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SUSTAINABLE BUSINESS SOLUTIONS THROUGH LEAN PRODUCT LIFECYCLE MANAGEMENT

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ABSTRACT: In today's process manufacturing environment, innovation is viewed as critical to sustainable growth and business profitability. While open innovation is regarded as the answer, the companies can effectively measure the return on R&D investment, have acceptable product success rates, achieve acceptable promotional effectiveness, or have visibility into their compliance risks or operational readiness for new product launches. While open innovation is an actual topic, capitalizing on the opportunity requires holistic strategy, not just increased collaboration. Companies must have repeatable, compliant and responsive business processes, global information infrastructure that provides a single source of the truth, alignment across departments and solutions that evolve without coding. With holistic strategy and supporting infrastructure, companies can consistently minimize the time to scale, improve product success rates and promotional effectiveness, and enjoy sustainable and profitable growth. With open innovation providing unlimited opportunities, the company should start to identify the best open innovation opportunity and deliver top and bottom line of the company's benefits. The companies must first focus on the needs of their customer, continually minimize time to scale, eliminate waste, drive out costs and improve. These are core concepts of a Lean strategy. This paper will describe how Lean concept with PLM business strategy can leverage Lean with integrated compliance, continual improvement and other PLM best practices to increase the return on R&D investments and provide sustainable and profitable growth for business processes mainly manufacturing processes. The purpose of this paper is to review PLM approach linked to Lean concepts in order to achieve sustainable and innovative business processes with sustainable and profitable growth.

KEYWORDS: PLM, Business solution, Lean PLM, Sustainable business process

INTRODUCTION

In today's challenging global market, enterprises must innovate to survive. Business innovation must occur in all dimensions—product, process, and organization—to improve competitiveness and business performance. To differentiate themselves, enterprises must capture, manage, and leverage their intellectual assets. This can best be accomplished through proper application of a Product Lifecycle Management (PLM) approach that addresses the needs of the extended enterprise [2,5,6]. PLM is a strategic business approach that helps enterprises achieve its business goals of reducing costs, improving quality, and shortening time to market, while innovating its products, services, and business operations and also, with including the idea of open innovation [2,4,8].

Once implemented, PLM solutions provide benefits that have demonstrated a positive impact on an enterprise's top and bottom lines. PLM solutions can improve business efficiency by providing:

- Reductions in time and cost of product changes;
- Significantly shorter product cycle and lead times;
- Decreased scrap and rework during production;
- Improved productivity in design engineering.

In a now-a-day enterprise business solutions, lean concept is high popular. The real means of lean is given according to LEI (Lean Enterprise Institute) [9]:

"The core idea is to maximize customer value while minimizing waste. Simply, lean means creating more value for customers with less resource".

A lean organization understands customer value and focuses its key processes to continuously increase it. The ultimate goal is to provide perfect value to the customer through a perfect value creation process that has zero waste.

There for, where is the link between lean and PLM enterprise business solutions? The focus of lean PLM is to address the need of the right amount of product data in different stages of product life cycle to serve the requirement of business intelligence, based on which sound business decisions can be made in a timely fashion [13]. PLM is often global, and/or across multiple business entities, therefore, lean PLM would also address the needs for intelligent, secure and efficient communication across board.

Lean PLM implementation is to apply the lean principles to a PLM implementation to ensure that all ingredients in the implementation is well justified and of value and there is no waste and there is minimum change needs.

BUSINESS CHALLENGES

Businesses today face three on-going challenges: improving customer intimacy, achieving operational excellence, and providing product leadership. Improving customer intimacy requires understanding

and responding quickly to current and potential customers, their needs and providing consist, long-term customer value. Achieving operational excellence requires enterprises to focus on operating efficiently, effectively, and flexibly, working with their partners to reduce the cost and time necessary to deliver high-quality products meet their customer’s requirements in a timely manner. Providing product leadership means delivering leading edge products and solutions tailored to customer needs.

To meet these challenges, businesses must become more innovative. However, being an innovative business doesn’t simply mean creating innovative products.

It also means improving the processes a company uses to produce its products and how it supports its products using innovative approaches to the complete product lifecycle. Today, innovation is recognized as critical for a business to maintain its competitiveness in the marketplace. However, innovation must be achieved while reducing overall product-related costs across development, production, and service.

To be successful in global markets, organizations must develop and apply a diverse set of skills and business processes. Global enterprises must:

- Make effective use of a widely-distributed worldwide organization, creating a virtual value chain with no time, distance, or organizational boundaries.
- Ensure that corporate acquisitions and mergers work together.
- Create and enable virtual product teams composed of people that are spread around the world
- Leverage the intellectual assets in these dispersed teams and organizations
- Enable 24 x 7 development and product support using global teams

These drivers are putting increasing pressure on organizations to invest in solutions that include technologies, methodologies, best practices that can help them improve their ability to focus on product innovation, leverage business partners, and compete more effectively in the global market place.

There has been a continuous evolution of what PLM represents, as illustrated in the figure below, Fig.1. Fifteen years ago, custom implementations focused on precise applications wrapped around primarily engineering design data. In the late 1980’s, the major emphasis was on how to manage engineering drawings, with limited solutions primarily sold to managers in engineering departments. Today, the focus is on complete business solutions that address top and bottom line issues. These solutions incorporate best practices to allow organizations to

migrate their business processes toward industry standards.

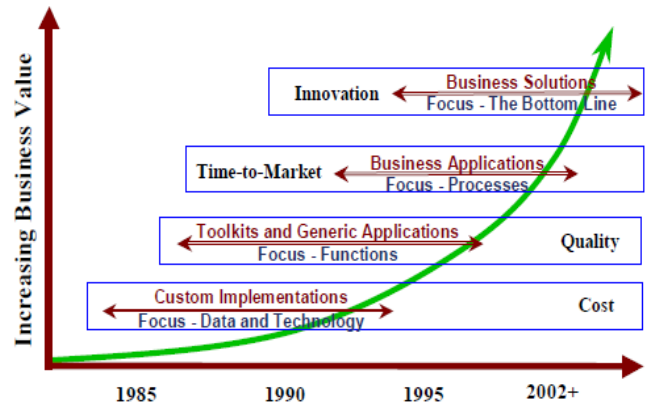


Figure 1. Evolution of PLM idea [1]

BUSINESS APPROACH

PLM is a definition of a business approach to solving the problem of managing the complete set of product definition information— creating that information, managing it through its life and disseminating and using it throughout the lifecycle of the product. PLM is not just a technology, but is an approach in which processes are as important as or more important than data. It is critical to note that PLM is as concerned with “how a business works” as with “what is being created.”

Three core or fundamental concepts of PLM are:

1. Universal, secure, managed access and use of product definition information
2. Maintaining the integrity of that product definition and related information throughout the life of the product or plant
3. Managing and maintaining business processes used to create, manage, disseminate, share and use the information.

PLM model describes the technology, management and process components of an enterprise PLM solution. Across the bottom of the model are technology foundation components that are an integral part of any PLM solution. Solution providers use these foundation elements to construct core functions, such as design automation, product structures and Bills of Materials, workflow and process management, and information and content management and vaulting. These core functions are inherent capabilities contained within PLM solutions.

ERP is integrated or interfaced with PLM. ERP has traditionally dealt with the product production lifecycle. Over the last several years, the focus shifted from ERP to other enterprise solutions such as SCM, CRM, and now, PLM. As part of the continuing evolution, new solution providers are beginning to deliver products that combine some ERP and some PLM capabilities into one offering. Other business functions, such as the logistics of supply chain

management, logistics itself, marketing and sales, distribution, HR, and finance are not part of the basic PLM capabilities, but they all interact at multiple points along the product lifecycle or with components of a comprehensive PLM solution.

The figure below (Fig.2) shows the relationships between these enterprise solutions. Product businesses have at their core the intellectual assets describing their products. Typically, PDM solutions were used to manage product development and design work-in-process. Once a product could be released to manufacturing, ERP took over. Supply chain management was often used by procurement to support the production function. Once the product was in the field, CRM systems helped manage the customer relationship. Today's businesses require enterprise solutions that can integrate all of this disparate information to optimize product development, production, and deployment. CRM data must be used to embody today's customer requirements into the next product generation. To save money, SCM systems must be active from the beginning of the product definition lifecycle, saving procurement time and money while supporting the product development process. Business partners, suppliers, and customers must all have visibility into this information to optimize their decision processes to benefit the enterprise. PLM is becoming the overall view port or portal into such product definition information and processes, providing collaboration and integration functions to synthesize information residing in CRM, SCM, ERP, and other business systems to enable new, complex business solutions.

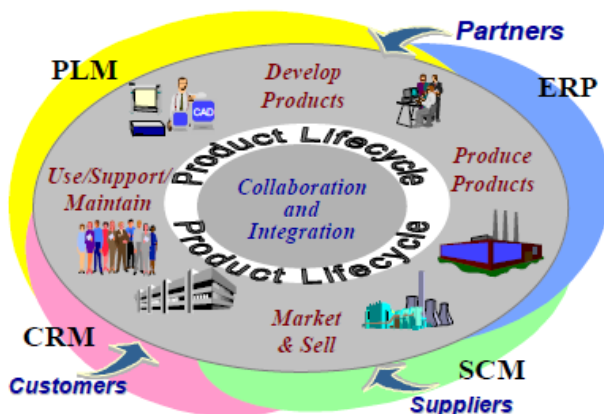


Figure 2. Relationships among Enterprise Solutions

Additionally, PLM solutions improve an individual's performance by managing not only product definition information, but by guiding and facilitating their tasks through well-defined business processes and workflows.

PLM solutions have a very positive effect on process efficiency and effectiveness by supporting and encouraging work in a more structured manner and providing the right information, at the right time, to the right people.

PLM solutions touch every aspect of an enterprise. The ability to effectively integrate and use product definition information is important to sales and service, marketing, production planning, plant operations, customers and suppliers. All disciplines need detailed, timely knowledge of what products are being designed and produced.

LEAN CONCEPTS COMPLIMENT PLM BEST PRACTICES

Defining Lean

According to LEI (Lean Enterprise Institute) [9], the core idea of Lean Management (LM) is to maximize customer value while minimizing waste. Simply, lean means creating more value for customers with fewer resources.

A lean organization understands customer value and focuses its key processes to continuously increase it. The ultimate goal is to provide perfect value to the customer through a perfect value creation process that has zero waste.

To accomplish this, lean thinking changes the focus of management from optimizing separate technologies, assets, and vertical departments to optimizing the flow of products and services through entire value streams that flow horizontally across technologies, assets, and departments to customers.

Eliminating waste along entire value streams, instead of at isolated points, creates processes that need less human effort, less space, less capital, and less time to make products and services at far less costs and with much fewer defects, compared with traditional business systems. Companies are able to respond to changing customer desires with high variety, high quality, low cost, and with very fast throughput times. Lean Manufacturing is the practice of eliminating waste in every area of production including customer relations (sales, delivery, billing, service and product satisfaction), product design, supplier networks, production flow, maintenance, engineering, quality assurance and factory management. Its goal is to utilize less human effort, less inventory, less time to respond to customer demand, less time to develop products and less space to produce top quality products in the most efficient and economical manner possible.

Lean Concept

When considering the lean concept for Lean Enterprise (Figure 3) [10], defining it must be done within several self contained domains. There are at first the principles of Lean that must be dominant in all aspects of the Lean Enterprises practices (including the subset of Lean implementation principles). Within that concept, there are the characteristics of the operation, the concepts under which the enterprise operates and the tools used in making the lean journey.

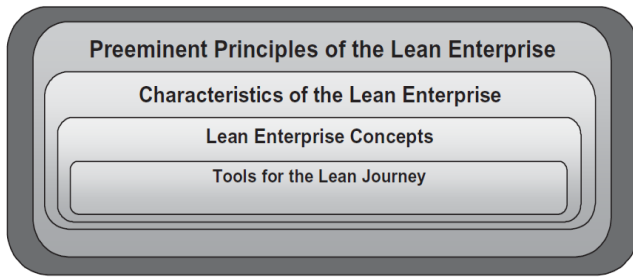


Figure 3. Lean Enterprise

□ **Pre-eminent Principles**

- Customer Focused
- Doing More with Less (Waste Elimination)
- Quality at the Source

□ **Principles of Implementation—a Subset of Pre-eminent Principles**

- Specify (value)
- Map (process/value stream)
- Apply (process flow)
- Selectivity (pull)
- Continuous Improvement (perfection)

□ **Characteristics**

- Standardize-Do-Check-Act (SDCA) to Plan-Do-Check-Act (PDCA)
- Next Production Line Process is Your Customer
- Quality the First Time, Every Time
- Market-in vs. Product-out
- Upstream Levelled Management Structure
- Let Data Speak
- Variability Control and Recurrence Prevention

□ **Concepts**

- Waste Reduction
- Integrated Supply Chain
- Enhanced Customer Value
- Value Creating Organization
- Committed Management
- Winning Employee Commitment/Empowering Employees
- Optimized Equipment Reliability
- Measurement (Lean Performance) Systems
- Plant-Wide Lines of Communication
- Making and Sustaining Cultural Change

□ **Tools**

- 5-S Process
- Seven Deadly Wastes
- Standardized Work Flow (TAKT Time)
- Value Stream
- Kanban (Pull System & Visual Cues)
- Jidoka (Quality at the Source)
- Poka-Yoke (Mistake [Error] Proofing)
- JIT (Just-in-Time)

□ **Lean PLM**

The focus of lean PLM is to address the need of the right amount of product data in different stages of product life cycle to serve the requirement of business

intelligence, based on which sound business decisions can be made in a timely fashion [10].

PLM is often global, across multiple business entities, therefore, lean PLM would also address the needs for intelligent, secure and efficient communication across board. For small and medium local businesses, lean PLM would address PLM needs in the form of on-demand requirements for on-demand services.

□ **Lean PLM Implementation**

Lean PLM implementation is to apply the lean principles to a PLM implementation to ensure that all ingredients in the implementation is well justified and of value and there is no waste and there is minimum change needs.

According to LEI [9], there are 5 steps in the lean practice:

1. **Identify value** - Specify value from the standpoint of the end customer by product family.
2. **Map the value stream** - Identify all the steps in the value stream for each product family, eliminating whenever possible those steps that do not create value.
3. **Create flow** - Make the value-creating steps occur in tight sequence so the product will flow smoothly toward the customer.
4. **Establish pull** - As flow is introduced, let customers pull value from the next upstream activity.
5. **Seek perfection** - As value is specified, value streams are identified, wasted steps are removed, and flow and pull are introduced, begin the process again and continue it until a state of perfection is reached in which perfect value is created with no waste.

□ **Lean PLM collaborating aspects**

A core component of Lean is focusing on the customer. For many production and manufacturing processes, they must need to focus on the consumer or customer, retailer and distribution. To achieve this, collaborating with aspects of the value chain, validating constraints and compliance early and often, continually optimizing portfolio management opportunities, managing knowledge and intellectual property, integrating to the extended enterprise systems, engraining governance into processes and continually improving without coding are standard PLM best practices [12]. These PLM best practices will allow the company to continually minimize time to scale, eliminate waste, and drive out costs.

- **Focusing on the customers:** To drive growth and profitability, companies need to focus on the customer and must identify their unique value propositions for customers and align these with their channel. Defining your critical-to-customer, critical-to-retailer and critical-to-quality

characteristics is an important first step. With these critical characteristics, R&D costs can be lowered by not designing in non-value added capabilities, time can be reduced by eliminating non-value added iterations, excess material costs and carrying costs can be eliminated, product quality and consistency improved, and regulatory risks reduced. Integrating these into R&D concept, development and commercial applications and providing continual validation will ensure products meet customer expectations and improve product success rates. Additionally, lead times are reduced, waste is eliminated and costs are reduced.

- **Collaborating with aspects of the value chain:** To improve quality, increase innovation, reduce costs and time, many researches concluded that increased collaboration is essential. Extending collaboration from R&D (research & development) and SCM (supply chain management) to suppliers and retailers will provide increased agility, extend internal capabilities, reduce time, improve quality, lower costs and improve innovation. To identify the best way to optimize profit potential, retailer collaboration can result in better shelf placement, increased revenue, improved turns and lower retailer costs. As part of developing retailer-specific products, the supply chain must be integrated into the process and operational readiness improved. As new capabilities or capacity are required, supplier collaboration and enablement programs can reduce time and costs, improve quality and increase innovation. Further, many companies are increased levels of collaboration, both internally and across the enterprise, in an effort to increase agility and velocity. This results in reduced lead times, lower costs, improved quality and compliance and increased innovation, not to mention sustainable growth and profitability.
- **Validating constraints and compliance:** As lead times are compressed, participation of additional resources and product complexity increased; early identification of potential issues and timely mitigation is critical. The earlier a project can be stopped or realigned, the less capacity is wasted, the further costs are reduced. At any stage of development, target specifications, product and project costs and projected dates can be validated, and regulatory restrictions by market and product type best-practices guidelines can be checked. In addition to these R&D-oriented validations, supply chain constraints and vendor compliance capabilities that are validated late in the development process can be proactively validated. A supplier's capability matrix rating, social

responsibility, sustainability index, enablement status, quality rating, preference status, compliance risk and readiness values can be used to identify the best sustainable source of materials or products.

- **Managing knowledge:** This is crucial phase of product's realization. Effective reuse of knowledge and intellectual property is keys to reducing time, eliminating waste, reducing costs and improving quality while meeting customer requirements. Ready access to relevant and accurate information can eliminate the need to search for information in multiple systems or offline sources. It will eliminate non-value added, trial-and-error iterations and halt the initiation of dead end projects. To achieve these benefits, information must be effectively captured, categorized, validated, secured, put into global content, referenced to adjacent information, and the relevance status maintained through the lifecycle. Semantic search engines can mine the data and visual-comparison engines can help turn data into relevant and actionable information. When information needs to be provided to the extended value chain, specifications are used to communicate the appropriate information and secure intellectual property.
- **Integration to the extended enterprise system:** To make, source, distribute and sell products, PLM information must be integrated into extended enterprise systems. For most companies, the PLM system information will not be different from the operational planning systems. Some R&D-oriented or proprietary information will not be integrated to the extended enterprise systems. Items, components, formulas/recipes, routings, products, new vendors, quality specifications and new customers must be sent to the ERP system. To ensure R&D is working with the most current information, costs, quality, sourcing, product or pilot assays and production volumes and status changes must be communicated back into PLM. Collaboration with vendors, customers and retailers via collaborative workspaces or integration can shorten time, reduce costs and improve quality.

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 4, conceptually presents the metrics development process.

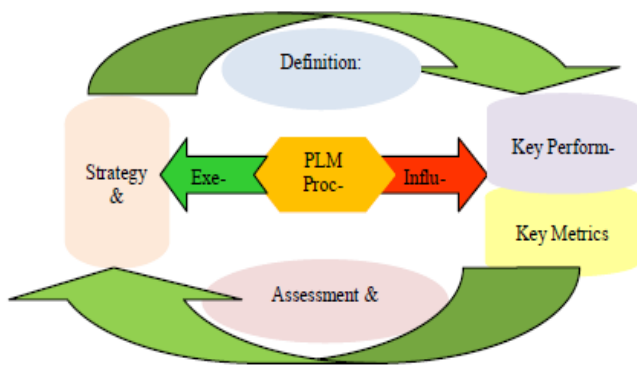


Figure 4. PLM Assessment Model [7]

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 organization 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.

PLM metrics can be applied at various levels of complexity, explained in follow according to [2,6].

- 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 5.

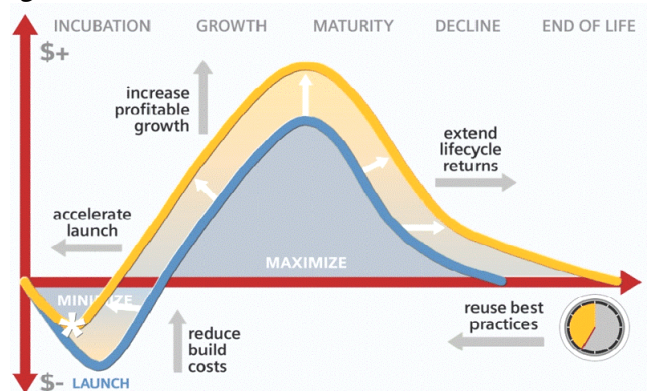


Figure 5. PLM business value

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 the enterprise to beat the competition to market with innovative product content that carries first to-market advantages and drives early product sales.

□ 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 additions 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.

CONCLUSIONS

PLM is much more than a technology or software product. PLM is a strategic business approach to improve the business, to enable product and process innovation and enhance both top and bottom line business performance. It includes technology, processes, best practices, and other elements that provide a complete solution to business problems.

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. In this paper, it is made analysis of using of PLM approach, by those who are doing execution and by decision makers within the organization answering to the rapid changes in the business environment. 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. PLM workflows are implemented to control progress of design from project management level to document lifecycle management level and connection with lean management is analysed.

To accomplish this, lean thinking changes the focus of management from optimizing separate technologies, assets, and vertical departments to optimizing the flow of products and services through entire value streams that flow horizontally across technologies, assets, and departments to customers.

Eliminating waste along entire value streams, instead of at isolated points, creates processes that need less human effort, less space, less capital, and less time to make products and services at far less costs and with much fewer defects, compared with traditional business systems. Companies are able to respond to changing customer desires with high variety, high quality, low cost, and with very fast throughput times. Also, information management becomes much simpler and more accurate.

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