Project Management for Linear Infrastructure: Studying PLM and BIM for an Efficient Set of Basic Functionalities

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PROJECT MANAGEMENT FOR LINEAR INFRASTRUCTURE: STUDYING PLM AND BIM FOR AN EFFICIENT SET OF BASIC FUNCTIONALITIES

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ABSTRACT:
Managing an infrastructure today from the idea to the in-use phases is mainly addressed through BIM (Building Information Modelling) functionalities. As BIM often focuses on the management of building data, it hardly covers the specificities of infrastructures. The problem becomes critical when dealing with linear infrastructures. Such infrastructures are driven by linear installations across multiple constructions in which interactions with specific information, geotechnical or topographic information for example, are required.
As PLM (Product Lifecycle Management) has shown its efficiency in the past decade for the management of different expertise through a common information system, we propose to study the functionalities covered by PLM. By comparing them to those covered by BIM, we will be able to identify a basic set of functions that could meet linear infrastructures management requirements.

KEYWORDS: *PLM, BIM, Linear Infrastructures*

1 INTRODUCTION

Building and Linear Infrastructures can be considered as the main sections of the industry sector. We differentiate these two notions.

- Building is defined here as an edifice: Permanent or temporary structure enclosed within exterior walls and a roof, and including all attached apparatus, equipment, and fixtures Due to its common and repetitive aspects, this section has known an earlier numerical development, through BIM.
- Linear Infrastructures are set of constructions, installations and their environment, spread over many meters or kilometres around a guideline: roads, railways, tunnels, etc. Its diversity can explain its critical digital delay. This paper challenge is to float an idea of a digital project management system for Linear Infrastructures, as is PLM for manufactured products, and BIM for Building.

The different and various characteristics of Linear Infrastructures make them is somehow similar to both a product (in a PLM way) and a building. Hence, it can be assumed that project management for Linear Infrastructures presents key characteristics that can be addressed by PLM or by BIM initiatives, depending on the type or level of information that must be managed.

1.1 PLM initiative

In the PLM field, we address the need for an efficient product management in which the product definition corresponds to a set of specifications. It serves as a reference towards its customers and the market, as well as for production and maintenance teams (Kurkin et al., 2010). Two interesting features of the product that we can bring out at the first glance are its **virtuality** and **scalability**. Virtuality corresponds to the product as it should be, before physically exists. Scalability comes from the fact that the product definition evolves during its lifecycle under the effect of modifications, following a change of the need or an impact completely outside of the project.
After going through CAD (Computer-Aided Design) and CAE (Computer-Aided Engineering), the manufacturing industry in general, the aeronautics and the automobile especially, continues its digital revolution by the complete dematerialization management of the products lifecycle: it is Product Lifecycle Management PLM (G Chryssolouris et al., 2008). These manufacturers have come to consider PLM as the solution in a context of an increasingly complex business world: large companies, ever-increasing competition, and new customers' requirements in emerging markets (PTC, 2015). Thus, having reached a level of maturity around the uses and the deployment of digital tools in these industries, the PLM today attracts more and more new sectors: Energy, Transport, Chemistry, Distribution, Finance, and Building.

1.2 BIM initiative

In the BIM field, we address a different organization progress, especially in terms of lifecycle. However, we often apply the same contractual rules than in a manufacturing industry. Like PLM for manufactured products, BIM drives the building evolution in its lifecycle. However, the construction industry experiences major differences within it, especially between the Building section and the Linear Infrastructure section, often with identical actors. The Infrastructure's field, because of its specificities, remains apart from the development of BIM.

Before future researches/studies determine and conclude whether a Linear Infrastructure is closer related to either products (thus PLM) or building (thus BIM), we will equally consider those two options. A Linear Infrastructure is close to a building on its construction aspect. It can also be considered as a product for the manufacturer. Therefore, the infrastructures research field should focus on forms of representation and evolution of objects to build or manage the infrastructures in their spatial, social and especially temporal environment. support BIM and PLM support the product lifecycle management, these are two different concepts. BIM relies on PLM to optimize the digital management of AEC (Architecture Engineering and Construction) projects. They come together and differ on several points. In this paper, we are analysing the characteristics of manufacturing industry, Building and Linear infrastructure, as well as a mapping between the PLM and BIM functionalities. The objective is to raise the idea of developing a new project management system adapted to the field of linear infrastructures and its needs. Therefore, we address in this paper different aspects from the characteristics of the infrastructures to the lifecycle phases that are need for their management (physical characteristics, lifecycle phases and actors, lifespan, diversity and configurations).

2 PLM IN MANUFACTURING, THE AERONAUTICS CASE

Manufacturing industries are, according to the French INSEE (National Institute for Statistics and Economic Studies) processing industries of goods, that is mainly for the industries' own account. But they also concern the repair and the installation of industrial plants as well as operations in subcontracting for a third contractor. We could also list food companies, textile industry, automobile, aeronautical industries, etc. (INSEE, 2017).

If manufacturing industries evolved well during these last centuries, they always had an objective to produce much more by spending less. Indeed, the aspects of development of products and profitability are strongly connected within the manufacturing industry today. This causal connection is understandable by their direct impact on manufacturers to guarantee a financial optimization for their company. Their growth is slowed down because these manufacturers are confronted with difficulties due to actual professional context: extended enterprises, competition always growing, as well as requirements of new customers on emerging markets. To do it, they find the solution in PLM.

PLM consists in capitalizing all the information concerning a product throughout the processes of the company by facilitating the exchanges. It allows the various entities of the company to share the information associated with the product lifecycle. PLM finds its origin in the aeronautics, let's focus on the product "plane". The objective of this product is to transport of people or goods, between two distant points. Today, among the numerous types of planes on the market, the Boeing 777, long-haul airliner is one of the most wide-spread planes.

2.1 Lifecycle and actors

Through features which we will see farther in this paper, PLM perpetuates the technical information of products as complex as a plane, during the stages of its lifecycle: Design - Production / industrialization - Maintenance.

Engineers, technicians and operators (AirEmploi,2017) can be divided within aircraft industries into four categories:

- Project owners, and system designers: aircraft manufacturers, manufacturers of missiles, satellites, designers of embarked electronic systems,
- Engine: designers of propulsion systems,
- The equipment manufacturers: pneumatic, electric, electronic, mechanical...
- The support: commercial, logistics, quality, purchase.

To understand the chain of activity, it is necessary to start from a customer command (Airemploi, 2012). Everything begins with a design phase in the research department. The engineers work in various state of the art domains such as the structure of the plane and the materials which constitute it: aerodynamics, acoustics, electric and hydraulic systems, motorization, cockpit design, etc. which will fly in the respect for the strictest international regulations: certifications, safety, environment, etc. while meeting the expectations of the market, particularly in terms of technology. Then tests are taken in prototype rooms. Prototypes are only designed for new products. Then, the methods develop the process of production to be followed, and finally workshops make and assemble the product which will be delivered to the customer (airline companies, military armies, etc). Throughout its life, the aircraft or the aeronautical equipment is maintained by the customer or the manufacturer during the visits of maintenance of planes. Support functions are important during the phases described above. The logistics, the purchases, the customer commercial support and the quality are considered as transverse jobs in support of the functions of design and production.

2.2 PLM Features

In an aeronautical company, the design and development phases are the longest. It is on these two phases that PLM is most used, as seen in Figure 1.

The phase of use and thus the maintenance remains complicated, but it is now eased. Indeed, the database PLM contains the digital twin of the product and all its real characteristics. It is this real - virtual connection that is going to facilitate the establishment of maintenance cycles.

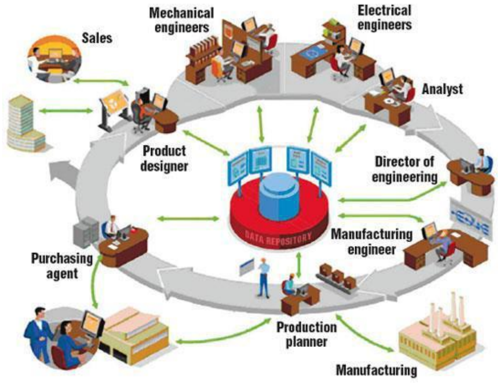

Figure 1 : Actor's distribution during design and industrialization phases (PSG College of Technology, 2012)

To be effective, and follow the management of the product lifecycle, six PLM features can be fixed:

1. **Vaulting**: it is the server who stores the data and the technical information of the product.
2. **Access rights**: every user must have the right necessities to reach the data he needs; the access is limited. This feature is important because products are the result of a collaboration between several actors spread worldwide.
3. **Configurations and composition management**: it is a question here to follow the evolution of the composition of products, and of its various presentations. It will also facilitate the cohabitation between the various corporate associations, between the mechanics and the electronics engineers.
4. **Change Management**: the changes being inevitable during the process of development of products, and whatever is the cause - requirements of the customer, the new market conditions, the technological innovation, the cost-cutting measures or the update of the regulations - their management is essential. The PLM will insure throughout the history of modifications (versions, revisions) and the various states by which products and objects passed, will keep data traceability. With the two first features, they will favour the carry-over from previous projects, with the aim of shortening future phases of development.
5. **CAD**: an effective PLM must allow visualization of objects without opening the document in detail. It must also allow the integration of CAD parts from several CAD systems. With the various options of interoperability, this feature will favour data sharing between various 3D designers, via standard formats of exchange such as STEP (STandard for the Exchange of Product model).
6. **Workflows**: it is computerized process which allow to model successive tasks or operations made by one or several actors involved in the product lifecycle. The workflow will help to describe the process and its construction.

Beyond these six features, we could also add the features of planning and management. The objective of any management is to insure the project dynamics via the piloting solutions such as KPI (Key Performance Indicator).

2.3 The advantage of the PLM

The PLM is comparable to the management of the reference table products. It is built from all the 3D software's necessary for the product conception (management of the requirements, design, mechanics, electronics, software, simulation, etc.). An engineering consulting firm can have access to the specifications whereas the data of the software of CAD are available for Research and Development

The PLM software allow to optimize each of the tasks made in the company, to solve bugs and to reduce delays. Some profits are not directly quantifiable:

- Improvement of the productivity due to the strengthening of the integration
- Rigorous follow-up of the procedures Improvement of the control
- Reduction of Time-To-Market
- Reduction time during the stages of development products

3 THE PRODUCT "BUILDING"

A building in the common sense is a real estate construction, realized by human intervention, intended on one hand to serve as shelter, that is to protect bad weather of the people, the goods and the activities, on the other hand to show their social, political or cultural function (Max et al, 2002). Just like the manufacturer, Building constructor must deal with a difficult industrial context today. The constraints that must be met:

1. Reduce the ecological impact of a building (emissions of carbon and greenhouse gases, biodegradable materials and electric consumption).
2. Face the natural resources which diminish.
3. Improve the efficiency and the quality of the construction.
4. Manage more easily the real estate / infrastructural heritage (holdings).
5. Reduce the cost of maintenance and operations.

If we follow the definition of the product given in introduction, we can affirm that a building is a product. It is in this sense that it possesses, just like a plane, actors distributed around a lifecycle.

3.1 Lifecycle and actors

Except for support functions mentioned before, three main functions under construction are:

1. Project ownership: It is the one for whom we build, the customer. He defines the program, the financial envelope and the schedule of the operation.
2. Project management: It designs, draws and describes the building: architects, engineers (technical, finance, management), land surveyors, etc.
3. Construction companies themselves: main part of work, technical installation, second works and completions.

The building lifecycle contains stages of a sequential or traditional construction project as shown by Figure 2. During the preliminary studies the customer chose an architect for the project feasibility. Once the definitions are concluded with the project ownership, the detailed design of the building begins: it is the phase of definition and technical description of the work. After studies and execution plans, the construction of the building can begin, it ends in the delivery of the "as-built" for operations and maintenance (O&M).

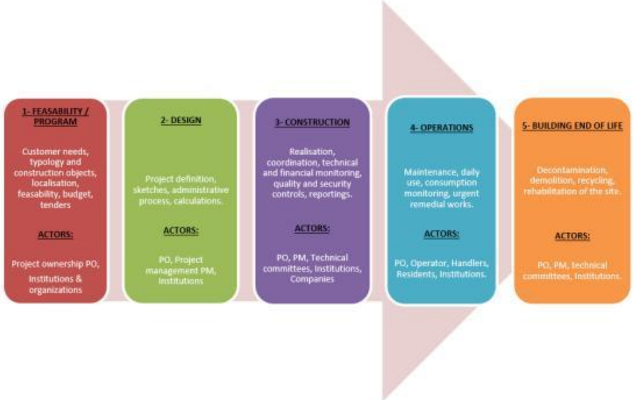

Figure 2: Phases of a Building project

3.2 BIM features

Building Information Modelling is a model-driven approach to designing, constructing, operating and maintaining buildings. The model that forms the core of the BIM approach is a shared and computable 3D model of the building that helps overcome the shortcomings of a 2D paper-based approach. BIM is therefore a methodology that facilitates multidiscipline collaboration and information management between different project stakeholders (Jupp et al, 2013).

To manage efficiently the process of construction, (Bouguessa et al, 2013) took out again seven main features BIM:

1. **Display of the shape**: display and evaluation of the intern and extern aesthetics of the products
2. **Fast generation of the multiple changes of the design**: the model becomes "intelligent" by applying a chain (sequence of movements) of the modifications due to the other integral parts of the model. It was impossible with the former CAD Systems.
3. **Re-use of the model for a predictive analysis of the performance of the building**: it is about the use of the model of the building for energy and financial analyses, as well as the simulations of calculations to size the structure.
4. **The maintenance of the information and the design of the integrity of the model**: it is a question of keeping the information generated in the form of drawing, facades and volumes only once and without repetition. As for the integrity of the model, it is improved thanks to the automatic function of detection of the collisions between the components of the model.
5. **The automation of the generation of drawings and documents**: it is a question of create an object in 3D then thanks to the database we give it a definition; automatically, the software is going to generate the details of this object according to the definition attributed to the latter.
6. **Collaboration in the design and the construction**: it comes in two phases, "inside" when several users of the same organization edit the model simultaneously, and "outside" when of multiple designers visualize simultaneously the model merged or separated according to the coordination of the design. However, the collaboration is insured by means of the exchanges of the interoperable files, under IFC format, but not by means of a display which allows to see the versions, the states, the notifications and the validation of workflows.
7. **Evaluation and fast generation of the plan of the construction**: this feature becomes a reality via the modelling 4D (3D + Time), a progressive simulation of the project in its lifecycle while modelling its schedule. It offers the capacity to visualize immediately the various impacts in every variation of the project.

3.3 The advantages of the BIM

The previous 7 features result in many advantages:

1. Communication and exchanges facilitated between project ownership and project management, other actors, and limitation of the conflicts.
2. Better planning and control of the optimized deadlines, minimization of the seized again and associated financial gains, construction facilitated during the realization
3. Capitalized optimization once BIM is mature: costs decrease and optimization, better of risk management

Having listed the features BIM and PLM, the Figure 3 shows us that those features can group together in three big categories: 3D, management of the diversity and the change, collaborative engineering (Jayasena et al,2013).

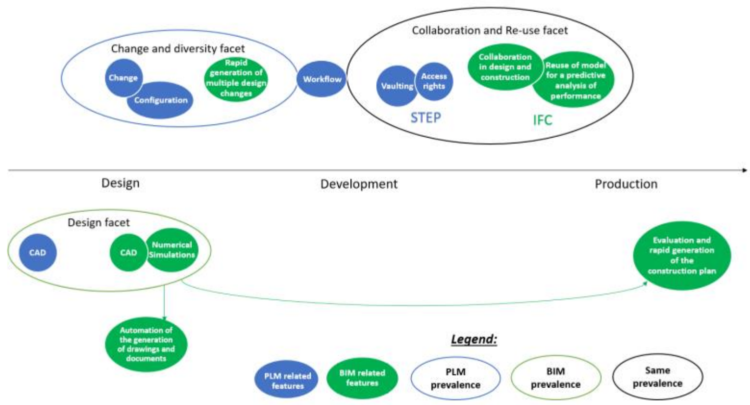

Figure 3: Common points between BIM and PLM features

3.4. BIM vs PLM

If BIM and PLM support the management of lifecycle of buildings and products, it is about two different notions. The BIM leans on the PLM to optimize the digital management of the project BTP. They join and differ on several points.

As similarities:

- The Digital Model: Both notions are based upon a Digital Mock-Up. BIM and PLM manage a centralized digital model.
- Data sharing: Around the centralized model, users can extract data or models corresponding at their working needs. This information sharing between various tools or software is possible thanks to the interoperability, in BIM and PLM respectively by formats IFC and " Standard for the Exchanges of Product model data" STEP.
- Tools structuration: Both concepts share the structuring of their tools. A web accessible platform, connected to a database, where we can extract and or modify a centralized digital model, or then just view it by means of viewers

As differences, the BIM focuses on visualization, the calculations of the properties, the check of the interactions between the various elements. It does not handle the management of documents nor controls it states and versions, whereas The PLM formalizes the processes of validation, exchange, modification.

So, the BIM is a passive tool allowing to determine the state of the building at a moment, whereas the PLM allows to know change management. Being two different and complementary tools, it is in the sense that many researchers thought that their association could allow a complete management of the infrastructure.

4 THE LINEAR INFRASTRUCTURES (LI)

An infrastructure is a set of constructions, installations and their environment, making up the project or the work to be realized and/or to be ran. It is called linear because the linearity and the length influence the structuring of the project, and on which interact strongly with geotechnical and topographic conditions. We know among others:

1. The urban or interurban(long-distance) linear infrastructures of transport (road, highway, rail-road, streetcar, subway, networks)
2. The heavy industrial infrastructures (nuclear power plant, water-treatment plant, industrial building, station).

4.1 Physical specificities

Answer to specificities compared to other models which we analysed in other more industrial sectors or in the Building, he got some specificities of this type of infrastructures with, for example the major influence of the existing (natural ground, geotechnics of the basement, etc.), the local natural environment into which fits the work is not exactly known. Yet, the created objects are linked to this environment. Their definition thus must consider this uncertainty and adapt itself to the evolution of the quality of the collected data. The case of the natural ground illustrates this problem. The construction of the infrastructure is strongly dependent on many hazards. For example, the meteorology is a fundamental datum of construction of the objects of excavation. Objects thus must know how to record these hazards and adapt itself to their evolution.

- Length of the projects which can reach affect several hundred kilometres.
- Very numerous actors: necessity of dialogue with the owners, the residents and the associations.
- Importance of the environmental integration.

4.2 Lifecycles and actors

The sector of the public works is split up and less ranked than the other industrial sectors. For every project, the actors are new and partnerships build up themselves in extremely varied contractual logics. Due to their aspect construction, infrastructures share the same lifecycles and the actors as those of the Building. Besides these actors, we find in the field of the linear infrastructures, the clients (contracting authorities) of size and organization very varied (State, highway, General Councils, etc.). They sign a contract of very diverse natures transferring everything or a part of the responsibility of the design. As shown in Table 1, LI project duration is close to buildings'.

	Manufacturing	Buildings	Infrastructures
Design phase duration	3 to 15 years	2 to 5 years	4 to 6 years
Construction phase duration		2 to 5 years	2 to 4 years
Operations and Maintenance duration	10 to 50 years	50 years + (75-80%)	100 + years (75-80%)

Table 1: Estimated durations of phases

It would be then necessary to develop a digital twin of the such - as built to follow the progress of the project around a digital model. These needs are the results of studies conducted by the French national project MINND (Modelling Interoperable Information for Sustainable Infrastructure) (MINND, 2010):

1. For the collaborative work: the accessibility to the information must be chosen by business, while watching the uniqueness of the model, over necessity of a unique model of data and a neutral exchange format to create, integrate or merge, and manage, partial models. It would be necessary to define protocols prefiguring standards then standards. It is to satisfy this collaborative aspect that the standard IFC (Industry Foundation Classes) is being developed.
2. Tool of structuring: the system must allow to manage the models of data to everyone according to their roles, every information must have an owner and owner is responsible for the shared information
3. Tool of creation and 3D display: for the creation and the integration of CAD models, and the management of the 2D plans associated to the 3D model. We find this need in manufacturing industries and for the Building
4. Capitalize tool for the optimization: manage the evolution of the information, the process of validation to pilot the quality level and the degree of reliability.
5. Tool of archiving and capitalization: the management system must allow to record the modifications that a digital twin the most

precise possible undergoes the objects of the model to have.

With these needs clearly defined by the industry of LI, we drew in Figure 4 the features that the system we propose could adopt from the BIM and the PLM.

We called Linear Infrastructure Management System LIMS in Figure 4 the digital project management proposed for Linear Infrastructures. It is clearly seen that some features (but not all) of PLM and BIM are very important for that system. Therefore, Linear Infrastructures make the association BIM/PLM interesting. Moreover, as it is written before in this paper, future researches/studies will determine and conclude whether a Linear Infrastructure is closer related to either products (thus PLM) or building (thus BIM). Hence, we will be able, from those results, to more clearly explain how the LIMS answers Linear Infrastructures needs.

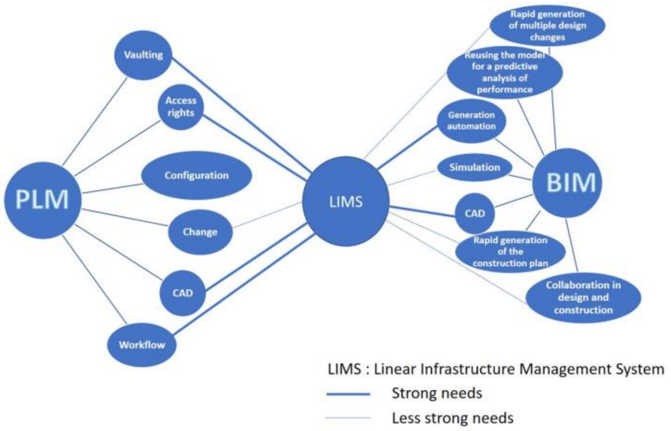

Figure 4: A new system for LI built on both BIM and PLM features

5 CONCLUSION

Industrial company developed in the past decades PLM strategies for producing more by spending less, and this is true even when it comes to complex products, such as planes and cars. Most of manufacturers are now driven in this strategy by the PLM. Product Lifecycle Management showed its ability today and other industries thought that he was convenient for them to develop for their own account a PLM-like system: it is what made the Building with the BIM. An aspect of the construction company is that LI and Building related projects differ enormously. Because neither BIM nor PLM thoroughly answers LI requirements, it is somehow not true to say that BIM can be regarded to be the PLM for infrastructure products. The management of Linear Infrastructures implies multiple needs in terms of data management. These needs are partially covered by PLM and BIM initiatives depending on the lifecycle granularity of data required.

In this paper we presented the Linear Infrastructure Management System - LIMS as a combination of both PLM and BIM initiatives. For PLM, the principal needs concern Vaulting, Access Right, CAD and Workflow. For BIM, the principal needs concern CAD and Generation automation.

Nevertheless, it is not proved that this BIM-PLM alliance will completely satisfy needs of complex systems such as railways, highways.

Future works will deepen this BIM-PLM trends for Linear Infrastructures, by enlarging minds towards other technologies like Internet of Things IoT, Virtual Reality; etc.

REFERENCES

AirEmploi (2017), Découvrir les métiers de l'industrie aéronautique et spatiale. http://www.airemploi.org/metiers/industrie-aeronautique

AirEmploi (2012), Les Métiers de l'industrie aéronautique & spatiale, GIFAS, Paris, France. http://airemploi.org/medias/files_medias/livret-metiers2012-web-bassdef0138941001418823216.pdf

Bouguessa, A., Forgues, D. and Doré S. (2013), "La complémentarité entre le Building Information Modeling (BIM) et le Product LifeCycle Management (PLM) en passant par le Lean Construction (LC)", *CSCE 2013 General Conference - Congrès général 2013 de la SCG, Montréal, Québec May 29th to June 1st*

G Chryssolouris, D Mavrikios, N Papakostas, D Mourtzis, G Michalos, and K Georgoulias (2008). Digital manufacturing: history, perspectives, and outlook. DOI: 10.1243/09544054JEM1241

INSEE (2017), Industrie manufacturière. [Online]. https://www.insee.fr/fr/metadonnees/definition/c1934

Jayasena S., Weddikkara C. (2013), " Assessing the BIM maturity in a BIM infant industry", *The Second World Construction Symposium 2013, 14-15 june 2013, Colombo, Sri Lanka*

Jupp J., Bernard A., Rivest L., Dutta D., (2013), "Incomplete BIM Implementation: Exploring Challenges and the Role of Product Lifecycle Management Functions", *10th Product Lifecycle Management for Society (PLM), Jul 2013, Nantes, France. Springer, IFIP Advances in Information and Communication Technology, AICT-409, pp.630-640, 2013, Product Lifecycle Management for Society*

Kurkin, Ondřej; Januška, Marlin (2010). Product Life Cycle in Digital factory. *Knowledge management and innovation: a business competitive edge perspective. Cairo: International Business Information Management Association (IBIMA):* 1881–1886. ISBN 9780982148945

Max J. Egenhofer (2002). Geographic Information Science: *Second International Conference, GIScience 2002, Boulder, CO, USA, September 25–28, 2002. Proceedings. Springer Science & Business Media. p. 110. ISBN 978-3-540-44253-0.*

MINND (2010), Livrables L1 - Modèle global, COMMUNIC, France. http://www.minnd.fr/wp-content/uploads/2014/02/L1-Mod%C3%A8le-global-bis10.12.pdf

PTC (2015), Partie 1 : Définition du PLM – Présentation générale. http://www.cadesis.com/cms/resource/filecenter/document/042-00007r-092/5896a-definingplm1-wp-fr

PSG College of Technology (2012), The wondrous tool that is Product Lifecycle Management. http://thebridge.psgtech.ac.in/?p=1616

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