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Lean Product Lifecycle Management Approach

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Abstract
Companies in today's manufacturing environment must have repeatable, compliant and responsive business processes, global ICT information infrastructure that provides a single source of the truth and alignment across departments. The companies must first focus on the needs of their customer, continually minimize time to scale, eliminate waste, drive out costs and improve. With holistic strategy and supporting infrastructure, companies can achieve profitable growth. Lean as a strategy is about reducing waste wherever it occurs in the organization. It is useful to eliminate the unnecessary effort by people or machine, duplicated data and non-value activities as much as possible. This paper will describe how Lean concept with PLM business strategy can leverage Lean with integrated compliance and continual improvement to increase the return on R&D investments and provide sustainable and profitable growth for business processes mainly manufacturing processes. This paper presents one of the most widely-used PLM solution suites in the market, Siemens PLM software-Teamcenter, built on the latest IT technology. Teamcenter as an IT tool for Lean product lifecycle management (Lean PLM) offers the companies a lot of benefits. One of them is managing product structures, create and modify them in order to save time and resources.

Key words: *Product Lifecycle Management (PLM), Lean PLM, Product Structure*

1. INTRODUCTION

Engineering enterprises today have to cope with various challenges. Amongst others, the pressure of today competitive and globalized business contexts, the increasing complexity of products driven by the increasing number of product variants, which in turn is caused by customer needs for better and tailored products and the introduction of force enterprises to reduce their product development time and cost by simultaneously accounting for always stricter becoming product and environmental legislations, and by guaranteeing their customers permanent product innovation, high product quality and tailored product choices. These challenges have led to the adoption today of many engineering IT tools aiming at supporting the product development process. In order to be more competitive and efficient, many enterprises collaborate together in a supply chain manner to share their skills, services and competencies. This results into the creation of collaborative and multidisciplinary virtual engineering networks between enterprises. Therein, many enterprises contribute to the overall development of a product each of them focusing on its main competencies. Nowadays, more and more Small- and Medium Sized Enterprises (SME) are involved as first-, second- or x-tier suppliers in such complex multidisciplinary engineering contexts and are therefore also dared to overcome the associated challenges which were earlier mostly considered being related to only large enterprises having sufficient human and financial resources to overcome them.

From a product lifecycle management (PLM) perspective as a holistic approach, the most cumbersome gaps to bridge in this regard are the integration, federation, structuring, synchronization and management of disparate and complex engineering partner or discipline specific product data and related engineering processes, as well as the management of their configurations and high number of variants.

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 [2,4,6,7,8].

The need to improve product innovation, product development and engineering performance is leading many companies to adopt or extend PLM solutions. These solutions have proven value in helping

manufacturers improve their product innovation, product development, and engineering performance – and ultimately the profitability of their products.

To be competitive in the current world economy, companies need a PLM strategy focused on an integrated product model that incorporates manufacturing data.

However, many companies struggle with the best way to transform their business and take advantage of these enabling PLM technologies. For any technology to provide a business benefit, it has to allow companies to change the way they do business so that they are more competitive, reduce business risk, increase revenue, decrease cost, or in some other way recognize tangible business advantage.

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) [1,2,3,4,5,10]. As such, PLM is recognized by world's leading universities, institutes, and solution vendors as the next big wave in enterprise application software.

Lean thinking is a strategy that has already been successfully implemented at several manufacturing settings in order to produce efficiently. Any activity performed at a factory that creates no value for the customer such as loss of time, extra cost, or overstock of inventory can be considered as "waste." Consequently, lean thinking is the answer to eliminate such waste and achieve efficiency, quality, and safety in production.

Through the years, several different solutions have been proposed to achieve improvement, such as Enterprise Resource Planning (ERP), Supply Chain Management (SCM), and Customer Relationship Planning (CRP). Much of these systems adopt several interesting strategy management techniques. PLM is a relatively new concept that concentrates on the product; links the best practices of industrial engineering, lean thinking and operations management.

2. PLM - BUSSINES STRATEGY

PLM provides customers, developers, manufacturers, and suppliers with the most effective means of collaboratively managing business activities throughout product development. PLM supports the capability of innovation, creation, management, share, and use of product data, information and knowledge in virtual enterprise networks by integrating people, processes and technology.

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.

PLM systems manage a portfolio of products, processes, and services from its initial conception, through design, manufacture and supply, to service and disposal. Throughout the entire product lifecycle there exist three major objectives, which are:

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

To reach customer benefits (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 modeling and management, design knowledge management, collaborative design engineering, function/ behavior/ 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 and 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 design, etc.

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. 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 time to market cost and maximize the revenue generated by a product's initial release.

The most important part of the PLM model is information. This is the engine that moves all areas (see Figure 1). Following the characteristics of a product's life, the PLM model includes the following divisions: plan, design, build, support, and dispose.

The plan division is the study and examination of the future product before it is introduced into the market. All the characteristics of the product itself are analyzed in this phase with special emphasis is given to technical and engineering attributes. According to lean manufacturing strategies, the planning of a product should be based on customer needs and demands. In order to avoid any waste (extra inventory, extra cost, defects etc) it is important to anticipate demand and plan the production, in quality and quantity, according to what the customer wants.

There are several ways in which the product can be manufactured. In the design phase the physical attributes such as colour, form and size of the product have a great importance and quality standards are also

taken into account. Based on all attributes and requirements, the production engineers actually build the units and make sure design is achievable.

The building process involves all manufacturing procedures such: factory selection, machinery, materials, and the most qualified work force. It is not uncommon to discover that an apparently good design is actually not feasible. The assembly department will inform if indeed the machinery is appropriate to make a particular creation or if there are necessary tools, or human skills, to convert a sketch into a real product.

The support of a product can be divided into two goals: the marketing of the product and the maintenance of it. Marketing is informing the customers about the product and how to obtain the best performance of it. Maintenance has to do with solving any technical problem that may arise.

Finally, the last stage of the PLM model, dispose, has to do with all possibilities of reuse, reprocessing or any potential salvage of the product.

The figure below shows the relationships between these enterprise solutions. Product businesses have at their core the intellectual assets describing their products [10].

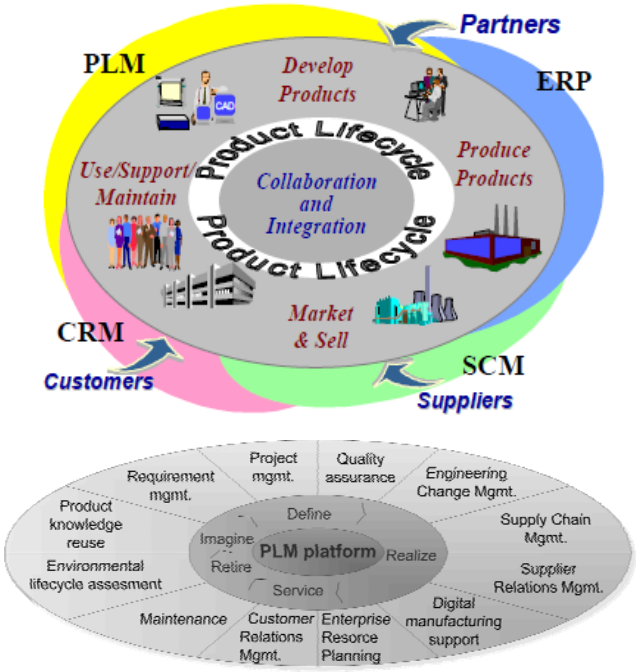

Figure 1. Relationships among Enterprise solutions [10]

3. LEAN CONCEPT THROUGH PLM

3.1 Lean concept

Lean means creating more value for customers with fewer resources[9,10,11]. 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. Also, information management becomes much simpler and more accurate.

According to LEI (Lean Enterprise Institute), there are 5 steps in the lean practice:

1. Specify value from the standpoint of the end customer by product family.
2. Identify all the steps in the value stream for each product family, eliminating whenever possible those steps that do not create value.
3. Make the value-creating steps occur in tight sequence so the product will flow smoothly toward the customer.
4. As flow is introduced, let customers pull value from the next upstream activity.
5. 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.

Fugure 2. Five steps in the lean practice

3.2 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 [11].

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 way [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.

According to Aras Corp. [14], an enterprise PLM system that supports lean initiatives includes:

- Process Structure Ability to define product development phases, milestones and deliverables in formats that accommodate the many complexities of the business.
- Visual Management Ability to see the progress and status of product programs as they move through product development.
- Knowledge Management Ability to capture, store, sort, and easily retrieve product information in a comprehensive context.
- Process Flexibility Ability to easily modify business processes and information relationships to quickly adapt to business conditions, as opposed to the rigid nature of ERP and PDM (Product Data Management) systems. Internet-based enables communication, collaboration and coordination without the limitations inherent in conventional systems.

3.3 Lean PLM collaborating aspects

For many production and manufacturing processes, they must need to focus on the consumer or customer, retailer and distribution. Also, a core component of lean is focusing on the customer. To achieve 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 [10,12]. 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. With these 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.

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.

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[10].

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.

4. LEAN MANAGEMENT INTO PLM STAGES

Applying Lean initiatives in all stages of product lifecycle means bigger benefits for the companies. Every mistake detected in product lifecycle stages (product design, planning, manufacturing), costs a lot. Implementation of Lean Management in product lifecycle helps to reduce these costs in order to increase the profitability of the company, improving product innovation, or getting product to market faster. Organizations might look at these as cost reducing strategy or time-to-market strategy [13].

There are certain basic truths according to some of the PLM stages which are result of PLM and Lean Management. The key one is that for effective product development everybody who is involved shares the same data and information. But in organizations that often doesn't happen. For example, few organizations work with a single bill of materials (BOM), but all of them have different systems to view a bill of materials which are not connected. Changes made in one of them are not updated in the others. Lean means not to duplicate data, because it is expensive, and can introduce errors, additional costs and time waste.

Product lifecycle management, offers a way to collaborate, share, and exchange data in the organization and other involved users, without duplicating information or redoing tasks. PLM is a system for lean in eliminating: waste, risk of errors, and wasted time. Optimizing the time which is necessary for product development or product design is possible if companies can have two views of the BOMs without having two BOMs [13]. This is a solution for faster managing bill of materials.

In today's high competitive market companies are working on continuous improvement. All of them want to have a system which can faster adapt their processes to changing: market conditions, customer requirements and supply chain structures. PLM enables the necessary collaboration for following market trends.

5. TEAMCENTER (PLM SOFTWARE)

In this paper, it is described how lean approaches schould be interpreted using software based system and lean applied into Siemens PLM software as a global supplier of PLM solutions used by large number of enterproces around the world. We have used accademic partnership and licensed sites of Siemens PLM software at our PLM Centers at Universities in Skopje and Novi Sad. Siemens PLM provides one of the broadest and deepest suites of PLM offerings in the industry today, and has continued an program of acquisition and partnership to broaden their offerings even further [6]. This product is set up to take advantage of cross-business unit sinergies, regarding increasing the effectiveness (building the right product) and efficiency (building the product right). Siemens PLM reports that they have 63,000 customers in 62 countries, and they have 6.7 million licensed seats of PLM software of which 5 million are Teamcenter [6].

5.1 Teamcenter as a tool for Lean PLM

Teamcenter suite by Siemens PLM is built on the latest IT technology with a unified SOA (Service-oriented architecture) and all modules share a common data model and database [9,12]. Teamcenter includes three foundational areas: Enterprise Knowledge Foundation, Platform Extensibility Services and Lifecycle Visualization. Teamcenter also contains fourteen functional areas:

- Supplier Relationship Management;
- Systems Engineering and Requirements Management;
- Manufacturing Process Management;
- Simulation Process Management;
- Maintenance, Repair and Overhaul;
- Reporting and Analytics;
- Community Collaboration;
- Mechatronics Process Management;
- Engineering Process Management;
- BOM Management;
- Compliance Management;
- Content and Document Management;
- Formula, Package, and Brand Management;
- Portfolio Program Management.

In addition the application of Siemens PLM Software-Teamcenter is presented. Bill of Material (BOM) Management provides the ability to create and manage product structures and their multiple logical constructs. These product structures include part-to-part, part-to-document, and document-to-document relationships so that a complete bill of information (BOI) can be defined and managed throughout a product's and its associated information's lifecycles.

Teamcenter allows the companies to build, view, and manipulate the product structure in Structure Manager or to import it from an MCAD system such as NX. Using Structure Manager in the companies it is very easy to visualize assemblies, make visual comparison, and analyze clearances and tolerances. The main goal of the article is to present the benefits of Teamcenter Structure Manager using an example with a product (locomotive). This is a a lean soultion how companies can save time managing product structure [9].

When an item in Teamcenter is an assembly, there can see a BOM view object icon that exists for the item and a BOM view revision object that exists for the item revision. Teamcenter automatically creates a BOM view revision when user initially creates the product structure in Structure Manager.

Product structure appears in an indented BOM format similar to those used in many CAD systems. By viewing the product structure, there can see which components are parts and which are assemblies. Figure 3 shows the product structure of the locomotive with all parts of the product. Also, Structure Manager offers adding or removing components of the assembly, but if another user is editing a single-level assembly within the product structure, Teamcenter prevents the user making changes until the other user has saved the changes.

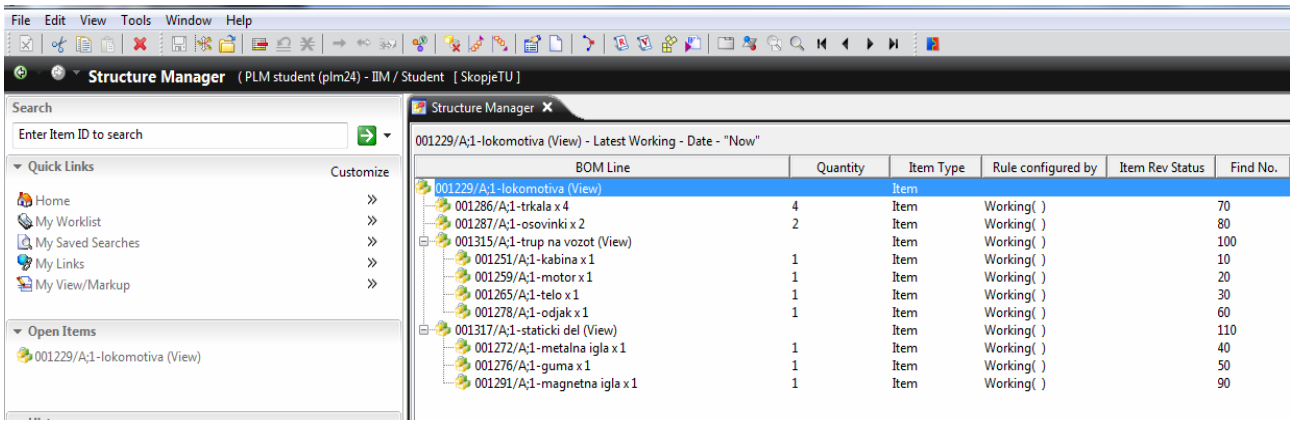

Figure 3. Product structure display

Another way to save time is to use precise part of the product structure, not the latest revision. The precise parts are always the green lines in Structure Manager like 'trup na vozot' in Figure 4. This means that any further changes and new revisions to the parts of the 'trup na vozot' will not impact this subassembly. But, if one or more of these parts are component of another assembly (that is not precise), it will use the latest version [11].

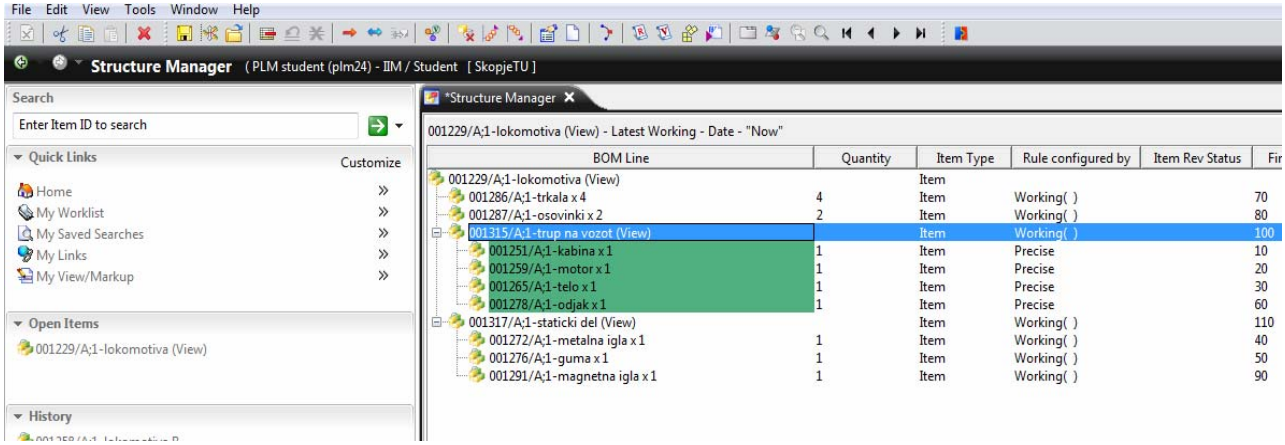

Figure 4. Precise part in the product structure

Comparing two product structures is very useful option for identifying changes or differences between two product structures. Product structures can be compare using one of the following standard modes (Table 1):

Table 1. Comparing product structures in different mode

Level mode	Explanation
Single level mode	compares only the first level of the product structures, with an option to include find numbers in the comparison or exclude them
Multi-level mode	performs a single-level comparison at the top level of the structure, Teamcenter then makes further comparisons of any subassemblies that are expanded in the two product structures
Lowest level mode	compares only the lowest level items of the product structures, ignoring all intermediate assemblies

For example we added one more component to our product, and than we compared both product structures in multi level mode. The difference (the new part) is in the red line on Figure 5. There can compare two configured structures displayed in separate Structure Manager windows. Also there is a report of the compare command [11].

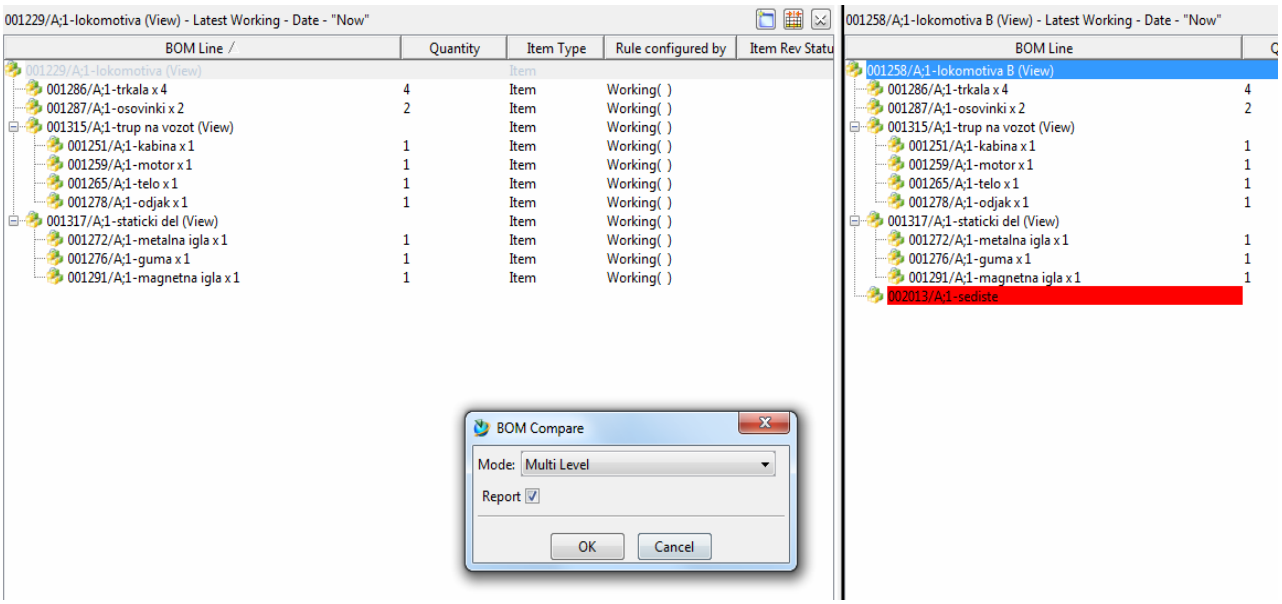

Figure 5. Comparing two product structures

6. CONCLUSION

PLM has evolved from an IT system for managing data to an IT system to help manage the processes which are based on those data. PLM establishes a coherent data structure that enables real-time collaboration and data sharing among geographically distributed teams.

Teamcenter as a Lean tool enables customers to increase the profitability and productivity of every stage in their product lifecycle. The companies which are using this software notice personal and team productivity, shorter time to market, increased product quality and minimized product and lifecycle costs. Also, they achieve continuous improvement or lean management in all stages of product lifecycle.

Modifying product structures with Teamcenter Structure Manager enables companies to save time and minimize the errors in all stages of product lifecycle. Also offers exchanging data without duplicate information and tasks. This is a solution that can be applied in companies from different industries or companies which offer services.

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Lean pristup upravljanju životnim ciklusom proizvoda

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Rezime

Kompanije u današnjem proizvodnom okruženju moraju da imaju poslovne procese koji mogu da se ponove, prilagode i odgovore na sugestije, zatim globalnu IKT (Informaciono komunikacijone tehnologije) informacionu infrastrukturu koja obezbeđuje jedinstven izvor tačnih podataka, kao i uređenje po departmanima. Kompanije moraju prvo da se usredsrede na potrebe svojih potrošača, konstantno smanjujući potrebno vreme, eliminišući gubitke, smanjujući troškove i unapređujući se. Sa holističkom strategijom i adekvatnom infrastrukturom, kompanije mogu da postignu profitabilan rast. Lean kao strategija u vezi je sa smanjenjem gubitaka gde god da se pojave u organizaciji. Korisno je eliminisati nepotreban napor ljudi ili mašina, redundantne podatke i aktivnosti bez vrednosti koliko god je to moguće. Ovaj rad opisuje kako lean koncept sa poslovnom strategijom upravljanja životnim ciklusom proizvoda može da obezbedi stratešku prednost za lean sa integrisanim usaglašavanjem i kontinualnim napretkom kako bi se povećao povraćaj R&D investicija i obezbedio održiv i profitabilan rast za poslovne procese, pre svega za proizvodne procese. Ovaj rad prikazuje jedno od najčešće korišćenih rešenja za upravljanje životnim ciklusom proizvoda (PLM) na tržištu, Simens PLM softver – Teamcenter, koji je zasnovan na poslednjoj IT tehnologiji. Teamcenter kao IT alat za lean upravljanje životnim ciklusom proizvoda (Lean PLM) nudi kompanijama veliki broj prednosti. Jedna od njih je upravljanje strukturama proizvoda, njihovo stvaranje i modifikacija kako bi se uštedelo vreme i resursi.

Ključne reči: *Upravljanje životnim ciklusom proizvoda (PLM), Lean PLM, struktura proizvoda*