From PLM to ERP : A software systems engineering integration

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FROM PLM TO ERP : A SOFTWARE SYSTEMS ENGINEERING INTEGRATION

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ABSTRACT

The present paper on three related issues and their integration Product lifecycle management , Enterprise Planning resources and Manufacturing execution systems. Our work is how to integrate all these in a unified systems engineering framework. As most company about two third claim to have integrate ERP to PLM, ; we still observe some related problems as also mentioned by Aberdeen group. In actual global data sharing, we have some options to also integrate systems best practices towards such objective. Such critical study come with solution by reverse engineering, revisiting requirement engineering steps and propose a validation and verification for the success factors of such integration.

KEYWORDS

Information technology, validation, verification, software systems, PLM, systems engineering, traceability, ERP, MES, processes, standards.

1. INTRODUCTION AND PROBLEM STATEMENT

This an extension work carried in [Messadia, jamalsahraoui 2005] on systems engineering deployment. The extension is on PLM integration

1.1 INTRODUCTION

In a study by Aberdeen group "When researching the number of companies integrating PLM and ERP, Aberdeen found that it is a step that is 40% more likely to be taken by the Best-in-Class (Figure 2). While the integrations between PLM and other enterprise applications are more dramatically differentiated across the competitive framework, it is important to recognize that these companies have expanded these programs from integration between PLM and ERP. Specifically, Best-in-Class performers that had not completed integration between PLM and ERP also did not report having integrated other enterprise applications. Laggards, on the other hand indicate a less focused approach to integration. Of those Laggards that have not integrated PLM with ERP: 38% report integrations with supply chain management applications, 29% have integrations with Customer Relationship Management (CRM), and 38% have integrated PLM with their Manufacturing Execution System (MES).

System engineering is an interdisciplinary approach which has concepts now on which it is possible to build new applications. It's a collaborative and interdisciplinary process of resolution

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of problems, supporting on knowledge, methods and techniques resulting from the sciences and experiment put in to define a system which satisfies a need identifies, and is acceptable for the environment, while seeking has to balance total economy of the solution, on all the aspects of the problem in all the phases of the development and the life of the system. Systems engineering concepts for the complex problems passes by their decomposition under more limiting problems to which one can bring a solution (Sahraoui, Buede and Sages, 2004).

PLM considered as a strategic approach of management of information relating to the product from its definition till the phases of maintenance. The PLM (Product Lifecycle Management) represents before a whole industrial discipline; it draws its origins from the air transport airs and of defence, be extends largely to the car, electronics, pharmacy, etc …and concerns now tertiary sectors such as the bank-insurance, services.

Deployment of the PLM technology implies a redefinition of the processes and a better communication between applications heterogeneous (internal and external)

1.2 Problem statement

In order to avoid any confusion, our work is not addressing all PLM deployment but system engineering framework for PLM integration. In this respect, our approach is on the linkage between product and enabling product. Actually SE (System Engineering) offers the possibility to link the development of product and the development of enabling product in a unified framework. Hence the PLM offers such integration solution to design and implement the linkage approach and the implementation approach. This work is a part of a project in deploying systems engineering; we address two issues; the first one is on maintenance and the second is on PLM which is the subject in this paper; our PLM is seen as sub product in the manufacturing structure and also as a tool for the linkage concept in systems engineering.

1.3 Outline of the paper

The paper is structured into five remaining parts; The second part gives a brief introduction of the emerging discipline of systems engineering in matter of key processes that can be applied to many application; we present in the third part an original approach to map PLM as key information system onto the systems engineering structure; the fourth parts refine the approach by identifying PLM processes that can be viewed through a systems engineering window; in the fifth part we propose a systems engineering framework for manufacturing and present a simple a case study to illustrate the approach called “linking enabling and final product through PLM; finally the six part focuses on an emerging work to develop a platform for collaborative working environment where a generic PLM can be implemented independently of the application, be it manufacturing or aeronautic or services production.

2. THE SYSTEMS ENGINEERING FRAMEWORK FOR MANUFACTURING SYSTEMS

We believe the failure of some PLM solutions is linked to difficulty of integration; a large amount effort is consumed for such integration as it was manly done on specific system development. We propose an alternative approach based on systems engineering; since the late 80’s more and more effort have been done and results have been reached in matter of best practices for systems design

, and also standards (EIA-632, IEEE P1220, ISO 15288); having establishing the SE as a basis for any systems design , we prone the PLM to be plugged in as an information system not only at design level of a system but also at the operational level for system production covering all lifecycle in both systems engineering and PLM taxonomies.

2.1 System Engineering Concepts

System engineering is the application of scientific and engineering efforts to:

-Transform an operational need into a description of system performance parameters and a system configuration through an iterative process of definition, synthesis, analysis, design, test, and evaluation.

-Integrate reliability, maintainability, expandability, safety, survivability, human engineering and other factors into the total engineering effort to meet cost, schedule, supportability, and technical performance objectives.

System Engineering is an interdisciplinary approach that:

Encompasses the scientific and engineering efforts related to the development, manufacturing, verification, deployment, operations, support, and disposal of systems products and processes.

Develops needed user training, equipment, procedures, and data.

Establishes and maintains configuration management of the system.

Develops work breakdown structures and statements of work and provides information for management decision making.

Systems Engineering is management technology to assist clients through the formulation, analysis, and interpretation of the impacts of proposed policies, controls, or complete systems upon the need perspectives, institutional perspectives, and value perspectives of stakeholders to issues under consideration.

System engineering is an appropriate combination of the methods and tools of systems engineering, made possible through use of a suitable methodological process and systems management procedures.

We distinguish three levels in system engineering as illustrated in Figure 1.

The third level, System Engineering processes, focuses on high level issues: high level requirements as business needs and strategic needs, and methods.

The second level, SE methodologies and methods, deals with all technical issues as systems requirements design methodologies standards.

The first level, SE tools or technologies, covers the implementation issues concerning the tools to be used, the required technologies to respond to the various assets of requirements as reliability costs, maintainability, enabling technologies.
To assist customers who desire to develop policies for management, direction, control, and regulation activities relative to forecasting, planning, development, production and operation of total systems Figure 1.

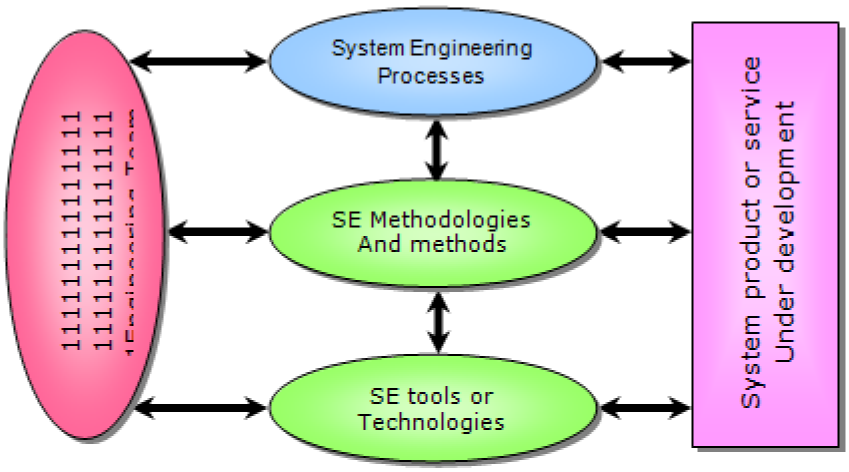

Figure 1 Three levels of system engineering

2.2 The Systems view through SE practice and standards

In SE good practice we have the following chain

Processes → Methods → Tools

Theses entities Processes, methods and tools are the conceptual basis of our approach taken from SE best practice. The first step the processes can be identified with respect the know how accumulated, can be also be taken from a standard as the thirteen generic processes proposed in standard EIA-632. The second step concerns the methods to be used; the methods can be either developed or used existing one that implement the process as we cannot choose a methods for its flexibility or popularity but only if reflects the semantics of the process. No taxonomy has been yet developed for corresponding processes and methods. The third step concerns the tools that do not correspond to the process but the methods; in this approach we cannot hence use a tool to implement a process but first identify the associated methods.

The processes are best described by the following EIA (Electronic Industries Alliance) standards Figure 2; there are thirteen processes covering the management issues, the supply/acquisition, design and requirement and verification validation processes (EIA- 632, 1998).

Technical management processes (three processes): these processes monitor the hall process ranging from the initial idea to build a system till the system delivering.

Acquisition and supply processes (two processes): these processes ensure the supply and acquisition (and are very close to logistics).

System design processes (two processes): these processes are on the elicitation and acquisition of requirements and their modelling, the definition of the solution and its logical design.

Product realization processes (two processes): theses processes deal with implementation issues of system design and its use.

Technical evaluation processes (four processes): theses processes deal with verification, validation and testing issues.

We are working on mapping on the challenge on mapping such processes onto PLM processes in the framework of a European project. The basic idea is to have make use of the SE tools and standards to develop a customised PLM products.

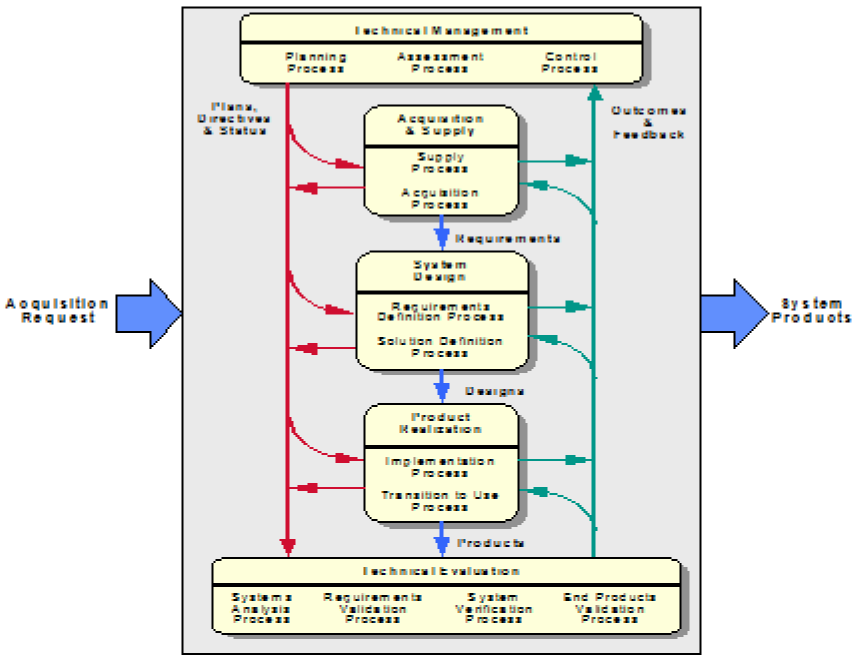

Figure 2 Systems Engineering Processes

3. THE PLM-ERP INFORMATION SYSTEM AS LINKAGE CONCEPT IN SYSTEMS

3.1 Product life cycle management

More commonly referred to as PLM – is emerging as the new method for industrial companies to better manage product development and "in-service" processes from beginning to end in the product cycle.

Product lifecycle management (PLM) is a systematic, controlled method for managing and developing industrially manufactured products and related information. PLM offers management and control of the product (Development and marketing) process and the order-delivery process, the control of product related data throughout the product life cycle, from the initial idea to the scrap yard Figure 3. Almost without exception, the PDM and PLM abbreviations also refer to a data system developed to manage product data (Saaksvuori, and Immonen, 2004).

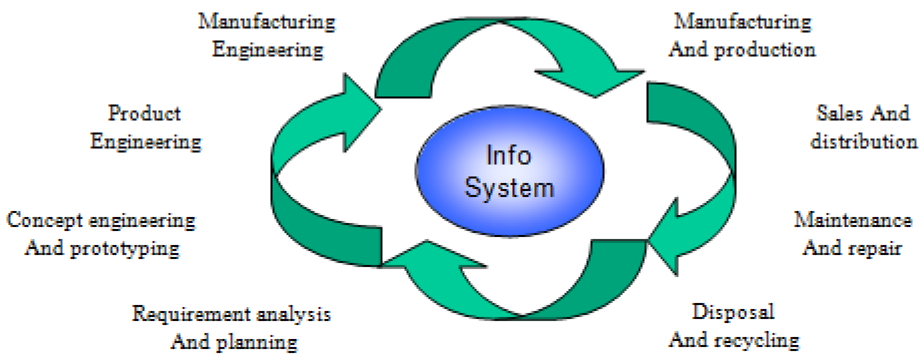

Figure 3 PLM information system context

In basic terms, product life cycle management involves the use of software to eliminate much of the costly trial and error that has plagued manufacturers since the industry took a step beyond the industrial revolution.

Product lifecycle management breaks down the technology that has limited interaction between the people who design products and the people who build, sell, and use them. Using the collaborative power of information technology and mainly Internet, PLM lets an organization begin innovative product design while reducing cycle times, streamlining manufacturing and cutting production costs.

3.2 What PLM is not?

PLM does not include other major enterprises solutions, such CRM, ERP, and logistics-based supply chain management. It also does not include systems supporting other major business functions, such as making and sales, distribution, human resource management, and finance. The processes are related merely to information handling but does covers the flow shop characteristics neither both the processes for developing both the product (final product) and the production systems (enabling product).

PLM is not systems engineering, there is no standard for PLM except data exchange standard as STEP or AP233 (emerging standard from SEDRES European project) (Messaadia, Eljamal and Sahraoui, 2005; Bodington and al, 1999).

3.3 PLM Requirements of Innovative Manufacturers

A comprehensive approach also means that many organizations and individuals must collaborate in the process. Because this collaboration spans different levels of the organizations, the solution requires seamless integration between the project information and the product information in order to allow for a coordinated, collaborative business process. The organizations and individuals are both internal (marketing, legal, advertising R&D, production, etc.) and external (testing labs, outsourced production, ad agencies, etc.).

Web-Based Deployment and development: this point will be discussed fully in the six parts.

Process Specific Tools
Global Standards or specific on process oriented

Centralized, Integrated Project and Product Information

PLM is seen as an information system; Product Lifecycle Management (PLM) systems control critical product information that must be shared with other enterprise systems such as ERP, CRM and SCM. Likewise, PLM systems need to leverage information that is managed in other enterprise systems. This bi-directional connection between PLM and other systems is critical to enabling a seamless flow of information among the different functional groups involved in product development, particularly engineering and manufacturing (Messaadia, Eljamal and Sahraoui, 2005; Bauer and al, 2002).

3.4 Linking enabling product and final product developments

For example consider the enabling product, the support system; we take specifically the maintenance system which is a part of the PLM in our taxonomy. We propose the following structure Figure 4 showing the structuring of enabling product and final product.

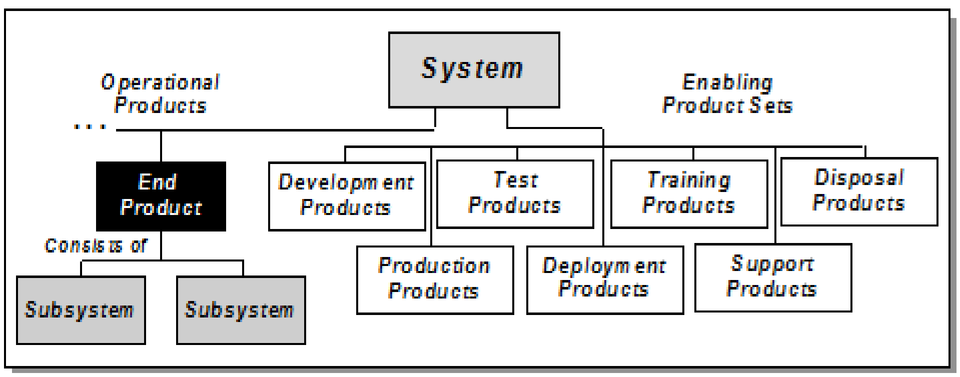

Figure 4 product and enabling products structuring

The maintenance system monitors the product behaviour; some observation will be introduced to improve the reliability of the final product. The PLM will be the information system that handles all data and internal processes that can be produced or consumed by the various products be it a subsystem (of the final product) or an enabling product). If we consider the maintenance process that is embedded in support product, all relative data concerning the reliability of the part can be handled by PLM to be used by the design team of the final product or the production system. This aspect will be discussed in the fourth part.

We see in this example that only PLM ensures that the linkage is carried out between the enabling product and final product. Of course this can be applied only in the case of applying system engineering concept: distinction between final and enabling product. This can be illustrated by the Figure 5.

In this example for bicycle frame design and production that is used as case study in part 5.3, we see the refined from step Y to step (Y+1), the enabling product is the production system and to each enabler we have the corresponding process that implement the operation on the part (painting, welding, cutting, the parts needed (circle) shows the input and output of the process.

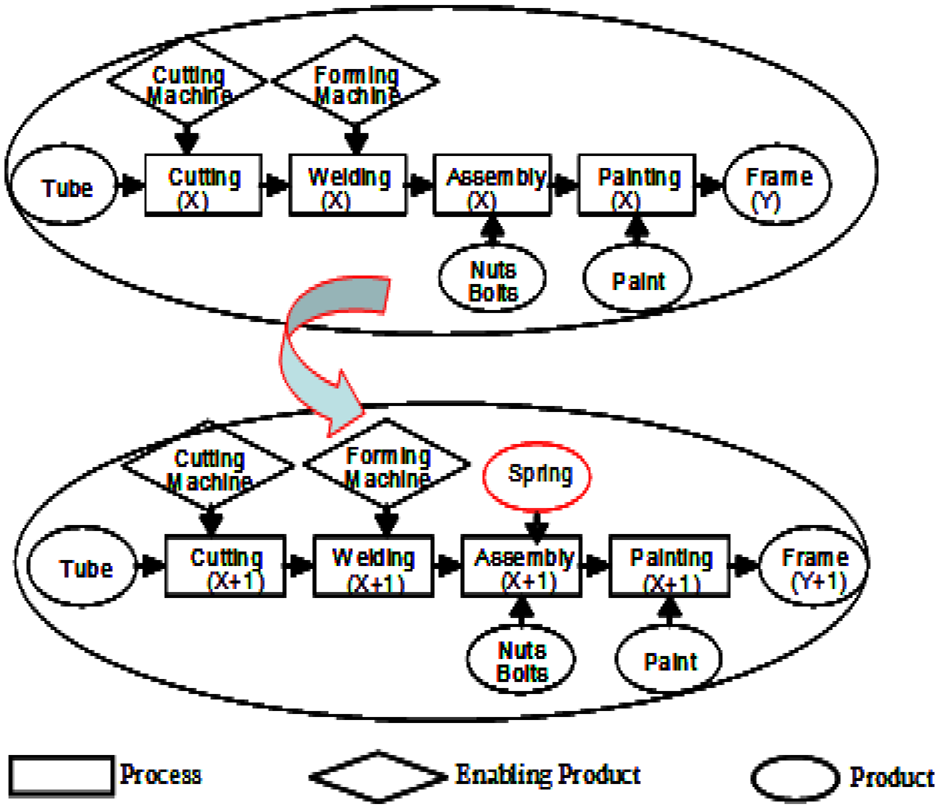

Figure 5 Bicycle frame manufacturing process

4. HOW TO MODEL PLM PROCESS WITH A SE VIEW

4.1 PLM as an end product

In designing systems and their operation there is one key aspect: separation of concern between the final product and enabling product. PLM is viewing as a subsystem which considered as a system in SE definition.

In SE practice, it is made use for such difference; this is illustrated by the following figure 4

In this paradigm system is decomposed initially into the end product (the operating system itself and the enabling product) all product that enable the production testing the deployment the support of the end product.

The end product is at this time decomposed into subsystems, then each subsystem are decomposed into end product and enabling products and such refinement process will follow until we obtain elementary parts or component on the shelf (COTS); this is illustrated in Figure 6.

PLM; is seen as the end product concerning the information system; the refinement is carried out in the same paradigm as separation of concern illustrated by the following Figure 6.

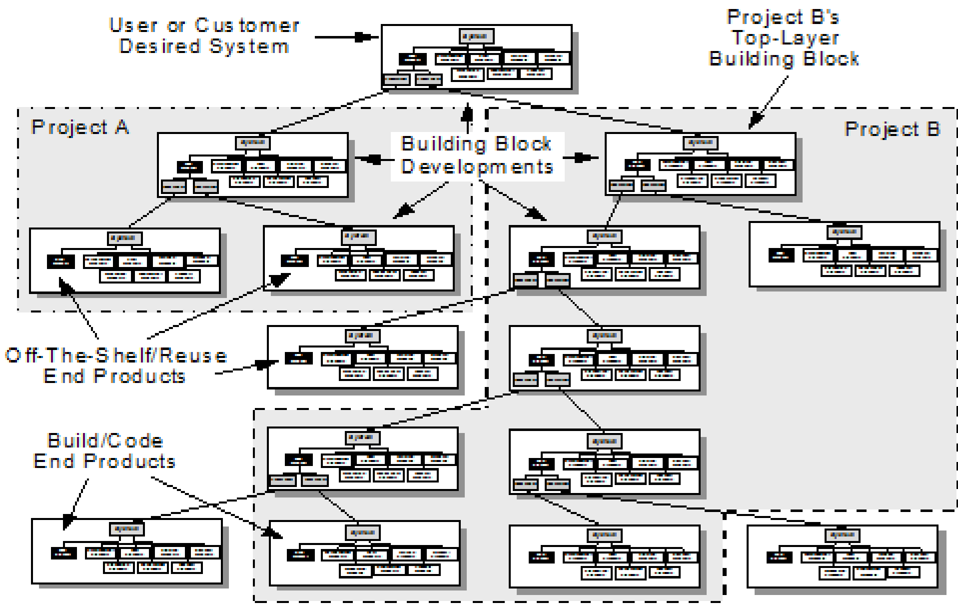

Figure 6 Systems development structure

We can see in the above Figure 6 that some subsystems or and products are refined and some others are not refined as they exist all ready or available, for instance a PC computer is an end product that don't need to be refined since it is a cots system (Eljamal and Sahraoui, 2005).

4.2 PLM linking enabler and final product

Integration of PLM and as link between enabling product and product relies on the difficulties observed when a feedback is needed to monitor new product. There is obviously a strong link between the quality of the product and the all enablers and mainly the support product and production system. We will be limited to this work at the support product and final product; as the design team must be aware of the dependability of the product through the relation between PLM and CRM and support system. Internal PLM processes will be the management system.

4.3 PLM linking enablers and operational level

Concerning the link between enablers and in this context, we were limited to support system and production system, the manufacturing system in the case study.

Here we make the hypothesis that the dependability problems are due to production system and hence sub-processes as machining, assembling etc..

5. TOWARDS A SYSTEMS ENGINEERING FRAMEWORK FOR PLM

5.1 The need for a SE Framework

Today, PLM encompasses significant areas of process. It's not just program and project management processes. It is also the processes required to manufacture the product or plant, operate it in the field, and dispose or decommission it at the end of its useful life. PLM solutions help define, execute, measure, and manage key product-related business processes. Manufacturing and operational process plans are also now viewed as an inherent part of PLM (Ming, Lu and Zhu, 2004). Processes, and the workflow engines that control them, ensure complete digital feedback to both users and other business systems throughout each lifecycle stage.

It is intended to develop a systems engineering framework based on requirements of PLM processes and SE good practices; we will be sing Se Standards to propose an operational framework.

5.2 Why the need for SE deployment and types of deployment

Systems engineering deployment is often seen as generalising systems engineering practice; however, such deployment can be carried out just by generalising such practice but to identify initial processes used in systems design before applying SE practice (Lardeur and Auzet, 2003). We distinguish many deployment types:

-customising SE processes

-Mapping SE processes

-Adapting SE to specific applications as manufacturing, building services, banking etc

Effectively these types are related by choosing the deployment paradigm.

Customising SE Processes: this customising process look at each SE process, for example requirement process, and we try to enable such deployment by identify initial need for requirement for such application or range of applications types. For a business process, requirement process may not need specific formal methods for modelling the requirements.

Mapping SE processes: here we need to identify the application processes and then doing a mapping process to process

Adapting SE process to industrial application: here we know the application as manufacturing application for example and we just adapt the SE to the specific needs in matter of processes to such application (Messaadia, Eljamal and Sahraoui, 2005).

An initial approach for a deployment methodology: after ad-hoc attempts for SE deployment, we prone to establish a methodology for SE deployment. We use three types of deployment depending of the nature of the application. For such purpose, we have to characterise the application among the set of applications as:

-manufacturing
-building
-financial/business
-critical systems

The steps that need to be addressed are:
-Identify main attributes of the application
-Hierarchical/strategic needs
-Planning and analysis
-Implementation
-Verification of the deployment process

5.3 A case study on prototyping a PLM product with Bicycle

We adopt the linking approach for a simple system as a bicycle production and focus on PLM. The bicycle is the final product in SE taxonomy we try to apply such framework for a bicycle manufacturing project by enhancing PLM processes as an information system.

The manufacturing is a part of the life cycle of the product which is cover by the PLM which contains the processes of manufacturing of the product.

In our exemplar of the bicycle, the final end product (or system) would be the finished and complete bicycle. The end products of subsystems would include things like the wheels, the handlebars, and the frame.

Each association between product and production systems can be managed as a connection between systems of each hierarchical system structure.

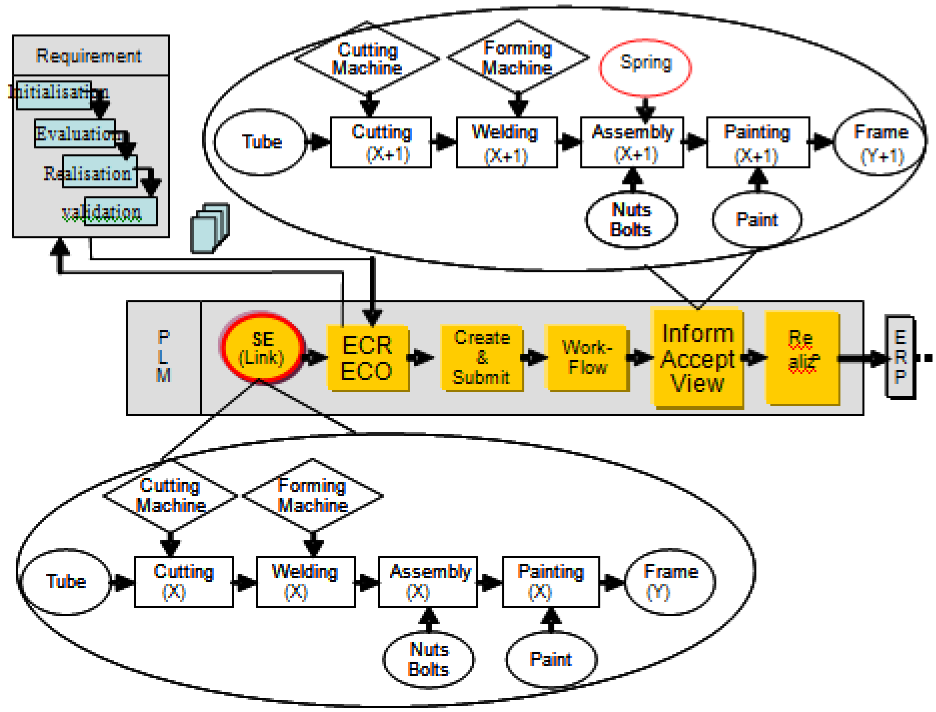

Figure 7 Bicycle Frame Manufacturing Process

In the example of the bicycle Figure 7 we can see the process of manufacturing (X), which defines the manufacturing of all parts of the bike until the end product. When the new requirement is emitted which is for example add a spring in the frame of the bicycle this decision is managed by the PLM system.
When the requirement is emitted it is transferred via the PLM towards the team from engineering which will take into account about the link established before between the bicycle and its system of manufacture (via SE) in order to define the impact of the addition of the spring on the bicycle and the system from manufacture which results in the change in the manufacturing processes. The PLM is given the responsibility to convey the emission of the ECR (Engineering Change Request) which will be validated in order to establish the new bicycle (Y+1) with spring and its new manufacturing processes (X+1) for a new framework addition of new part reprogramming of the machines....

The PLM will be also given the responsibility to safeguard and bring up to date the new product and its manufacturing process Figure 8.

We show in the above figure the PLM handling the link with product design at the requirements levels; requirement change is decided when at the operation level the part does not conform the quality needed. Such requirement change is traceable to the specific entity that needs to be redesigned; the traceability model used is based on (Terzi, 2005).

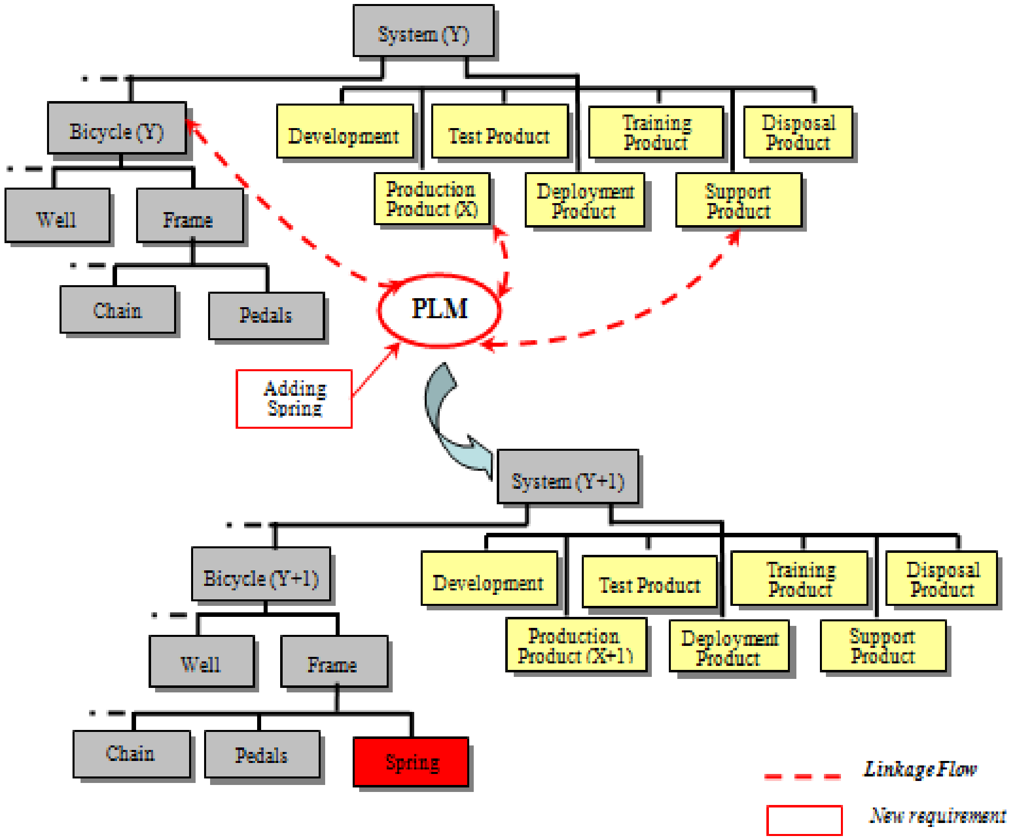

Figure 8 Bicycle frame linking processes

Such preliminary approach set the basis for further work on the generalisation of PLM and its extension to any system and its implementation on a firm system engineering basis.

6. COMMON REQUIREMENT IN ERP AND PRELIMINARY APPROACH

6.1 The approach:

This research focus on the following question which already defined before the start of the literature review.

1. Identify CSF of ERP implementation

2. Classify identifies CSF according to the requirement engineering view

For this author focus on papers and documents contains the following keywords "Enterprise resource planning implementation" and "critical success factors".

All paper review characterized by:

1. clearly related to research questions

2. come from trusted journals and conferences

3. publication year of the paper at 2012 or above

After 15 articles have been reviewed and used as a resource for CSF of ERP implementation discovered 46 CSF listed in the table [1] after careful analysis of CSF mentioned at the literature review via eliminate similar CSF or merging it in one CSF.

Table 1. CSF for ERP implementation

#	CSF
1.	Good project scope management
2.	Management expectations
3.	Project management
4.	Steering committee
5.	Legacy system
6.	Culture change / political issue and regulation
7.	Formalized project /plan schedule
8.	Business process reengineering
9.	Experience project manager leadership
10.	Project champion role
11.	Trust between partners
12.	Interdepartmental cooperation and communication
13.	Project team composition /team skill and team competence
14.	Empowered decision maker
15.	Management involvement .support and commitment
16.	Monitor and evaluation progress and performance
17.	Appropriate use and managing consultant
18.	Vendor tools
19.	Software customization
20.	Software configuration
21.	Appropriate technology and good IT infrastructure
22.	Reduce trouble shooting and project risk
23.	Training software
24.	Education on new business process
25.	Vendor support
26.	Data analysis and conversation
27.	Formal ERP implementation methodology
28.	Careful define information and system requirements
29.	Adequate ERP software selection
30.	Clear goal and objectives
31.	Careful change management
32.	End user involvement
33.	Organization fit ERP
34.	Motivational factor for ERP implementation
35.	Company wide support
36.	Business plan long term vision
37.	Vendor /customer partnership
38.	Integration business plan with ERP planning
39.	Ease of system use and user acceptance

40.	Data and information quality
41.	Focus on user requirement
42.	Rewards and recognition
43.	Standardized implementation sequence
44.	End user satisfaction
45.	Software reliability
46.	Adequate testing of system

6.2 Requirement engineering view for CSF:

Requirement engineering required for every software development and implementation even little literature about RE in ERP implantation projects, but some of CSF related to it. Table [2] shows these CSF.

Table 2. CSF for ERP implementation related to RE

#	CSF
1.	Good project scope management
2.	Legacy system
3.	Culture change / political issue and regulation
4.	Business process reengineering
5.	Software customization
6.	Careful define information and system requirements
7.	Adequate ERP software selection
8.	Clear goal and objectives
9.	Careful change management
10.	End user involvement
11.	Management involvement .support and commitment
12.	Appropriate use and managing consultant
13.	Focus on user requirement
14.	End user satisfaction
15.	Adequate testing of system
16.	Vendor support

Linking RE to both PLM and ERP in a systems engineering framework is promising research topic that part of it have been proposed; the second part will be carried in the validation and verification processes ion the same systems engineering framework.

6. TOWARDS A PETRI NET MODEL EVALUATION AND VALIDATION

Many software oriented towards PLM platform for collaborative working (CEW); these offer a solution dedicated to specific aspect and their lack is in the generalisation to other type of systems. We prone a CEW for system engineering; such CEW will be the PLM system itself; it is a generic as it based on system engineering processes; the difficulty and drawback of this approach is that it imposes that the system respect the SE practices; However, we are confident as the SE discipline is gaining more and more recognition and application in system design. Effectively, the SE approach was limited for aeronautic, space and military systems but there is a great interest in its deployment in other industries. Such collaboration can be modelled by Petri nets based approach from low level dynamic systems of subparts to high level. Such prospective wok will be developed un CPN tool.

7. CONCLUSION AND PERSPECTIVES

A preliminary approach for PLM used as a tool for linking both the development of the product and the development of enabling products, has been presented. Such approach is highly based on a systems engineering framework for manufacturing systems. Perspectives forward are planned to refine the approach for maintenance process as enabling support product and the development of the tool. Such tool will be experimented for aeronautic applications.

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