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Lean Approach in Concurrent Engineering Applications

Şenay KARADEMİR [a,1] and Can CANGELİR [b,1]
[a] *Concurrent Engineering Section, Turkish Aerospace Industries, Inc., Turkey*
[b] *Concurrent Engineering Section, Turkish Aerospace Industries, Inc., Turkey*

Abstract. Early on, with the technological developments, machines have replaced the human workers which pave the way to mass production for decades. With the increase of variety of goods and number of producers, competition has grown to produce cheap, high number of goods with high quality. This has led the producers to think about ways to lessen the scraps and prevent problems. Thus, techniques and approaches like Total Quality Management, Lean Manufacturing, Six-Sigma have been developed and grown in importance.

Whereas in today's competitive world what is counted as success is no more the ability to produce but also to design. World trend is growing to find ways to design the most rapid, cost effective and quality product. In a similar way to the progress of production, new approaches, methodologies and principles are being generated and initiatives are established to fulfill this need in engineering area.

Challenges increase in diversity and difficulty in parallel with the complexity of the design. Until now, companies used product data management methods and tools in order to integrate and provide the running of the tasks. Further developments in information technology shall be used to put in more knowledge to these systems to lessen the routine design work while enabling the designer to touch the tacit-knowledge.

This paper will examine the lean thinking in engineering and try to harmonize the Lean Engineering Approach with Concurrent Engineering (CE) Philosophy. Principles to enable CE applications in Aerospace Industry will be developed and an analogy of Lean techniques will be outlined.

Keywords. Concurrent Engineering Principles, Knowledge Based Engineering, Lean Engineering, Concurrent Engineering in Aerospace Industry, Formal Methods in Concurrent Engineering, Concurrent Engineering in Practice

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[1] Engineer, Concurrent Engineering Section, Turkish Aerospace Industries, Inc., Fethiye Mahallesi, Havacılık Bulvarı No:17 06980 Kazan-ANKARA / TÜRKİYE
e-mail: skarademir@tai.com.tr
[2] Chief, Concurrent Engineering Section, Turkish Aerospace Industries, Inc., Fethiye Mahallesi, Havacılık Bulvarı No:17 06980 Kazan-ANKARA / TÜRKİYE
e-mail: ccangelir@tai.com.tr

Introduction

Former approach of the industry was intensively concentrated on improving the production and service of a quality product. In parallel with the purpose, Lean Manufacturing techniques have made a strong contribution to improving manufacturing efficiency. Among the new developing technology, new product introduction and development (NPID) is increased in criticality and importance for the firms in order to sustain a competitive advantage. As also stated by McManus and Haggerty [1], production and service of a quality product, usually seen as the delivered value are not valuable if the product itself does not please the customer. If lean improvements are confined to manufacturing, they will represent only islands of success in a sea of inefficiency. Thus, lean thinking concepts might be applied to all stages of new product design and development progressively, in order to enhance the performance and provide efficient products. This idea is also supported by Haque and Moore [2], stating that the success of lean in NPID depends on following the footsteps of manufacturing and identify metrics that are conducive to lean thinking.

Information plays the same role in the product development value stream that material plays in the manufacturing value stream. Product development activities transform Information. Information in many forms converges to define a design just as many parts come together to make a product.

Lean Manufacturing principles aim to increase the efficiency through inventory control and production process improvements whereas engineering does not have inventory and in most cases is not a "production" environment. In addition, NPID processes are mostly uncertain and confined by tacit knowledge.

1. Base of Lean Techniques in Engineering

Engineering is fundamentally different than the ways applied in factories. However it is still possible to link the lean thinking concepts with engineering processes. As a start point, Womack and Jones's 5 steps to lean which are, value, value stream, flow, pull and perfection might be considered. Following examples can be considered as the adjusted steps of lean engineering.

- Value: a producible, low cost design; a design that is expected to satisfy customer requirements with an acceptable level of risk; or a supplier infrastructure which supports production as well as the operations and sustainment [3].
- Value Stream: NPID processes act upon information and knowledge (which is mostly tacit) to produce product specification.
- Flow: Wastes like early/ late or overqualified/not yet mature delivery of information should be avoided. This could be provided by defining the satisfactory information and using an iterative method to provide only the satisfactory information to the following step.
- Pull: Defining the required documents/ maturity of information precisely to enable that information generation is only driven by the needs of the next step.
- Perfection: Efficient product development process.

Re-imagining these concepts, study of MacManus has revealed the conclusion as shown in the Table 1[4].

Table 1. Applying the lean steps to Engineering

	Manufacturing	**Engineering**
Value	Visible at each step, defined goal	Harder to see, emergent goals
Value Stream	Parts and material	Information and knowledge
Flow	Iterations are waste	Planned Iterations must be efficient
Pull	Driven by takt time	Driven by needs of enterprise
Perfection	Process repeatable without errors	Process enables enterprise improvement

2. Concurrent Engineering (CE) Approach

Concurrent Engineering is an engineering management philosophy and a set of operating principles that guide a product development process through an accelerated successful completion. Overall CE philosophy rests on a single, but powerful, principle that promotes the incorporation of downstream concerns into the upstream phases of a product development process [5]. This approach is intended to cause the developers from the outset to consider all elements of the product lifecycle from conception to disposal, including quality, cost, schedule, and user requirements [6]. The concept of Concurrent Engineering has been widely recognized as a major enabler of fast and efficient product development [7].

CE paves the way for real time collaborative work environments where multidisciplinary teams can work to generate solutions for design problems. In order to provide the required environment for CE, basic principles might be adopted which roots from the company requirements harmonized with the capabilities of computer-based tools. Each principle aims either reducing the time spent and costs or increasing the quality.

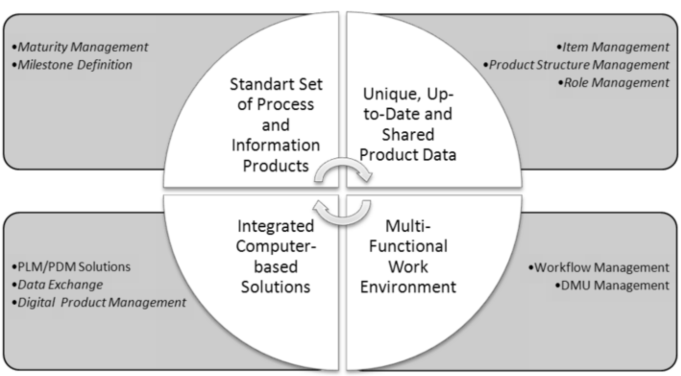

Figure 1. Principles adopted in TAI (Turkish Aerospace Industries, Inc.) in the concept of Concurrent Engineering.

2.1. Standard Set of Process and Information Product

An important criterion for CE is that an organization systematically identifies and defines its “Standard Information Products”. Without defining a standard set of products, it is impossible to systematize the process and gain productivity benefits from the application of CE [8]. In this context, maturation path of the information products shall be managed in order to describe the required sufficiency degree of the outcome of different processes. The maturation path will represent the iterations to the desired final product which shall also needs to be reviewed and assessed at defined checkpoints – milestones-. These cross checks among various other disciplines to either monitor/observe or confirm the sufficiency of the information for their own tasks and processes. Determination of the cross flow of information products is a must to manage all these maturities and milestones.

2.2. Unique, Up-to-Date and Shared Product Data

Standard information products will ensure the content but not the unicity. In order to keep track of the change and development of an information product, it has to be generated and published uniquely. Unnecessary duplications have to be avoided by any means in order to avoid waste. Information products have to be traceable and accessible during the processes. An additional must is that access to the information products shall be limited in order to prevent them from being used or updated improperly.

2.3. Multi-functional Work Environment

CE deals with multifunctional project groups where complex products are produced. It is beyond the imagination of a single person, a single team, or even a single department to comprehend fully all the aspects of the product needs [9]. Thus, a main requirement of CE approach is to provide the designers, analysts, managers etc. an environment where they can easily communicate, collaborate and compromise. By these multi-functional work environments, parallel evolution of the design will be enabled. An absolute must of these teams is that they can easily access to the up-to-date data and feed and respond to each other’s work instantly.

2.4. Integrated Computer-Based Solutions

The base of CE – multi-functional teams- in today’s world is mostly spread around. It is usually not possible to bring all disciplines which are required to build the whole product in one premise of any company. Developing IT technologies enable the teams to work together by not being physically together. End to end information flow among the teams can be provided digitally. All the processes can be fed from a common database seamlessly by the computer-based solutions. With the integration of computer-based solutions, CE aims to minimize the manual work, to share the data instantly with the teams and by exchanging the information products among tools. Computer-based solutions shall also be in line with the processes to provide results for monitoring the program and store and collect the company knowhow.

3. Application of Concurrent Engineering in Aerospace Industry– TAI example

Following section will examine how CE is perceived and the aforementioned principles are applied in TAI (Turkish Aerospace Industries, Inc.)

3.1. Standard Set of Process and Information Product

Standard Information Product is perceived as any type of document, CAD Model, 2D drawing, etc. which is mainly various forms of information. Standard Process is perceived as the lifecycle of these products during the development of the end-product. The stakeholders and the relations in between are defined in order to put the whole process in a logical maturation path. As a result of a stage by stage modular approach as explained by Karademir and Cangelir [10], two maturity levels are defined for both Structural Design and Systems Design.

Further study is carried to define the milestones of these maturity levels, where the crosscheck of the stakeholders are required. As a result of the study, 14 milestones are adopted in order to establish the sustainability, sufficiency and the correctness of the information products.

Similar study is also carried by Airbus as stated by Landeg and Ash [11], resulting on 3 maturity levels and 14 milestones Concurrent Engineering Model.

3.2. Unique, Up-to-Date and Shared Product Data

In order to provide the unity of the information products, all items are numbered in a logical manner by which the standardization is familiar to every stakeholder. All types of information products are defined digitally –called as item- in computer-based systems. Each and every item has its unique specifications depending on the type and content such as “Structural Item”, “Harness Item” or “Vendor Item”. All the items are kept in a “Product Structure” or linked to the corresponding documentation in the system. Role management is the essential part of this scenario where the items – Standard Information Products- are only available to the relevant roles. Availability rules are also various among roles, providing that different roles can add different value to the items.

3.3. Multi-functional Work Environment

By keeping whole information products in a common database, it is possible for various teams to access the data without the necessity to physically being together. Workflows in the computer based solutions are defined which enable the relevant role to access the data with corresponding user rights and at the required time without any delays. The use of workflows, provide the teams to work / analyze / assess the information product at the right time with the right detail. Information products are released and published with different status during the process in order to take a baseline by which other teams get started their own work.

Aim of a workflow can be either to involve parallel processes to the evolution decisions or to confirm the sufficiency of the information product to be used in their own processes.

3D CAD Model is the main information product of the design groups which in total forms the Digital Mock-up (DMU). All items of DMU are preserved in computer-based tools so that all the teams can access the up-to-date, unique data.

3.4. Integrated Computer-Based Solutions

Product Data Management tools are mainly used as the enablers of a Concurrent Engineering applications. A seamless flow of information via the computer-base tools is essential to lessen the time spent on communication and wastes on miscommunication. Computer-based solutions shall also be improved in accordance with the process and business requirements to minimize the manual and routine work.

Standard information products are defined digitally in computer-based solutions to that a common and easy-to-access, role based environment be provided to the teams. The nature of product data management brings out the need for various softwares. Variability of the software raises no problems as long as the systems can communicate seamlessly.

4. Concurrent Engineering Approach based upon Lean Engineering

As the Concurrent Engineering Approach aims to prevent problems, it coincides with the aim of Lean Engineering by means of eliminating the time and resource wastes caused by unnecessary knowledge generation and lack of communication, which are the root causes of complex design and poor compatibility with manufacturing processes. Studies indicate that 40% - 60% of the typical engineer's or designer's time is spent on nonvalue-added activities [12]. These may represent tasks such as operation system functions (integrating multiple platforms, multiple operating systems), business interfacing (data transfer, file management, backup), communication (fixing network, protocols) and others [12].

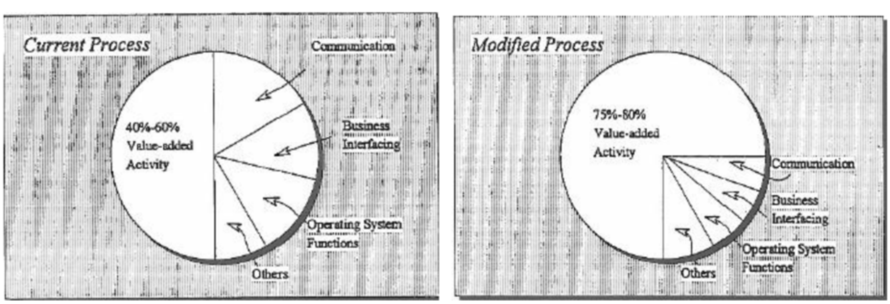

Figure 2: Typical Team's Time Distribution Chart (Current Process: As-Is, Modified Process: To-be)[12]

With the principles mentioned above, CE in application is significantly parallel with lean way of thinking. It is possible to use lean techniques to provide continuous improvement on communication, business interfacing and operating system functions. This section will try to make an analogy between the lean techniques and applications of CE in TAI.

During the process of maturity and milestone definition, all processes are to be visualized by value stream mapping. The bottlenecks of the processes to be identified and root causes are to be revealed. Critical to Quality analysis are to be performed to find out the actual "wants and needs" of the tasks. Once these are determined, a maturation path can be specified for the standard information products (Requirement Documents, Specification Documents, CAD Models etc.). In accordance with the pull requirements of the next or parallel tasks, using the JIT methods, sufficiency levels of the information products can be determined and milestones can be settled (checklists, assessment lists etc.) All these studies will result in a maturity model which will provide visual supplier-input-process-output-customer loop. Way of communicating among teams will be standardized and classified.

Item, Roles and Product Structure Management can be seen as a 5S application. Information products are sorted – 1st S- in accordance with their content and application area. With the aid of Product Structure, all the items are straightened and settled in order - 2nd S- in a way it is easy and logical to find the location of the information product. Via roles, only relevant information product is available to the users which in fact is in tune with 3rd S : Sweeping or Shine. Although the contents are different for items, information products are standardized – 4th S – such that they hold the same specifications and relations in the system. Lastly, 5th S is provided by managing all these in a common to all computer-based solution.

Workflow management can be perceived as a representation of the Value Stream Maps of the approval process for each information product. Rules of the workflows are results of Poka Yoke studies. Workflows also provide a balanced line for the information products to follow. Business Interfacing and communication is improved via workflows and DMU since there is a single media to perform all activities.

Integrated Computer-based Solutions are enablers of the whole environment. With the help of SIPOC and VSM, the gaps between the software can be identified and solutions shall be provided. For Engineering, software are analogous to the manufacturing task centers. In order to provide a seamless flow of information, Single point flow and Line Balancing techniques can be applied.

Table 2. Analogy between Concurrent Engineering Application and Lean Engineering

Principle of CE	Application of CE	Lean Techniques	Improvement Area
Standard Set of Process and Information Product	Maturity Management Milestone Definition	Value Stream Mapping Root Cause and Bottleneck CTQ Just in Time Kanban	Business Interfacing Communication
Unique, Up-to-Date and Shared Product Data	Item Management Product Structure Management Role Management	5S Poka Yoke	Communication Operating system functions
Multi-functional Work Environment	Workflow Management DMU Management	Poka Yoke VSM SIPOC Line Balancing	Business Interfacing Communication
Integrated Computer-Based Solutions	PLM/PDM Solutions Data Exchange Digital Product Management	VSM Standardization Line Balancing Best Practice Single Point Flow Kaizen	Communication Operating system functions

5. Conclusion

In this paper, base of lean techniques in engineering and application of Concurrent Engineering in aerospace industry is discussed. 4 basic principles are determined for the proper implementation of CE philosophy. Discussion carried on lean techniques and their scope of application. Lastly an analogy of lean techniques and CE principles which are determined in the paper is provided while showing the improvement areas.

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