Chapter 3
Lean Thinking

Applying lean to the PDP takes IPD a step further to create Lean Product Design and Development (LDP). While LPD keeps the integrative aspect of IPD, the LPD is rooted in the lean philosophy, which advocates full commitment to delivering the pulled value (do the right), and yet continuously works on eliminating the waste from the PD process (do right). This idea of "doing more with less", which was the after war reality in Japan, is nowadays commonsense everywhere. Environmental and scarce resources concerns pull the modern companies to a more "lean philosophy aligned" behavior. Considering that the LPD is this book's main subject, which will be discussed from now on, this chapter focuses on presenting a brief review of the lean philosophy and its impact on the manufacturing and on the product development systems.

3.1 Introduction

In the 1950s, Eiji Toyoda, Shigeo Shingo and Taiichi Ohno at Toyota Motor Company in Japan, developed the Toyota Production System (TPS). The TPS, which most people now associate with the term *Lean*, or more with the *Just-in-Time* (JIT) principle, was born when the Japanese car industry was stuck in a severe crisis. At that time, it became clear that the only way to escape from the possible impending doom of this industry were drastic changes in efficiency and productivity. This change happened through lean thinking (or philosophy) that means thoroughly working on waste reduction while guaranteeing the value creation. The lean philosophy was presented to the rest of the world by the results of the MIT International Motor Vehicle Program (IMVP) whose goal was to compare the performance differences between car companies operating with traditional mass manufacturing systems and those using the TPS [1]. Besides seeking an optimum flow (waste reduction), lean philosophy focuses on value identification and value delivery to the customer.

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The lean thinking or philosophy main's goal is to getting closer and closer to provide what the customers exactly want: the value pulled by them. In order to do so a simple and yet difficult set of principles shall be followed [2]

1. **Specify value**: The value, as defined by the final client, is the basis of lean thinking and guide all processes in the company. Without identifying the value one cannot discern value added activities from wasteful activities.
2. **Identify the value stream**: The value stream is a theoretical and ideal sequence of exclusively value-added tasks, where a value-added activity transforms the deliverables of the project in such a way that the customer recognizes the transformation and is willing to pay for it. By lining up the value delivery activities the wasteful activities are reduced if not eliminated, therefore more time, money, human resources, etc. can be redirected to what really matters.
3. **Guarantee the flow:** All the value-added activities should be conducted without interruption.
4. **Pull the value**: No activity in the value stream should be produced without being requested by the next activity in the flow.
5. **Seek perfection**: The relentless continuous improvement is the motor that sustains and evolves the lean philosophy.

While the first two principles guarantee the value delivery, the remaining three work on waste reduction. Indeed, seeking perfection, which is the reason for continuous improvement, means relentless continuous waste reduction.

As a target condition, any Lean System should deliver maximum value, while reducing waste. The term "waste reduction," though, is not limited to waste itself, but also includes unevenness and overburden (Fig. 3.1) where:

- **Value**: Value to a stakeholder is the total and balanced perception from all the benefits provided by the results of the life cycle processes. "Total perception" is considered to be not only results directly related to the product, but also expectancies related to cost, on time delivery, risk level, etc. [3].
- **Waste** (Muda, 無駄 or ムダ): Waste refers to all elements of a process that only increase cost without adding value or any human activity that absorbs resources but creates no value; any activities that lengthen lead times and add extra cost to the product for which the customer is unwilling to pay. [2, 4].

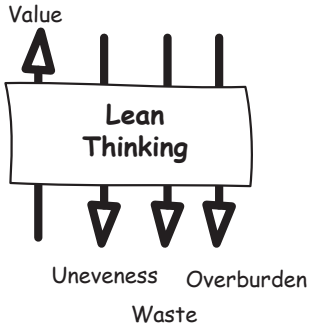


Fig. 3.1 Lean system target condition

- **Overburden** (Muri, 無理): Overburden is viewed as pushing a machine, process, or person beyond natural limits [4].
- **Unevenness** (Mura, 斑 or ムラ): The results from an irregular production schedule or fluctuating product volumes caused by internal problems create unevenness [4].

Waste can manifest as excess inventory, excessive production, extraneous processing steps waiting, unnecessary movement, and defective products, etc. All these "waste" drivers intertwine with each other to create more waste [5, 6], eventually impacting beyond the specific area where their root causes appear and escalating even to the management of the corporation itself.

The lean thinking success, though, is not limited to manufacturing. It can be applied to other processes with high cost reduction and quality improvement potential, which is the case of product development. In fact, the success of Toyota relies on the application of lean philosophy on the product development rather than on the manufacturing.

By teaching Lean Product Design and Development through the years we could see how the students and practitioners made connections about applying the lean philosophy into the most diverse areas, including the daily life.

The transitioning to lean is a mindset change; it's a cultural change in the organizations and an attitude change in each individual. Therefore the lean thinking person takes the philosophy to all aspects in his/her life.

3.2 Lean Manufacturing

The Toyota Production System (TPS), sometimes called *lean manufacturing system* or a *Just-in-Time* (JIT) system, is a way of "making things" by applying the lean philosophy into a company, and which has evolved into a world-renowned production system.

The TPS imbues all aspects of production in pursuit of the most efficient methods. The TPS has evolved through many years of trial and error to improve efficiency based on the Just-in-Time concept, where the ideal conditions for making things are created when machines, facilities, and people work together as needed to add value without generating waste [7].

Figure 3.2 shows the TPS house [8]. The house metaphor depicts all the TPS elements. Therefore, in order to sustain the roof, its two pillars (the TPS objectives, jidoka and just-in-time) have to be sustained by a solid base of standards and principles. The motivated team populates this house, and is the key element to set the TPS in motion [9].

These principles have been adopted by diverse sectors of industry such as aerospace, consumer products, metal processing and industrial products.

The TPS house shows that the lean system is a complex socio-technical system and not only a set of lean labeled tools and techniques. Therefore, having a

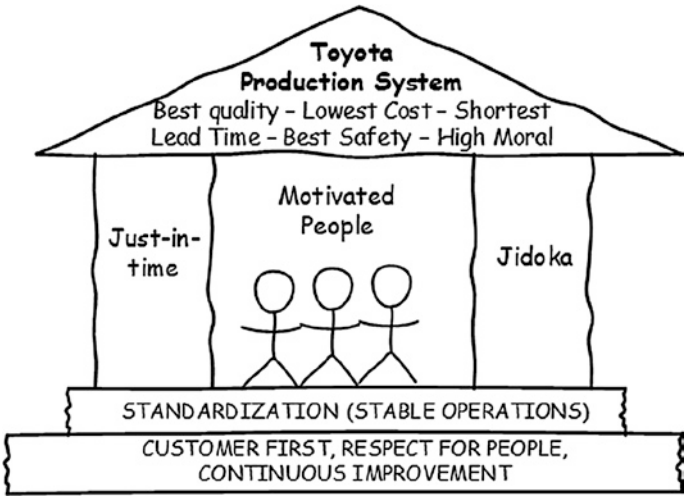


Fig. 3.2 The Toyota production system house

true lean manufacturing system requires changes and adaptations in several dimensions: attitude, standards, tools, techniques, people, etc.

Next we discuss the TPS's two main pillars: just-in-time and *jidoka*. In our experience, the concepts behind these two pillars remains the same whatever is the process or area you are going to apply the lean philosophy.

3.2.1 Just-in-Time[1]

Just-in-Time means making only what is needed, when it is needed, and in the amount needed; this can eliminate waste, inconsistencies, and unreasonable requirements, resulting in improved productivity and continuous flow.

In order to deliver a product (a vehicle, in the case of Toyota) ordered by a customer as quickly as possible, the product is efficiently built within the shortest possible period of time by adhering to the following:

- When a product order is received, a production instruction must be issued to the beginning of the vehicle production line as soon as possible.
- The assembly line must be stocked with the required number of all needed parts so that any type of ordered product can be assembled.
- The assembly line must replace the parts used by retrieving the same number of parts from the parts-producing process (the preceding process).

[1] Adapted from [9].

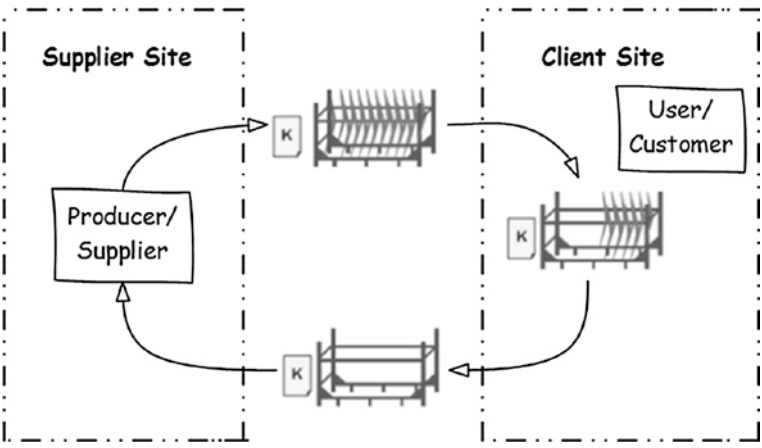


Fig. 3.3 Conceptual diagram of the Kanban system

- The preceding process must be stocked with small numbers of all types of parts and produce only the numbers of parts that were retrieved by an operator from the next process.

Whatever the steps are of your production process, the logic remains the same—the next process pulls what it needs from the previous one. In the TPS, a *kanban system* is used to control the flow. The *kanban* system has also been called the *Supermarket method* since it is inspired by the product control cards used in these stores. These cards normally contain product-related information, such as a product's name, code, and storage location. At Toyota, when a process refers to a preceding process to retrieve parts, it uses a *kanban* to communicate which parts have been used.

By having the next process (the customer) go to the preceding process (the supermarket) to retrieve the necessary parts when they are needed and in the amount needed, it was possible to improve upon the existing inefficient production system. No longer were the preceding processes making excess parts and delivering them to the next process (Fig. 3.3).

The just-in-time pillar acts on guaranteeing an effective and flexible process and reducing process waste, work in process, and inventory. In this kind of process waste is easier to see, and improvements are easier to implement.

3.2.2 Jidoka[2]

For the Just-in-Time system to function, all of the parts that are made and supplied must meet predetermined quality standards. This is achieved through *jidoka*. The objective of jidoka is doing it right the first time (i.e.,"first time right").

[2]Adapted from [9].

Jidoka can be loosely translated as "automation with a human touch," meaning that when a problem occurs, the equipment should be stopped immediately, preventing defective products from being produced:

- A machine safely stops when the normal processing is completed.
- Should a quality/equipment problem arise, the machine detects the problem on its own and stops, preventing defective products from being produced.
- This is opposed to a machine that simply moves under the monitoring and supervision of an operator.

As a result:

- Only products satisfying quality standards are passed on to the following processes on the production line.
- Operators can confidently continue performing work at another machine, and work on identifying the problem's cause to prevent its recurrence.

Jidoka supports the defect-free production line vision. As a consequence defects are not tolerated, and whenever a defect is spotted the process should guarantee that no defective parts are produced until the problem's cause is identified and solved.

3.3 Lean Product Development

In PDP, lean thinking goes beyond systematic waste reduction and the application of lean manufacturing techniques to product development. To allow Lean Product Development, besides lean itself, the project plan must allow value creation while providing for waste reduction.

In PD, adding customer value can be less a function of doing the right activities (or of not doing the wrong ones) than of getting the right information in the right place at the right time. Hence, the focus of lean must not be restricted to activity "liposuction" (waste reduction), but must address the PD process as a system (value creation). To guarantee the value creation and to create the needed countermeasures against waste, we adapted the five lean principles initially proposed by Womack and Jones [2] to the PD context:

1. **Specify value**: In a program or project, the value is the *raison d'être* of the project team, which means they must understand all the required product/service characteristics regarding the value that all stakeholders of the program expect to receive during the product life cycle.
2. **Identify the value stream**: Consequently, the Product Development Process must be simple, highlighting key dates and responsibilities and defining optimized information flows (what, when, sender, receiver, and media) in order to prevent excessive data traffic and promote efficient communication.

3. **Guarantee the flow**: The ideal PD process should work congruently with the single-piece flow in manufacturing, representing a value flow from conception to production, without stops due to bureaucracy and loop backs to correct errors. Every development value flow obstacle (functional departments, executive gate meetings, firefighting, changing requirements, management interference, etc.) must be eliminated.
4. **Pull the value**: Instead of pushing scheduled activities, which themselves push information and materials through the development process, pull events must be defined. Different from tall gates, where information batches are created, pull events guarantee the value flow, make quality problems visible, and create knowledge.
5. **Seek perfection**: The continuous improvement of the development process is achieved by the capability of the process and effective knowledge management. This knowledge is systematically documented and disseminated through trade curves which everyone can access and is expected to use, including management. The relentless continuous improvement is the motor that sustains and evolves the lean philosophy.

Lean Development, although at first glance looks a lot like the Integrated Product Development since it includes the same practices, proposes a more organic view of the process. In this way, the value flow is sustained by two pillars (Fig. 3.4), based on waste reduction (efficiency: do the job right) and the creation of value (efficacy: do the right job).

This vision must be achieved through maximum simplification of the process (removing the activities that do not add value), and enforcing the activities of prototyping and testing; the idea is to maximize experimentation and learning. The development project manager must assume roles beyond coordinating and motivating, he/she is expected to coach the engineers and technicians under his/her supervision, in a constant quest for innovation. At this point, he/she is concerned with the enhancement of organizational learning and knowledge management.

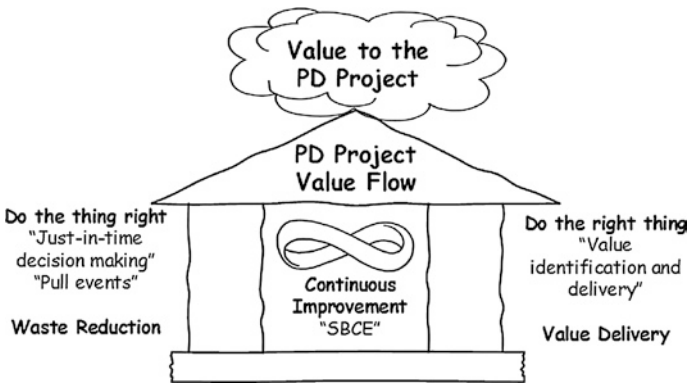


Fig. 3.4 Value creation pillars to product development

In the integrated development approaches, this aspect from working in teams was not valued.

Indeed, the application of Lean Philosophy has three core elements to the PDS:

1. **Do the right thing** = deliver the Value = create the correct products: Create product families and projects that create value for all stakeholders of the enterprise architectures. The understanding of value in the PDP context is paramount (see Chap. 4), and correct value identification is the most critical success factor in any PD project (see Chap. 10), once no one is going to buy and/or use the wrong product.
2. **Do the thing right** = use effective engineering processes: Eliminate waste (for a complete description of the PD wastes see Chap. 5) and improve cycle time and quality engineering while achieving effective integration between the development process and the company using lean engineering to create value on the interfaces between the development process and the various parts of the company. Just-in-time decision making (JIT-DM) supports waste reduction by guaranteeing that decision is only taken (and is taken quickly) when the necessary information is available. To operationalize JIT-DM we recommend planning you development by defining pull events, which pull the necessary information from the development team at the right moment during the PD project (see Chap. 12).
3. **Never rest on previous successes** = continuous improvement: Be a learning organization and keep improving every day. One can improve both the executing process and its deliverables (Chap. 6). The PDP goal is to gradually reduce the risk and uncertainty while develop a new product (Chap. 1). As a consequence, the PDP itself functions a continuous improvement process. The Set-Based Concurrent Engineering (SBCE) , which is further detailed in Chaps. 9 and 11, plays a key role to guarantee the continuous development results evolution towards delivering the identified pulled value.

We can see (Fig. 3.5) the elements of Lean Thinking applied in the Lean Wheel System (value, waste, continuous improvement); they make the wheel hub which sustains the remaining parts of the system to be further described in Part II of this book.

3.4 Key Aspects from the Lean Product Development System

The wheel and tire elements from the "Lean Wheel System" (Fig. 3.5) encompass the key aspects of the Lean Product Development System:

1. **Culture**: Culture guarantees the creation and maintenance of the organizational environment; it gives the necessary "code of conduct" to the people performing the Lean PDP.

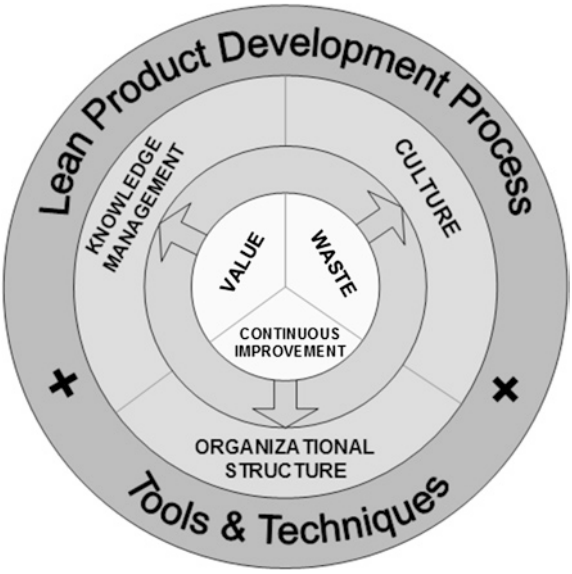
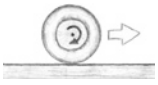


Fig. 3.5 Lean wheel system elements

2. **Knowledge management**: In order to keep moving forward, the company has to be a learning organization; failing to learn may result in repeating the same mistakes and reinventing.
3. **Organizational structure**: Hierarchical structure defines the company and the peoples' roles necessary to perform the Lean PDP.
4. **Tools and Technology Subsystem**: This encompasses all the tools and Technologies used by the development organization, CAD systems (*Computer Aided Design*), digital manufacturing, test technologies, etc.
5. **Lean Development Process**: The process includes all activities required to bring the product from concept to production, passing through the entire value stream. It focuses on both identifying the value and guaranteeing the flow and the emergence of the final product.

These elements are going to be further described in Parts III and IV of this book. The list on Table 3.1 summarizes the philosophy's impact through the Lean Product Development Organization.



3.5 A Practical View

Many people get lost while trying to apply the Lean Philosophy. This fact is not limited to Lean Product Development, but occurs in any process improvement effort. They get lost because they work hard on understanding how Toyota works and they start to believe that being lean is replicating Toyota (Fig. 3.6).

Table 3.1 Key elements of the LPDS [2, 10]

Element	Description
Culture	• Support excellence and relentless improvement • Adapt technology to fit your people and process • Align your organization through simple, visual communication
Knowledge management	• Standardized "performance tradeoff" data are collected for each alternative • Use powerful tools for standardization and organizational learning • Engineers are required to be knowledgeable about all solutions • Detailed engineering checklists and design standards are used to assure focus on product performance • Fully integrate suppliers into the product development system • Build in learning and continuous improvement
Organizational structure	• Managers are the most technically competent in engineering: "your boss can always do your job better than you" • The manager's primary role is to teach by assigning questions (mentoring) • Authority and rewarding in the system derives from technical knowledge and competence • Develop a value-centered system to integrate development from start to finish • Organize to balance functional expertise and cross-functional integration
Process	• No elaborate sub-schedules; chief engineer sets "key integration events" • Work is pulled to these events • Milestones are never missed • Multiple alternatives are developed for each subsystem • Combinations that meet performance tradeoffs "survive" • Establish customer-defined value to separate value-added from waste • Create leveled product development process flow • Utilize rigorous standardization to reduce variation, and create flexibility and predictable outcomes
Tools and technology	• The lean tools and technology are those you use in the lean way, not the "lean labeled tools" • The tools and techniques do not make you lean, the way you use the tools is what makes them lean

Wrong! In order to adopt the Lean Philosophy one has to understand its roots and adapt. By studying Toyota you can learn how they created/adapted tools, techniques, and process into their own reality, in order to apply the philosophy. Whenever you see a successful approach performed by any company, you must ask what are they achieving and why did they work that way.

The lean philosophy has its roots in the post-war Japan. At that time the western way of designing, developing, and producing cars were the best practices to be copied. Toyota managers understood how their company, culture, and country differed from the western benchmark; they studied and positively exploited these differences. There is no reason to not believe that you and your company might do the same and become the next benchmark.

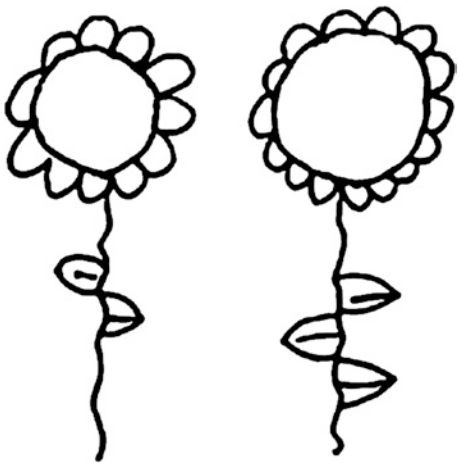


Fig. 3.6 No two flowers are the same

A good way to do so is applying the lean product design and development method presented in this book, having your product design development process (or any process you want to improve) as the "product" to be designed and developed.

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