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Project Lifecycle Management Systems and Business Process Involvement – A Report on Case Study Research

Abstract—This paper explores the role of Product Life-cycle Management (PLM) systems in industry by evaluating their impact on business process improvement. In addition, future trends of these systems are also analyzed. A literature review and three case studies are used to answer specific research hypothesis, reflecting the suitability of qualitative research methods in this field. The case studies employed detailed questionnaires to support the literature review. Research findings indicate a strong correlation between PLM systems implementation and business process improvement. This is identified as a clear benefit for their deployment in engineering/manufacturing companies.

Index Terms—product lifecycle management, business process improvement, systems integration, case study.

I. INTRODUCTION

The European Commission onlinemagazine has established beyond doubt that manufacturing industry in the United Kingdom and occidental countries is facing increasing pressure due to competition from low-cost countries such as China, where its recent fast adoption of new technologies contrasts markedly with its previous image as a low quality product manufacturer [1].

“The China Price” is an expression, which strikes fear into many European manufacturers [2]. In the future, it will be essential to get a competitive price, often requiring innovation in the manufacture of their products. The occidental manufacturing industrial companies are trying to improve their business processes to produce more within less time and with high quality. The objective is to remain competitive by decreasing their price, producing more with less waste. Fortunately, they are finding many different ways to achieve this benefit and process improvement through the deployment of PLM systems is an increasingly significant initiative being pursued by a range of engineering companies [3].

II. PRODUCT LIFECYCLE MANAGEMENT

Product Lifecycle Management (PLM) systems evolved from earlier Product Data Management (PDM) systems [4]. Now PDM can be seen as a subset of a PLM. In the 1980s, engineers had recognized the need to manage the increasing volumes of design data produced by, and contained in, a range of automated and semi automated systems, such as Computer Aided Design (CAD) files, specifications and requirement documents, Computer Aided Manufacture (CAM) programs, and Computer Aided Engineering (CAE) analysis. PDM allowed them to store and control all product data, manage document issue levels, maintain Bill of Materials (BOM) and immediately visualize the relationship between parts and assemblies [5].

However, being able to manage the data alone was not enough. There was the clear need to manage the entire product lifecycle, of which product development is just a part. According to reference [4] a product lifecycle can be divided into 5 stages: imagine, define, realize, use/support and retire. The first three stages are part of product development but engineers needed a more comprehensive system to support both product development and the full product lifecycle [6]. PLM can be defined as a general plan of the product lifecycle in a particular business or product area. It is a compilation of business rules, methods, processes and guidelines as well as instructions on how to apply the rules in practice [5]. The PLM concept encompasses several systems. Reference [3] describes change management, document management, workflow management and project management as PLM systems that support concurrent engineering and streamlined product development processes. PLM seeks to extend the reach of PDM beyond design and manufacturing into other areas like marketing, sales and after sales service, and at the same time addresses all the stakeholders of the product throughout its lifecycle.

PLM extends PDM functionalities to include the creation of product definition information as well as the management and control of such information. Looking at this another way, PDM is focused on the management of data created by information authoring tools, whereas PLM also includes the authoring tools themselves. PLM seeks to fill the gap between enterprise business processes and product development processes [3]. Fig. 1 gives a summary of PLM sub-systems.

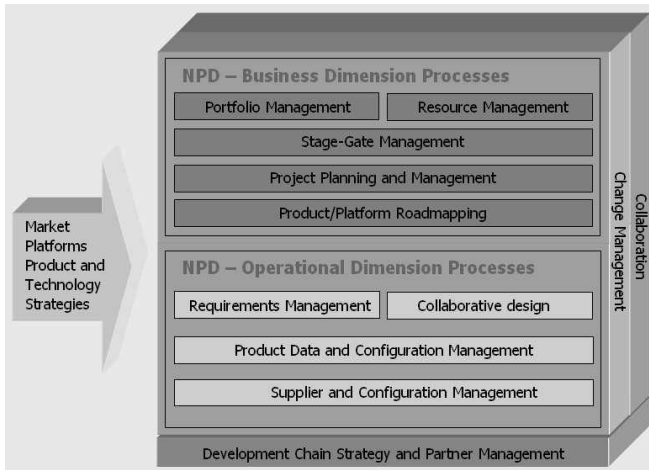


Fig. 1. Product Lifecycle Management subsystems and which business levels each one sits.

III. METHODOLOGY

PLM systems vendors claim that this technology can improve the whole product lifecycle, including new product development and change to existing products. This paper answers 3 research questions:

- Can PLM systems deliver business process improvement?
- What are the real benefits of a PLM implementation?
- Is the integration between PLM, CAD and CAM systems with Computer Numerical Controls (CNCs) and Coordinate Measuring Machines (CMMs) a growing trend in manufacturing industry?

A. Research Method

Reference [7] highlights that qualitative and inductive research can be done in different ways encompassing case studies, grounded theory, and ethnography, for example. Reference [8] also agrees that case studies are likely to be used as part of an inductive research approach. Reference [9] defines case study research as a “detailed investigation ... of one or more organizations, or groups within organizations, with a view to providing an analysis of the context and processes involved in the phenomenon under study”.

The research method employed here is based on a number of case studies of PLM systems in industry. A multiple-case design consists of a diverse range of organizations, which can increase the validity of generalizations [10]. Beside, Reference [11] suggests that a single case study is vulnerable, and there may be substantial analytical benefits of having multiple case studies.

The evaluation of results was done comparing relationships between evidence from case studies. This was analyzed in conjunction with the findings of an extensive literature review, allowing empirical generalizations and a series of clear statements to be developed [8].

B. Data Collection Methods

There are several ways to collect qualitative data that have a multiple-case study research framework. Examples include questionnaires, interviews and observation [7] [8]. After carefully analyzing data collection methods, questionnaire was selected for data collection. Observation was deemed unsuitable due to the nature of the research questions. It is not possible to observe the past and current impacts of the deployment of a PLM by visiting organizations. Although future impacts could be observed, it would require spending significant time within each organization; therefore this was considered inappropriate.

C. Case Study Selections

13 companies were identified as being potential case studies. After collating and analyzing responses to an initial pre-questionnaire enquiry, the three most complete case studies were selected to participate in the research. Few of the others had enough data to support the research analysis.

Following the selection of appropriate organizations, a member of staff was identified within each organization and asked to participate in the study. ‘The suitable subject’ was deemed to be a person who had a comprehensive knowledge of the business, and who would be in a position to identify the impacts that the PLM deployment had had on the organization and its business processes. Reference [12] suggests that subjects must be in a position to generalize about business behavior. Only employees at the level of manager or higher were considered for participation in the study.

IV. FINDINGS

A. *The Company Case Studies*

All three case studies were based on business units categorized as large-size (251-1000 employees) or very large-size organization (More than 1000 employees). These three companies had more than one strategic business unit (SBU) or branch. According to their websites, two of the companies are considered as group companies with divisions or SBUs operating across the world. The case studies were based in three different countries - the United Kingdom, the United States and Brazil. The three case studies showed that the companies concerned had a good understanding of their basic business processes. All of them plan their product development before manufacturing it, which shows an appreciation of time to market and product quality issues.

B. *PLM in the Company Environment*

Different kinds of PLM systems were used in the three case studies, with different features in their business environments. The first company has a commercial stand-alone version of software; the second uses a customized concurrent integrated version. Finally, the third company is different again, deploying a system that has been somewhat customized to their requirements. The number of licenses, quantity of PLM users and time span since implementation were also different in each case study. This helps in the validation of hypotheses because if they can be proved in these different environments, they will probably be valid in similar environments. The results also reveal that just two main functions of PLM were found in all three case studies: the deployment of a data vault and the use of embedded CAD. A vault is a safe place for storage of electronic information (files and metadata). Vaults are used to control and secure information regarding version handling and access control. It manages the access of those documents [14].

In addition, a vital part of the management of formal product data is to integrate the data-generating applications that are the most important ones in the product development process. Applications with a one-to-one relation between application file and "print" document, which is the case for typical word processors and low-end and primarily drawings-based CAD systems, are preferably tightly integrated with the PLM system. Application files should be treated as original data and thus adequately vaulted [13].

Having the CAD integrated with the PLM means that all product information, including customer specification and requirements, can be stored within the data vault. This can easily be accessed using just one source rather than opening many computer programs or getting hard copies to work in front of the computer. Reference [15] supports this integration when the author says, "The users of application programs are of course much more interested in real objects such as products and parts, than in the structure and format of data in files. Very often though, the information on the products is only available after wading through and understanding many sets of files. Again, this represents a waste of time. 'Bridges' need to be built so that information can be moved from one Island to another e.g., part specifications and engineering changes must be transferred from the CAD Island to the ERP and PLM Islands. Bridges often need to be company-specific, and are time-consuming to build and maintain. Even when the bridges are in place, it will often be found that the information needs additional conversion, interpretation and synchronization".

Another six PLM main functions were used in two of the three case studies. They were configuration management, product workflow definition, workflow control, revision and version control process, CAD embedded and CAM embedded. In addition, one company have change management functionality and another, which has the most complete PLM

system, contains within their PLM lessons learned, bill of materials, CAE embedded and communication/notification. In all three case studies, the design and production engineering departments shared the experience of use of the PLM. One company deploys the system across different departments including purchasing, production planning, quality and shop floor. It means that possibly the information flows on a process using a single or most likely few systems helps on productivity and generates a more organized business environment [16].

C. Business Process Improvements

The case study analyses showed the following:

- “increased transparency and better information flow” was ranked in first place as an impact after deploying a PLM system.
- “higher reliability” was strongly supported as a result of PLM system implementation.
- “shorter cycle time” and “shorter implementation time” were also strongly supported as outcomes of PLM systems implementation
- “increased organizational flexibility”, “improvement of organizational structure”, “positive impact on business strategy” and “better application of management style” were supported as outcomes in the majority of question responses across the three cases.

The results suggest there is a correlation between PLM functionalities and the characteristics of process improvement.

No negative impacts on business processes were detected after PLM implementation and, surprisingly, relatively little up-front investigation was necessary to implement these new systems successfully. Positive results of PLM implementation included speeding up many processes and one company specifically cited some processes that they'd improved. At one of the other companies, PLM resulted in discussions about how to control better their artifacts and their internal processes. They stressed the positive opportunity that the new PLM systems represented for achieving improvement in other functions. Another of the three companies commented that “the PLM has been deployed worldwide to improve and accelerate the Company's product lifecycle.”

The only negatives concerned “Improved innovation capabilities” and “Increased know how” neither of which received majority support as outcomes.

D. PLM and Machines Integration Analysis

In past years integration between CAD and CAM systems usually meant buying the same brand of CAD and CAM products. These products typically provide data, interface and application integration. Given the problems of integrating CAD and CAM products from different suppliers, no mixing and matching of products were generally pursued if the user wanted to retain the advantages of full integration [17].

One feature of some PLM systems is that they provide industry standard manufacturing features to intermediate CAD file formats that enable the controlling devices on manufacturing machines to read these features more efficiently with Numerical Controlled machines and dynamic re-planning. In essence, one sends a CAD file directly to a controller, bypassing the NC programming function.

The questionnaire analyses revealed that two out of three case studies already had a CAD and a CAM integrated to the PLM. This, combined with the results of the literature review, support the third research question, suggesting that there is a trend of integration between PLM systems and machines such as CNCs and CMMs.

In addition, one company reported that they have included in their PLM system a module that associates the product components with required tools for manufacture and within these tools, CNC tares are stored. In this way, the information needed by the shop floor can easily be retrieved so that tooling can be stored in an organized way.

Two of the companies did not have any integration between PLM systems and machines but they recognized that it would be useful to have.

V. CONCLUSION

In conclusion, the three case studies support the view that PLM systems implementation brings a relative improvement in business processes. The improvement was mainly evident in processes used by departments and functions that directly used the new systems. Results strongly suggest that PLM systems adoption has a positive impact on business processes within industry.

Reference [13] asserted that an analysis of business processes needed to be done before implementing a PLM system. The results of the study showed that none of the companies analyzed did any significant business process analysis before implementing the PLM system. However, in all case studies, some process improvement was achieved by just deploying the system, which challenged the suggestion contained in reference [13]. However their study was conducted a decade ago when the impact on the market of PLM systems was more limited due to

restricted nature of PLM functionalities at that time.

The questionnaire, interviews and observations that were at the heart of this study confirmed that improvements were delivered in the three case studies by PLM implementation in a number of activities, including:

- increased transparency and better information- flow
- shorter cycle times
- increased organizational flexibility
- increased customer satisfaction
- shorter implementation time
- improved innovation capabilities

Overall, the product life-cycle was better managed and many core business processes were improved after the implementation of PLM systems.

A trend of integration between PLM solutions and shop floor machines was also revealed in this study. The results revealed that some case studies had already CAD and CAM integrated to their PLM solution. The purpose of CAM is to generate a standard code that is amended by the machine's post-processors before being used in the machine. Therefore, a process can be followed just using the PLM system. It can store all customer requirements and any internal documentation, with CAD embedded it helps to produce 3D modules which can be used by the CAM embedded to produce the standard codes. Those codes are used by the machine's specific post-processors and finally downloaded to the machine. This supports the view that there is a trend of integration between PLM systems and machines such as CNCs and CMMs.

In addition, another kind of integration was found. A module of a PLM that associates product components with required tools for manufacture and within these tools, CNC files are stored. It means that information needed by the shop floor can be retrieved using this module and probably other modules of a PLM solution. It is also worth noting that software developers and engineers are still striving to integrate CAD in a faster and better way with machines. Reference [18] was studying the possibility of cutting out some steps in the process, integrating the CAD modules directly with machines. It would possibly remove the CAM altogether from the process and perhaps the post-processor steps as well.

In summary, the following statements have been developed in response to the research questions:

- 1: PLM systems adoption has a large positive impact on business processes within industry
- 2: The impact of PLM adoption is mainly on New Product Development and changes on existing products but it can also have an influence on other processes in the product lifecycle
- 3: Integration between PLM systems and machines (for example CNCs and CMMs) is now a standard feature of these systems albeit via an indirect process linking product specification to machine code.

Overall, a better understanding of the role of PLM systems in industry was achieved showing that these systems will allow an engineering based company to be more competitive in today's market. The deployment of PLM is one way to achieve process improvement and their integration with machines accelerates time to market, reduces the risk associated with human error thereby improving product quality.

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