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Person-Based Design: A Human-Centered Approach for Lean Factory Design

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Abstract

In a highly competitive and changing industrial environment, an organizational system that remains permanently aligned with the market is becoming a competitiveness factor. Consequently, industrial organizations face the challenge of building effective production systems that integrate the development of people, thus improving their capacities and skills for solving complex problems while respecting their needs and aspirations as individuals. This challenge is particularly relevant when intensive handwork is needed and, consequently, high pressure on labor (and space) productivity constitutes the main cost drivers. This paper proposes a method to design lean factories, thus fostering high productivity rates and respect-for-human.
A holistic model for a system is developed as an integrated set of Principles, Tools and Methods in constant interaction with people. A specific human-centered method (Person-Based Design) is proposed to guide an effective lean factory design in a real industrial setting. The Person-Based Design method defines seven layers of sequential design starting by the central layer “respect for people” and progressing outward into broader layers which include packaging, tools, value flow, layout and supply flows. The presented method is then implemented in a real industrial context and compared with an existing design.
The outcomes of this research provide a coherent mindset for managers facing an organizational change, and our structured method allows for the design of effective lean factories, which are particularly useful when space and/or labor productivity constitute the main factors of a firm’s competitiveness.

Keywords: Lean Production Systems; Respect-for-people; Lean Manufacturing; Lean priciples, tools and methods

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1. Introduction and literature review.

In the last decade, global markets have been becoming more and more competitive as they change at increasingly faster rates. As a consequence, industrial organizations are suffering from growing pressure due to shortening product-life-cycles, quality improvement, cost reduction, and the need to cut delivery times. This pressure is transmitted to their factories in the form of aggressive targets for raising productivity, improving quality excellence and shortening lead time.

Nowadays, having a production system adapted to this market dynamism, forms a key competitive factor for modern factories. Lean Production Systems (LPS) are particularly suitable in these contexts.

Lean Production is a generic name for the Toyota Production System (TPS), published for the first time in 1990 by Womack et al. [1]. TPS began development in a very practical way at Toyota from 1950 on, and it was fully documented by Taiichi Ohno (considered the father of TPS) [2] in a first English translation in 1978.

According to Holweg [3], the first English-language academic paper on TPS was published in 1977 [4]. This early article already introduces two central ideas for successfully implementing TPS:

- Systemic view. The production way developed by Toyota is considered a whole “system”.
- *Respect-for-human* is considered one of TPS’s *two major distinctive features* (together with Just-In-Time).

The literature shows that considering Lean to be a fragmented set of tools, rather than a whole system, forms one of the key factors for failure when implementing LPS [5,6]. Additionally, there is a general agreement about the importance of what some authors refer to as people involvement when facing necessary cultural changes [7]. The respect-for-human system has long been unrecognized, ignored or misunderstood by most senior managers outside Toyota, even though Ohno [2] and Monden [8] referred to it directly in their writings. Respect-for-human is a key antecedent of people involvement and active participation in process improvement [4].

Unfortunately, pressures on labor and space productivity usually involve a stressful and uncomfortable workplace. Additionally, cost reduction is too often interpreted purely as “job cutting”. These factors create a paradox: Individuals perceive “active participation” as a firm’s demand to deteriorate their workplace or, even worst, the previous step of losing their jobs, which goes against the respect-for-human system.

There is no simple answer to solve this paradox, which generates a high risk of failure when implementing LPS; however, industrial organizations should face the challenge to build effective production systems while developing people as well as respecting their needs and aspirations as individuals.

Interest is growing among firms who are seeking a holistic approach for designing Lean tools (see Carsten and al. [9]) and for Lean Production Systems (see de Kogel et al. [10]), yet a literature review finds neither a specific approach nor a specific method to mitigate this risk.

The aim of this study is to contribute to LPS understanding for manufacturing systems design. To do so, this paper develops a model of factory design from a human-centered approach and consistent with LPS principles. Figure 1 shows a visual summary of the paper’s structure.

2. Lean Production as a socio-technical System.

Senge et al. [11] define a system as “a perceived whole whose elements hang together because they continually affect each other over time and operate toward a common purpose”.

This paper proposes a specific model to describe a generic socio-technical system [12] as a set of elements (People, Principles, Tool and Methods) constantly interacting in order to achieve a certain objective (Fig 1a). This conceptualization is specified for Lean Production Systems below as a socio-technical system.

2.1. Set of a system elements.

- People: Individuals who perform their functions in permanent interaction with the Principles, Tools and Methods.
- Principles: Set of concepts which are considered valid and reliable: axioms, beliefs, dogmas, laws, etc. They shape the mindset of individuals. Principles shape “***how to think”***.

- Tools: Elements to bring Principles into action. They are used by individuals and the community: a court, a ritual, a notation, a computer, etc. Tools establish "***how to do***".
- Methods: An orderly sequence in which tools are used to achieve a certain purpose. They establish the "***the order for doing***" or better: "***the right order for doing***".

2.2. Interactions between people, principles, methods and tools.

These four elements perpetually interact. The model postulates that the stability of the system is possible only if these interrelations are coherent. For this coherency, the following rules are proposed.

- Principles must be embedded in Tools and Methods. Tools and Methods must be complementary.
- People must feel integrated in the system and rewarded by it.

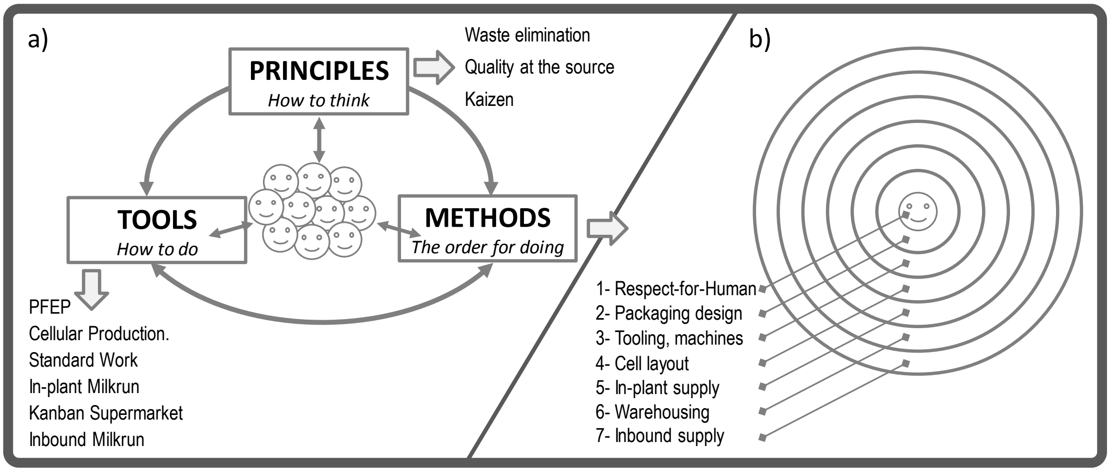


Fig. 1. Visual summary of the paper: (a) Lean as a system. (b) Person-Based Design method.

2.3. Lean Production System from a systemic perspective.

A Lean Production System could be defined as a social-technical system bounded to a human community (the factory) with the common objective of producing goods efficiently. A Lean Production System can be modeled as follows:

Lean Production Principles.

Different sets of principles have been proposed by different authors [13,14]. They can be reformulated in the following three principles:

- Reduce Waste (Muda). A customer obtains a product because he has needs. A product covers a customer´s need by doing what the customer expects and wants (functioning). In consequence, Added Value is defined as every process in the Value Chain which strictly adds functionality to the product. All the rest comprises waste to be eliminated or minimized.
- Quality at the Source. Every step in the process must supply just one quality part to the next step (which is considered its customer). The customer defines quality according to his needs.
- Continuous Improvement (Kaizen). Every person participates each time in waste elimination, with the collective objective of improving each process every day in search of operational excellence.

Lean Production Tools

Lean tools have been widely described in the literature (see, for example, [15]). The most relevant tools for the purposes of this paper are: Value Stream Mapping [16], 5S [17], Standard Work, U-Shaped Lines [18], Plan-For-Every-Part [19], In-plant Milkrun [20], Kanban Supermarket.

Lean Production Methods

An efficient Method should have Principles embedded, use Tools in the right order and ensure the *respect-for-people* through empowering people and active participation. Developing a detailed and repeatable Method that fits in any situation is difficult because of the wide range of variables involved: market, product, building, people skills, organizational culture, etc. Nevertheless, this paper proposes *Person-Based Design* (PBD) as a general Method for designing Lean Factories, particularly for manual or semi-automated processes. PBD has been induced from empirical Lean practice and it is implemented and discussed for a case study below.

3. Person-Based Design. An efficient Method for designing Lean Factories.

Person-Based Design is a human-centered method (Fig. 1b) that proposes a sequential process that begins with the person and progresses outward into broader design layers, following just one prioritization rule:

"The optimization of one layer must never have a negative impact on the efficiency of any of the inner layers."

Therefore, the design sequence can be described as follows.

3.1. Layer 1. Respect for people.

In manual or semi-automatic production processes, efficiency is based on people's skills and motivation. In this sense, the *respect-for-human* principle [4] requires the creation of a comfortable work space in the following ways:

- Minimizing motion waste.
- Optimizing ergonomics to focus human effort on adding value.

Involving workers in the design of the workspace is a key tool in this layer.

3.2. Layer 2. Packaging design.

Most of the workplace waste concerns the motions of picking up items and efforts to handle materials. To minimize this waste, parts must be placed close to the point of assembly and laid out in the right position to avoid risky motions and minimize variability. Additionally, the parts must be supplied with consideration toward the ergonomics of the materials-handling people.

This entails making containers as small and light as possible, easy-to-handle, and with parts arranged inside easy-to-pick.

Plan for Every Part [19] is the tool used to design the packaging.

3.3. Layer 3. Designing tools and machines.

The design of tools and machines must integrate the supply of parts in order to minimize, not only picking-up motions, but also operational motions and mental stress. Automation should support this objective by mitigating painful tasks in a better way than simply removing people from the process (see an example in [21]).

Standardized work and standardized workplace design are the tools for this layer.

3.4. Layer 4. Production line design.

Lean Production Systems seek continuous flow through “one-piece-flow” processes [18]. Workplaces must be arranged close to each other and laid out in accordance with the assembly process. This is the basis for the Cellular Manufacturing tool [22,18]. U-shaped production lines are widely preferred because they allow *shojinka* (adaptability) [8], but I-shaped lines can be used too (see [23] for a comparison between “I” and “U”). In any case, layout configuration must create a “working” area that is independent of the “supplying” area.

3.5. Layer 5. In-plant supply design.

Parts are delivered to the workplace in small amounts and in small containers, thus increasing the need for transportation and handling. In-plant supply design must minimize motion and ergonomic risks for people handling materials.

An in-plant Milkrun is the tool for this layer [20]. It consists of designing frequent, standardized and fixed-period loops to supply parts using multi-reference cart or train. The Milkrun stops are standardized, and containers must be arranged on the cart in a mirror configuration of the delivery points at the workplace.

3.6. Layer 6. Warehouse design.

After Milkrun cart are defined to minimize efforts supplying the production workplaces, the warehouse must be designed to minimize the motions required for loading the carts. Containers must be placed in a “ready-to-pick-up” manner, again, in a mirror configuration of the Milkrun carts (consequently, in the delivery order).

“Kanban Supermarket” is the name of the tool used to achieve this design (based on the PFEP from layer 2).

3.7. Layer 6. Inbound supply chain design.

Inbound Supply Chain connects the factory with external suppliers. Its design must be oriented toward optimizing the supermarket warehouse with frequent deliveries, thus reducing the quantities and packaging for direct delivery to the supermarket shelves.

Kanban, external Milkrun and Vendor Integration are the tools for this layer.

4. Real case of Person-Based Design implementation.

In this real case study, *Person-Based Design* was used to re-design a production area (fig. 2a) that supplied five different subassemblies to a production line with a nominal cycle time of 30 s/ut.

a) b) c)

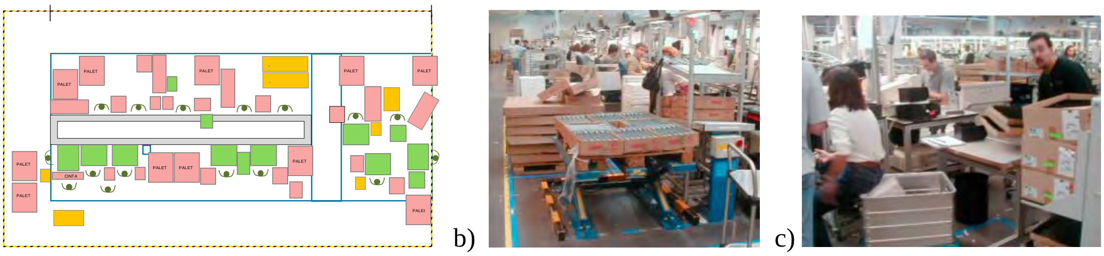


Fig. 2. Initial state: a) Layout; b) Materials around workplaces; c) Isolated workstation with high motion.

The initial production area was designed with a traditional mindset. Labor productivity was achieved through automation and work-in-process to compensate for variability among workstations. Materials were placed around workplaces to allow self-supplying if necessary (Fig. 2b). People were isolated in workstations, surrounded by big containers with high levels of motion waste (Fig. 2c).

Person-Based Design. Layer 1. The respect-for-people principle.

The redesign was performed by a cross-functional team: operators, line supervisors and process engineers. A kaizen area was set up to collect ideas for improvement and to promote continuous improvement.

Layers 2 and 3. Packaging design and the design of tools and machines.

Packaging and workstations (Fig. 3) were redesigned at the same time to achieve two main objectives:

- Improve ergonomics and reduce motion waste in order to increase labor productivity.
- Minimize the required surface in order to increase surface productivity.

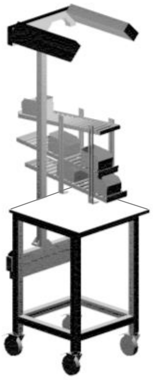
a)  b)  c) 

Fig. 3. a) Standard workstation design. b,c) Examples of real workplaces.

Layer 4. Production line design.

The production process was redesigned to produce one-piece-flow for every subassembly within the Takt Time of the customer line. This means that every 30 seconds the production cell produced the 5 different subassemblies within the established time.

Based on a “U-shaped” configuration, workstations were balanced to 25 seconds and the tasks from different subassemblies were combined. The work area (Fig. 4a) and supply area (Fig. 4b) were clearly independent of each other.

Layer 5. In-plant supply design.

The in-plant Milkrun route was designed to supply the line every 45 minutes from a Kanban Supermarket system set up close to the assembly area. Due to the small size of all components, only one cart was needed (Fig. 5b)

Layer 6. Warehouse design.

The warehouse was redesigned as a Kanban Supermarket (Fig. 5c). All parts were ready to pick up by the Milkrun operator. Some parts required re-packaging, which was done during the Milkrun loop using a double bin kanban system.

Layer 7. Inbound supply chain design.

The inbound supply chain was designed to fulfill the Kanban Supermarket system every 4 hours, with external Milkrun trucks following a predefined loop through different suppliers and external warehouses.

Fig. 4. a) Value-added area. b) Supply area with Milkrun. c) Kanban Supermarket

Table 1 shows the significant improvements achieved using Person-Based Design:

Table 1. Summary of achieved results

KPI	Before	After	% improvement
Work in Process (h)	13	2	550%
Surface (m^2)	102.6	57	70%
Labor Productivity (u/h/p) (including Material Handlers)	6.7	7.9	18%

Fig. 6 shows the evolution of the production area. Attention must be paid to the fact that productivity increased with one less person in the workplace. This person was re-trained to work as a Milkrun driver.

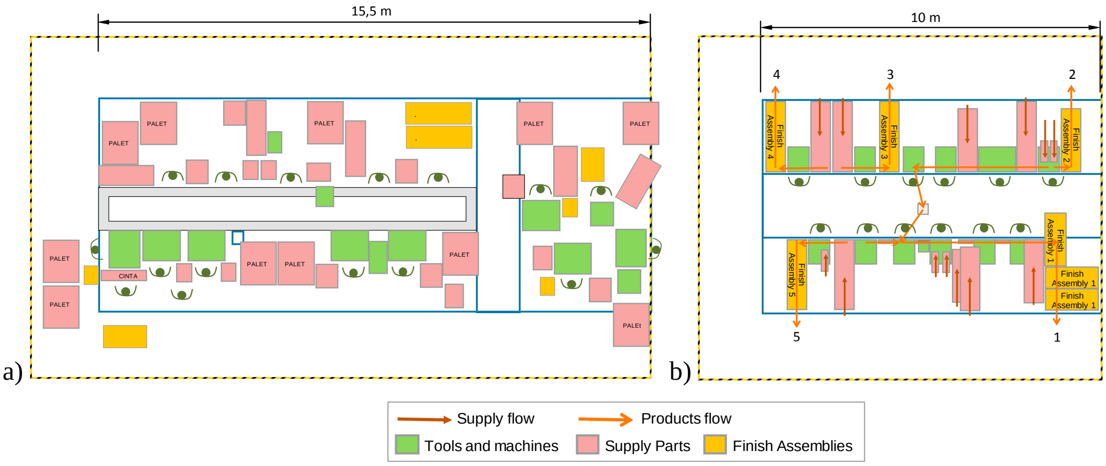


Fig. 5. Layout. a) Initial state before Person-Based Design b) U-shaped configuration showing five different product flows.

5. Case discussion.

The initial design (Fig. 5a) was based, not in "reducing waste" Principle, but in automating transportation waste with a conveyor, laying out workstations around it. Workers self-supplied their workstations and material surrounded them creating isolated work areas. Stock and transportation required more surface than value added activities despite a full-time material handler was hired to move materials and set in order the working area.

When *People Based-Design* was applied, the conveyor was eliminated, workstations were redesigned and laid out as a U-Shape Assembly line (fig. 5b), tasks were rebalanced to customer Takt Time and material handler tasks were redesigned in a Milkrun circuit. Labor and surface productivity improved as shown in Table 1.

6. Conclusions and areas for further research.

This paper introduces *Person-Based Design* as an efficient sequential method to design a Lean Factory when labor and surface productivity are key for competitiveness, thus ensuring *Respect for People*.

The *Person-Based Design* method first takes a systems perspective to integrate Lean Production principles, tools and methods. Later, the method is applied to a real case in a production area, showing significant improvement in surface reduction, WIP reduction and an increase in labor productivity (Table 1).

This research has some limitations; the most important one is lack of generalizability of case study results. Although the *Person-Based Design* method has been conceptualized as a general method, its implementation to a particular case cannot be directly generalized in other industrial settings. This pragmatic development has been performed for internal validity purposes. Future research would benefit from multiple case analyses of Person-Based Design implementation and comparison in other industrial contexts. Other open avenues for future research may include; developing the tools required at every layer of design in more detail, understanding the interactions among layers, extending research on people's perceptions and assessments in order to confirm that the *respect-for-people principle* is achieved and investigating how Person-Based Design contributes to firm competitiveness.

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