

Lean Design for Integrated Product Realization

2010-01-0400

Published
04/12/2010Mohamed E. M. El-Sayed
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ABSTRACT

Implementing the lean principles and tools in manufacturing has been successful in many companies. This success has led to different implementations, of these principles, in other organizational activities such as design and management. While these implementations can produce some improvements, the segmentation of the product development processes in most company limits the potential for achieving the desired goals and in some cases the success of the implementation process itself. In other words, full success of lean principles implementation cannot be achieved when applied to isolated segments of the product development process. This paper addresses lean design, in the context of a fully integrated product realization process. The paper discusses the integrated nature of any product realization process and its flow from concept to production. It also addresses the effect of this integrated nature of the process on the implementation of the different lean principles such as value, value streaming, flow, pull, and perfection.

INTRODUCTION

Henry Ford has moved the auto industry from craft production to mass production by introducing standardized parts and assembly lines. By implementing the lean thinking approach in its production system TOYOTA Motor Company has moved the auto industry from mass production to lean production. The Machine That Changed the World book [16], states that: "The lean producer combines the advantages of craft and mass production, while avoiding the high cost of the former and the rigidity of the later". Through its focus on value creating processes lean thinking has provided a system-based approach, to enterprise continuous improvement [17]. Due to its flexibility and proven success in production systems lean thinking has been expanded to other industries

such as software development, health care, construction industries, and financial services [1, 4, 6, 9].

Several efforts have been directed towards utilizing lean thinking in the area of design. While successful applications are sometimes reported, due to the drive for being lean, the full understanding and applications of lean design have not been totally realized. In most cases the lean thinking approach has been stretched to cover the design activities. Most of these efforts are focused on directing the design activities to enable lean manufacturing, cost reduction, or managing the traditional design process [10, 12].

In the following, the implementation of lean thinking to reshape the design process itself, as phases of an integrated product realization cycle, will be discussed. First, the traditional product development process and the concept of integrated product realization will be studied then the lean principles will be discussed. Finally, the implementation of lean thinking will be applied to reshape the design process. While the focus will be on the application of the lean principles, some of the lean tools will be identified as enablers to achieve the lean design process.

TRADITIONAL PRODUCT DEVELOPMENT

Product Development Processes differ from one company to another based on the product and the corporate culture. Some of the goals of these processes, however, can be similar among companies in the same industry. The traditional reasons for developing and implementing a Product Development Processes model are: to facilitate coordination, planning and project management; to locate where improvements are needed; to establish a comprehensive view on an operations level; to support knowledge transfer; to

oblige customer demands; and to show how the business is performed [3].

A traditional Product Development Model, often consist of an illustration of the process together with detailed descriptions of the activities included in each phase [2]. Figure 1, illustrates a model developed by Wu [18]. In this model, each phase depends on the successful completion of the previous phase. For example, the “analysis of situation”, and “setting objectives” phases deal with the manufacturing strategy. The “conceptual modeling” and “detail design” in Wu's model are the main phases to accomplish a complete design. The model in general treats the design process as a sequential set of problem solving and decision making.

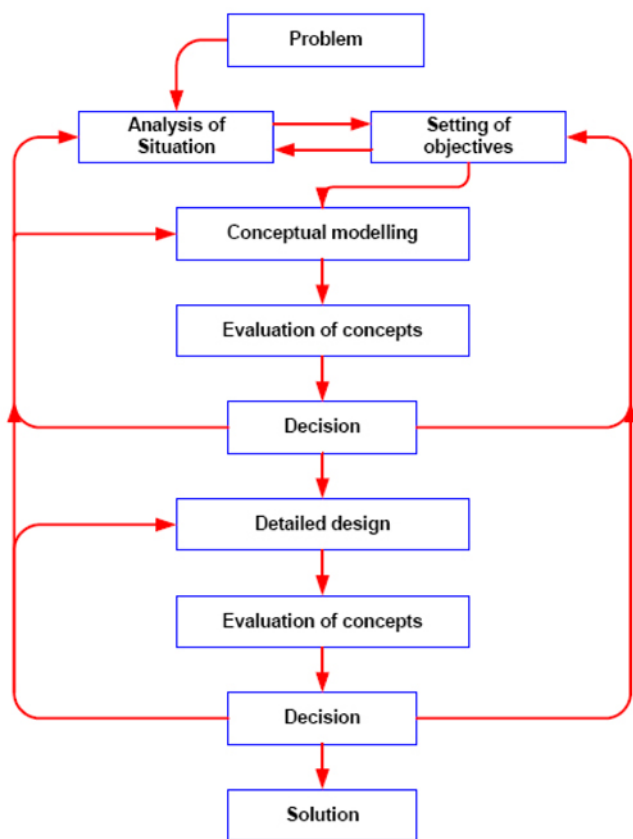


Fig. 1. Wu's Product Development Process

Figure 2, illustrates a six phases model developed by Ulrich and Eppinger [15]. In this model planning is the phase where the project gets approved and the product development process starts. The output of this phase specifies the target market, business goals, key assumptions, and constraints. In the second phase, concept development, the target market needs and customer requirements are identified. One or more concepts are selected from several alternatives for further development and testing. During the system-level design phase the focus is directed towards the products definition and architecture. The product's individual components and its

final assembly process are defined. In the detail design phase, the complete specification of the geometry, materials, and tolerances of all the components as well as the identification of all the supplied parts are completed. The establishment of a production system process plan is made and tools are designed for each part to be produced. During the testing and refinement phase multiple preproduction types of the product are constructed and evaluated. The prototypes can be divided into alpha or beta prototypes. Alpha prototypes are not necessarily fabricated by means of the actual processes to be used in production. Beta prototypes are usually built with parts supplied by the intended production process. Testing makes it possible to refine the product before the start of production. The last phase production ramp up consists of training the work force and resolving all remaining problems in the production process. While complete, this model tends to segments the design process and separates design from production.



Fig. 2. Ulrich and Eppinger's Development Process

INTEGRATED PRODUCT REALIZATION

Traditionally, the term product realization is usually used to describe the outcome of production or manufacturing processes. Considering that product realization means bringing a product to reality, which is the core of an integrated product development process including design and production activities, the concept of realization needs to be examined. In the following an expanded definition of the term realization will be discussed.

When interacting with the physical world humans have used their own perception of it as their own reality. Each individual has his or her own perception of this reality. In order to understand physical reality and collectively share their perceptions of it, humans have introduced a third domain known as the virtual world. It is a domain where perceptions, hypotheses, observations, imaginations etc are shared. It takes the form of simple arithmetic, complicated mathematics, drawings, internet, digital and computational world etc. Therefore, realization is the human interaction with a reality to figure it out, utilize it to achieve desired results, and/or alter it by deleting or bringing new objects to it. It is also clear that realities include other dimensions or domains that go beyond what is physical. Among these realities we consider three forms or domains:

- **Perceptual reality:** represented by individual paradigms or the internal images of other realities.

- **Virtual reality**: represented by modeling and simulation of physical and perceptual realities.
- **Physical reality**: represented by the physical universe that can be realized with the senses.

Examining all three realities it could be identified that: the perceptual is the domain where the individual realizations are being formulated (developed and validated), the virtual domain is the domain where collectively shared realizations are being formulated, and the physical domain is the domain where physical realizations are being actualized.

Based on the discussed realization concept, it could be stated that a typical product realization process from a concept to a physically produced object spans all three realization domains. The realization process starts from ideas at the perceptual domain to conceptualization and development in the virtual domain to validation and production in the physical domain. In fact, it becomes clear that a set of design drawings is the virtual realization and manufacturing is the physical realization of a specific product. In addition, a simulated manufacturing process model, for product development, is an element in the mapping from the virtual to the physical domain [7].

LEAN PRINCIPLES

There are five basic principles of lean thinking. Understanding of these five principles is fundamental to any lean implementation. These principles are interconnected and centered on the main principle of Value as shown in [figure 2](#).

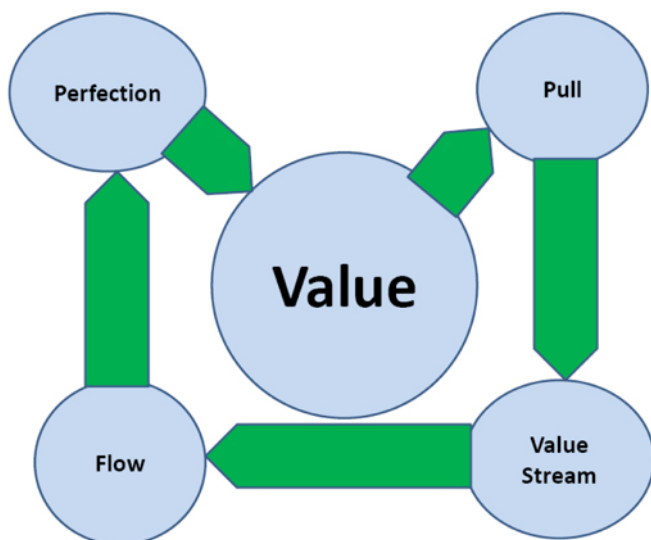


Figure 3. Lean Principles

VALUE - The first principle in lean thinking is to understand value from the customer's perspective. The basic concept of lean manufacturing is first to understand what adds value to the product. Second, what activities and resources are

necessary to create the desired value during the development process? Any feature in the product or steps/ resources in the process that does not add value are considered waste. Taiichi Ohno, the architect of the Toyota Production System (TPS), has identified the following seven wastes of manufacturing [5]:

- Overproduction
- Inventory
- Extra Processing Steps
- Motion
- Defects
- Waiting
- Transportation

PULL - Nothing should be done unless needed or demanded by a downstream process.

VALUE STREAM - Steps and activities needed for creating value through the process.

FLOW - By adding nothing but value, the process should flow as rapidly as possible.

PERFECTION - Continuously strive for perfection to satisfy the customer.

LEAN DESIGN REALIZATION

PRODUCT LIFECYCLE - The different phases of a product life cycle can be identified as:

- Inception
- Conception
- Development
- Production
- Utilization
- Termination

In the realization context, design is the creative and intellectual interaction that starts at the perceptual reality aiming at altering (enhancing) human physical or virtual realities by introducing desired objects. Design activities span the early three phases of the life cycle namely inception, conception, and development.

To achieve lean design the five principles of lean thinking, discussed earlier, should be the foundation of every phase and the entire process: