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SOLUTIONS OF COLLABORATIVE PRODUCT LIFECYCLE MANAGEMENT

ABSTRACT:
Product Lifecycle Management (PLM) is recognized as one of the most effective approaches for better, fast and cheaper product development and management. Mass customization is one of the key technologies in PLM to provide tailored product to end customers with the cost of mass production. In the modern global economy, companies are facing ever-increasing challenges for short time-to-market to enter into the market early, for reduced time-to-volume to occupy the market quickly, and for decreased time-to-profit to get return from market shortly. Product lifecycle management (PLM) is recognized as one of the key leading technologies to facilitate companies to overcome these challenges, which will offer companies a new way to rapidly plan, organize, manage, measure, and deliver new products or services much faster, better, and cheaper in an integrated way. Following this trend, this study proposes a full scenario of technology solutions for PLM based on the complete analysis of business drivers, industry requirements, limit of current solution, and recent state-of-the-art review in the domain related to PLM. Potential industrial impact of the developed PLM technology solutions is analyzed. It is hoped that the proposed PLM technology solutions will form the frontier basis for further research, development, and application of PLM systems to quickly adapt to the dynamic changing market for industry companies to pursue the most advanced competitiveness.

KEYWORDS:
Product Lifecycle Management, Business processes, Technology requirements

INTRODUCTION

In today's highly competitive environment, business requirements always drive technology solutions. In response to increasing customer demand and dynamic competition, companies are under high pressure to shorten time-to-market by providing tailored products to the customer for the economy of scope, to reduce time-to-volume via mass production for the economy of scale, and to decrease time-to-profit by increasing the efficiency of the entire lifecycle for the economy of service. These business requirements drive technology needs: (1) to speed up product development, (2) to enhance manufacturing and supply capability and capacity and (3) to improve revenue from lifecycle efficiency.

To tackle such challenges, in past decades, with the support of advanced manufacturing technologies, manufacturing industry has shifted from mass production, which takes the advantage of scale of production, to concurrent engineering, which optimizes internal enterprise processes, and virtual enterprise, which leverages intellectual capital via collaborative innovation [1]. In such a virtual enterprise environment, companies need to closely collaborate with customers, manufacturers, and suppliers in a real time manner so as to quickly respond to dynamic market changes.

Accordingly, the business model in the manufacturing industry has shifted from make-to-order, to build-to-order, to engineering-to-order, to configure-to-order, to design-to-order, and in near future to innovate-to-order.

Key technologies to support these business models have changed as well from mass production, to a flexible manufacturing system, to manufacturing knowledge management, to product customization, to product knowledge management, and to product lifecycle management (PLM) [1,2,3,4,5]. As such, PLM is recognized by world's leading universities, institutes, and solution vendors as the next big wave in enterprise application software market.

Product lifecycle includes the processes of portfolio management, product design, process design, supply, production, launch, service, and recycle. Throughout the entire product lifecycle [6], there exist three major objectives, which are:

- *customer benefit such as product quality and serviceability,*
- *company benefit such as product cost and profit,*
- *society benefit such as clean and green environment.*

These benefits become the 'WHY' aspect of product lifecycle. Bearing these benefits in mind, the 'WHAT' aspect of product lifecycle can be created, which is to model product specification, function, behaviour, structure, geometry, topology, machining process, schedule, supply chain, operation service, recycling, and disposal. The next step is 'HOW' to model the product lifecycle, which are lifecycle processes including specification management, conceptual design, detailed design, process design, production, supply, service, and recycle.

To reach customer benefits, mass customization, time-to-innovation, product quality, and reliability are recognized as the key approaches enabled with technologies e.g., product family design, platform based design, modular product design, design process modelling and management, design knowledge management, collaborative design engineering, function/ behaviour/ structure design, etc.

To achieve company benefits, time-to-market, time-to-volume, and time-to-profit are known as the key approaches enabled with technologies, e.g., collaborative product service, product lifecycle process management, product lifecycle information and knowledge management, etc.

To obtain society benefits, design for service, design for reuse, design for recycle are justified as the key approaches enabled with technologies, e.g. product/ service co-design, collaborative early design for lifecycle efficiency, environmentally conscious design, etc.

This article will focus on the discussion of technology solutions to achieve company benefits in product lifecycle, namely, product lifecycle management (PLM), which is also the dominant direction in the current market of enterprise software application. PLM provides customers, developers, manufacturers, and suppliers with the most effective means by collaboratively managing business activities throughout entire product lifecycle [4,6]. PLM supports the capability of collaborative creation, management, dissemination and use of product assets (including data, information and knowledge) in virtual enterprise integrating people, processes, and technology [1,2,3]. PLM systems manage a portfolio of products, processes, and services from initial concept, through design, engineering, to final disposal. As such, PLM offers companies a new way to rapidly plan, organize, manage, measure, and deliver new products or services much faster, better, and cheaper in an integrated way.

Following this trend, in this article, ever-increasing business drivers and industrial requirements are analyzed. PLM is proposed as a new weapon to satisfy modern needs for new business model of innovation-to-order. A recent state-of-the-art review for PLM, including both academe and industry is done.

To effectively manage these product lifecycle processes for competitive advantages via efficient collaboration, technology solutions for PLM are proposed as the future trend. Accordingly, the impacts of PLM technology solutions to industry are analyzed.

CHALLENGES IN PRODUCT LIFECYCLE

Business Driver

The current business environment faces new business challenges for effective management of whole product lifecycle [3], e.g., shorter product lifecycles, increased outsourcing, mass customization demands, more complex products, geographically dispersed design teams, inventories subject to rapid depreciation, and rapid fulfilment needs. In general, these challenges include increased speed, increased demand; increased outsourcing, and the use of Internet.

Industrial Requirement

To effectively tackle the above challenges in a modern collaborative enterprise environment [1,6], new industrial capabilities are required in order to obtain business success in today's Internet economy:

1. *Geographically scattered design teams and supply chain partners need to collaboratively design products on a virtual basis.*
2. *Static designs need to be replaced by mass customization often using predefined modules or building blocks to rapidly configure new product platforms that can be flexibly managed through lifecycle.*
3. *A new approach needs to be created to leverage net centric technology to liberate the inherent value in today's extended business model.*
4. *Such a new approach should enable business to use and leverage information needed by each partner to accelerate and enhance product development predictability.*
5. *That approach should provide a system to exchange and control product information and to perform real-time program/project management.*
6. *A system needs to emerge as the dominant technology for managing inter-enterprise data, information and knowledge.*

To meet these requirements, a new system is imperatively required:

- *to provide an information continuum in order to deliver pervasive, real-time analytics, querying, and reporting throughout the entire product lifecycle,*
- *to provide a collaborative environment bringing together multiple roles, constituents, and stakeholders in threaded discussions beyond four walls of enterprise,*
- *to enable interactive viewing upon product development through multiple devices, channels, and systems involved with the product lifecycle,*
- *to be an open but integrated solution supporting key enterprise value disciplines of product leadership, customer intimacy, and operational excellence.*

Such a new system will provide customers, developers, manufacturers, suppliers, and partners with the following capabilities:

- *product lifecycle collaboration across virtual enterprises,*
- *common product lifecycle processes management,*
- *effective management of product lifecycle activities,*
- *convenient integration with other enterprise systems.*

REVIEW OF PLM APPROACH

PLM Concept

As companies move towards providing better customer-centric products and services quickly to maximally satisfy customer requirements, to improve market share and market size with continuously growing revenue, the efficiency and effectiveness of product lifecycle management becomes much more important in modern enterprise application systems [1,7]. To address these needs, PLM has recently been recognized as a new strategic business approach in support of collaborative creation, management, dissemination, and use of product assets, including data, information, knowledge, etc., across extended enterprise from concept to end of life – integrating people, processes, and technology. PLM systems support the management of a portfolio of products, processes, and services from the initial concept, through the design, engineering, launch, production, and use to final disposal.

They coordinate and collaborate products, project and process information throughout the product value chain among various players, internal and external to enterprise. They also support a product-centric business solution that unifies product lifecycle by enabling online sharing of product knowledge and business applications [2,3,4].

As such, PLM enables manufacturing organizations to obtain the greatest competitive advantages by creating better products in less time, at a lower cost, and with fewer defects than ever before. In summary, PLM not only provides service throughout the entire product lifecycle, but also enables effective collaboration among networked participants in product value chain, which differentiates it from traditional enterprise application systems, such as Enterprise Resource Planning (ERP), Manufacturing Execution System (MES), etc.

Status Survey

This is because, traditional application systems, e.g., computer aided design (CAD)/computer aided manufacturing (CAM) [5], computer aided process planning (CAPP) [6], helped to make the design process more efficient, but they were usually separate from a manufacturing company's mainstream operations.

Design engineers and possibly manufacturing engineers could access these systems, but others, who may have been able to add value to the design, had no systematic process by which to influence or even comment on product design. By the time these other participants provided their input, resulting in high costs or inefficient product design that did not meet customer needs. Even though the modern manufacturing application systems, such as, product data management (PDM), supply chain management (SCM), enterprise resource management (ERP), manufacturing execution system (MES), customer relationship management (CRM), demand chain management (DCM), and so on, have been developed to overcome certain aspects of the above difficulties, they still cannot adequately address the need for collaborative capabilities throughout the product lifecycle because they focus on special activities in an enterprise and are not adequately designed to meet new business requirements [8,9].

A academic state-of-the-art review or the research effort related to PLM is summarized in research given in the references [1,6], where also is summarized the industrial status of PLM solutions from world's leading vendors [10,11]. These solutions from different vendors, particularly the PDM solutions, have been applied in manufacturing industry and have created a beneficial impact on enterprises.

Gap Analysis

However, to get the most competitive advantages in the modern dynamic global manufacturing era, there is still a big gap between increasing demands from industrial companies and available solutions from vendors. The gaps in PLM include:

1. *CAD/CAPP/CAM integration versus collaboration product development and real time design to manufacturing collaboration;*
2. *Product structure and configuration management versus collaborative product family design for mass customization;*
3. *Design for manufacturing versus design for supply chain and lifecycle efficiency;*
4. *Product planning versus product portfolio management;*
5. *Design workflow management versus product lifecycle process management;*
6. *Product and part maintenance versus extended product service.*

Therefore, it is imperatively required that new technology needs to be identified and further developed to enable current commercial PLM solutions to satisfy increasing industrial requirements.

COLLABORATIVE PLM STRATEGY

PLM Strategy

As a business strategy [2,3,4], PLM lets distributed organizations innovate, produce, develop, support, and retire products. It captures best practices creating a storehouse of valuable intellectual capital for systematic and repeatable re-use.

As an information technology strategy, PLM establishes a coherent data structure that enables real-time collaboration and data sharing among geographically distributed teams. PLM lets companies consolidate multiple application systems while leveraging existing legacy investments during their useful lives.

Through adherence to industry standards, PLM minimizes data translation issues while providing users with information access and process visibility at every stage of the product's life.

PLM systems support the management of a portfolio of products, processes and services from initial concept, through design, launch, production and use to final disposal [8]. They coordinate products, project and process information throughout new product introduction, production, service and retirement among the various players, internal and external, who must collaborate to bring the concept to fruition.

The PLM concept gives the strategies to organize and to manage product information the entire life cycle, from concept to re-cycling of the product through:

- *Share the updated product information's within the organization to design, manufacturing, marketing and procurement divisions,*
- *Collaborate internal team with external users, suppliers and customers for iterating new designs,*
- *Maintain a repository of product information for design reuse and to reduce part redundancy,*
- *Systematically gather and analyze customer or market product requirements,*
- *Streamline sourcing team to identify a list of preferred suppliers for purchasing custom and standard parts,*
- *Streamline resource management and analyze the cost-benefits of allocating resources for specific projects.*

Management and distribution of enterprise information by PLM system is realized on different data levels, as:

- *ICT*
  - *Compliance with existing legacy system*
  - *Integration of PLM and ERP/CAD systems*
- *Processes*
  - *Fragmented and unalterable*
  - *Modeling, controlling, improving*
- *Data & Objects*
  - *Different data formats; Standard data representation (IGES, STEP…)*
  - *Preserving data integrity along the time; Supporting data evolution*
- *Methods & Tools*
  - *Specific tools (CAD, CAE)*
  - *New development methodologies (Six Sigma, Axiomatic design…)*
- *People & Organization*
  - *Functional organization promotes incommu-nicability*
  - *Supply chain approach*

Establishing PLM

There are companies that supply software to support the PLM process. That software itself is just a tool and cannot make many contributions if the PLM process is not defined first and understood by its users whom it should contribute to at the end. Setting up PLM within the company is a process and project itself [6].

Select operations that should be managed as a part of the PLM across the company business would be:

- *Customer relationship management (CRM) system for managing customer record,*
- *Enterprise resource planning (ERP) system for managing financial records,*
- *Supply chain management (SCM) system for managing supplier support,*
- *Human resource management (HRM) system to manage the employee record,*
- *Requirement management (RM) system for managing of requirements,*
- *Project management (PM) system for managing capabilities provide project scheduling, tracking, and resource management while the change management is driving the execution of these projects via the process workflows and part/document management capabilities.*
- *Product data Management (PDM) system for managing product data and workflows.*

Fist step in establishing PLM would be understanding and analyzing the company way of work, organizational structure, roles and responsibilities within the organization. Each of the PLM operational systems should be defined to specify who is contributing to the system, how the information is shared and responsible person appointed for each of the systems. It is not necessary that all those operation systems are integrated within one software tool, and usually for small and medium companies they won't be, while on the other side big companies might need to adopt available software and tools to their specific needs.

Application of PLM in medium to large enterprises

In the current economic climate, addressing global business challenges is the top priority of most medium and large enterprises. Whether they want to expand their customer base in new markets, or to leverage more cost competitive resources, conducting their business globally is a necessity [1,7]. To sustain an advantage, they have to overcome the challenges of a dispersed organization, while still empowering individual team members.

PLM concept offers comprehensive solutions to help enterprises address their challenges and create competitive advantage. Five areas where medium and large enterprise should have achieved success include:

- *Managing new product introduction, to create a winning product portfolio.*
- *Achieving concurrent engineering globally, to be faster to market.*
- *Creating platforms for reuse, to reduce cost and speed product customization.*
- *Managing product and manufacturing complexity, to avoid program problems.*
- *Supporting products currently in-service, to ensure they are available for use at minimum cost.*

Application of PLM in small to medium enterprises

Small and medium enterprises have special needs and limited resources. PLM concept brings a complete solutions designed specifically for them; solutions that help them respond better to their customer's needs.

Small businesses need a product lifecycle management solution designed from the ground-up –one that is pre-configured with the industry's best practices, and offers fast and affordable deployment. Fully integrated PLM solutions are designed to provide what small and medium enterprises need to maximize their innovation strategy, and easily scale to meet their needs tomorrow.

One producer of that type of PLM software solutions is Siemens PLM software [8]. It helps mid-sized manufacturing companies to transform their process of innovation by applying preconfigured best practices to everyday engineering tasks and processes. Companies using PLM software benefit from:

- *Securing their corporate design data while facilitating access by authorized personnel*
- *A more successful move from 2D to 3D*
- *Increasing their design reuse, facilitated by a powerful and flexible search capability*
- *Streamlining their engineering process with simple design review and release workflows and effective change management*
- *Error reduction through more effective collaboration between their departments and the elimination of mistake manual handoffs to manufacturing*
- *Rapid deployment of a full-featured product data management (PDM) solution*
- *Low total cost of ownership.*

PLM METRICS DEVELOPMENT PROCESS

The questions often asked in business and commerce are how well do we know we're doing, and how do we know what we're doing is working? There is important to find out the metrics process for measuring what is important and meaningful [3,5,7]. The only way to find out answers to these questions is to measure the processes and outcomes of these processes. As PLM transforms the way companies do business, it is important that companies understand how well they are doing. To determine the effectiveness of PLM implementation within any context, PLM processes and outcomes need to be measured. Measurement of PLM requires the development of metrics that are important and meaningful to the process. It is essential that what is identified as a metric is relevant, appropriate and important, since typically what gets measured gets done.

The objective of the metrics development process is to identify, develop, and articulate PLM metrics that would help companies implementing PLM determine the extent to which their PLM efforts are paying off. The PLM assessment process model shown at the Figure 1, conceptually presents the metrics development process.

The PLM processes, including ideation, design, build, service, disposal, and recycling, on one hand influence the determination the key performance indicators of success on the other hand the execution of the strategies and initiatives depends on them.

The key performance indicators are directly impacted by the organizational strategies and initiatives. In other words, the organizational goals and objectives define what the organizational considers success which should determine the key performance indicators. Key metrics are derived from the performance indicators. The key metrics measure what is relevant and important to the organization as outlined by the organizational strategic plan. Outcomes of the assessment and analysis using the key metrics impact the organizational strategic plan. These metrics are all tied to business objectives related to growth, revenue, and profitability.

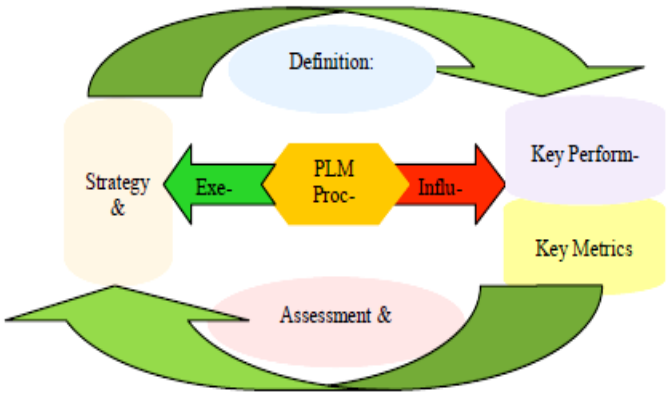

Fig. 1. PLM Assessment Process Model

PLM metrics can be applied at various levels of complexity.

- *At the very basic Level 1 Input metrics are measured. At this level, the question is whether the organization is applying appropriate resources to the PLM process, i.e. investments.*
- *At Level 2, metrics are used to determine if the appropriate PLM processes were implemented, e.g., Requirements Management, Sourcing and procurement, Distribution Quote/order generation.*
- *Level 3 focuses on customers being reached.*
- *Level 4 and 5 metrics examine the efficiency whether the outputs meet the needs of customers are being met (e.g., requirements traceability, visualization, concepts, design capture & accessibility, change control & change capacity, configuration management, commercial cost of risk, product quality) and effectiveness, if desirable results are being achieved (e.g., generation of new business, software integration, cost performance, market share, cost reduction, design reuse).*
- *At the highest Level 6 metrics are used to measure the impact of the implementation of PLM by measuring the extent to which procedures and controls have been integrated and the return on investment. Level 6 metrics are the most complex and difficult to measure. These include waste reduction, innovation/ new products, continuous improvement, and sustainable green manufacturing.*

PLM Business Value

When the enterprise implements the PLM concept in work, than it can move forward strategically while achieving near-term results and can establish a platform for innovation. As the enterprise address specific business issues and builds a solid foundation for future success through PLM platform, it will be able to realize measurable innovation benefits both immediately and over the long term, shown on the Figure 2.

Traditionally, companies brought their products to market in time-consuming serial processes that delayed the participation of downstream contributors, such as suppliers, manufacturing experts and service/maintenance providers. By allowing to the enterprise to execute as many lifecycle tasks as possible in parallel processes, PLM enables to the enterprise to streamline and collapse critical stages in the product lifecycle. PLM delivers aligned, accurate, and highly synchronized product knowledge to multiple disciplines early in product lifecycle – thereby avoiding the cost and scheduling impact that comes when late suggestions and unexpected concerns arise from downstream players. PLM enables to the enterprise to beat the competition to market with innovative product content that carries first to-market advantages and drives early product sales.

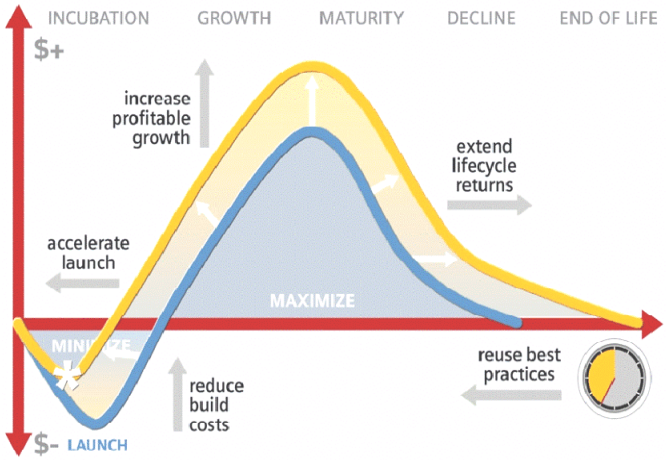

Fig. 2. PLM business value

Increase profitable growth

PLM allows the enterprise to create, capture and share the product-related requirements, expectations and preferences of targeted customers and markets and align these requirements with specific innovative content that customers want for a price they can afford at the time when it is needed. PLM concept gives new product ideas against quickly rising customer requirements and cost effective manufacturability. Global cross-functional teams collaborate in real time on the development process, each contributing their unique experience and perspective. Knowledge and "lessons learned" are captured for potential re-use in a process of continual innovation.

PLM facilitates mass customization by enabling to rapidly and costs effectively deliver customized product offerings that satisfy the needs of individual customers and targeted market segments. PLM combines the advantages of configuration management with option and variant management. These state-of-the-market capabilities allow the enterprise to perform portfolio planning in as flexible and continuous a process as possible.

Reduce build costs

PLM allows the enterprise to reduce cost across all of the stages in the product lifecycle – which in turn, enables to minimize the cost of the product offerings that plan, develop, manufacture, and support.

For example, by leveraging PLM to understand the time and resource impacts of proposed design changes and requirements changes, the enterprise's team can make decisions that minimize lifecycle and product costs. By using PLM to catch design flaws up front in the lifecycle, the team can avoid the cascading rework and cost associated with changing the products during the manufacturing stages of the product lifecycle. Also, the enterprise's team can use PLM to incorporate the concerns of the maintenance and service groups into the product designs and minimize warranty costs. By digitally creating and re-using the manufacturing plans, plant information and manufacturing processes, the enterprise can reduce the overall operational costs. The enterprise can also use PLM to implement virtual prototyping that enables to reduce the validation costs associated with physical prototyping.

Implementation of the PLM concept in the enterprise enables to cost effectively deliver product enhancements, derivatives, niche offerings and add-ons that extend the profitable duration of the product lifecycle. PLM facilitates this objective by enabling to create product platforms that accelerate start up processes, minimize take to market cost and maximize the revenue generated by a product's initial release.

PLM enables the enterprise to maximize the re-use of the best-practice processes, intellectual capital, human resources, product plans, production plans, production facilities and value chains across a continuing set of take-to-market programs and complete set of product and production management capabilities.

Conclusion

Although a quite new method with short history PLM has proven itself to be useful for all management levels within the company in both vertical and horizontal organization. By making relevant historical information structured and available PLM is used both for those who are doing execution and decision makers within the organization answering to the rapid changes in the business environment. A business approach for coordinating design process through the implementation of PLM systems is proposed for improving design coordination in SMEs.

Firstly, this business approach is based on a method for analysing informal collaborative practices and modelling detailed design processes. Secondly, these processes are implemented by using PLM technologies. Multi-level workflows are implemented to control progress of design schedule from project management level to document lifecycle management level.

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