this step allows the development of technical solutions, structures and system modelling. In a concurrent engineering trend, based on BOR and BOM management and Product Data Management (PDM), each achieved subtask in the preliminary PD leads the beginning of previous subtask in MPD and/or SCD (see table 2).

3rd Step: It comes to determine according to the BOM, the definition of plans and manufacturing resources, choose to do or outsource components and assemblies.

This step must be preceded by a project team meeting to define the components to manufacture or outsource based on the calculation and simulation results (see table 3).

TABLE 2
2nd step of the simultaneous integration 3-DDI

2nd Step		
MPD	**PD**	**SCD**
(1) Range of assembly (5) Simulation and calculation	(2) design draft (3) Calculation and simulation	• **Pre-selection of standard components to to purchase** • **Assembly line determination** (1) Choose to do or to outsource (2) Select suppliers (4) Location of assembly plant (5) Define production sites and their capabilities (6) Transportation and distribution (10) Storage sites allocation (14) Assign resources to tasks (15) Calculation and simulation

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TABLE 3
3rd step of the simultaneous integration 3-DDI

3rd Step		
MPD	**PD**	**SCD**
Parts to manufacture (1) Ranges of machining (2) Phase contract (4) Completion time (5) Calculation and simulation (6) Control sheet, follower plug, ...	• Complete product definition (4) Detailed Design (3) Calculation and simulation	**Parts to outsource** (2) Select suppliers (3) Location of production facilities (5) Study of production sites and their capacity (6) Transport and distribution (10) Storage sites allocation (14) Resources allocation to tasks (15) Calculation and simulation

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4th Step: It comes to planning the remains of tactical and operational decisions in the SCD and simulate CNC machine program if necessary (see table 4).

TABLE 4
4th step of the simultaneous integration 3-DDI

4th step	
MPD	**SCD**
(3) CNC machine and robots program (5) Simulation	(8) Products allocation to production sites (9) Plan the production process and associated transport (11) Define transport policy

			(12) Delivery Program (13) Allocation of transport means (15) Calculation and simulation				
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(15)							

4 Conclusion

In a first step, this paper defines different topics related to integration design themes. In the second step, a state of the art has been considered in order to explore all types of dimensions integrated design (2-DDI and 3-DDI) already done by several researchers. The ame of this step was to understand better the subject and to be inspired later, while developing a new model in 3-DID.

Reacting with 3-DDI goals and importance, undergoing work will be focused on establishing another proposition far from the limits previously mentioned. Further research work will be directed towards modelling an integrated PD, MPD and its SCD in a CEE. It will allows to a better product by improving the design process, reducing manufacturing, production, storage and distribution time and cost, in other words, the whole SC. Thus, it will be basically to design the whole project from the beginning and avoid the sequential passage from PD, to process manufacturing design then SCD. Modelling integrated 3-dimensional design process in a CEE will help organizations cope with new market requirements and have many other benefits.

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