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## Development of Design Support Tool for New Lean Production Systems

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### Abstract

Application of the Lean philosophy during the design of a new production system might result in a production system which is more Lean from the beginning and needs less improvement during its lifetime.

In this paper a design support tool for new Lean production systems is presented. It combines the theory on Lean and production system design. The design support tool consists of three elements with a strong interaction. The first element of the tool prescribes the steps in the design of a production system in general. The second element illustrates the flow of different types of information during the design process. The third element consists of guidelines for Lean design. Following the workflow that combines the three elements should result in a new Lean based production system.

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### 1. Introduction

Application of the Lean theory has proven to be an effective way of improving manufacturing systems. Lean is often referred to as a philosophy, as a way of thinking. Nonetheless it also embraces methods and tools to support its implementation. Determining when to apply which tool in the improvement processes is not bounded by any formal guideline. Indeed, a large Lean implementation experience has been gained by industry on this topic. This has contributed to the development of an empiric, and yet solidly demonstrated, body of knowledge on the sequential application of methods and tools for achieving a Lean system. However, how to start a green field design of a manufacturing system fully integrating Lean remains poorly documented in both Lean literature and best practice cases. More specifically, how can one take care of implementing Lean correctly from the starting phases of manufacturing design?

This paper proposes to answer this question. It presents an information driven method. It supports designers in determining which aspects of Lean have to be taken into

consideration and when to apply them during the development stages of the design process of a new manufacturing system. In order to develop the design support method, a short survey was carried out at five production companies [1]. The goal of this study was to determine the interest and expectations that these companies would have for such a design support tool. After that literature study was done to investigate the already existing design methods for manufacturing systems. An overview of possible Lean aspects that might be useful during design is made. With above mentioned knowledge it is possible to start to design the design support tool for new Lean manufacturing systems. The tool consists of three elements: design steps, an information flow table and a guide for Lean design. The workflow to use the design tool is prescribed and a verification of the tool is done.

### 2. Design of production systems

#### 2.1. Design methods

A lot of literature is written about the design of the different aspects of production systems, some of them describe the

process of designing itself. Tomphkins e.a. [2] distinguish 3 stages in the engineering design process; defining requirements, developing alternatives and evaluating /selecting the facilities plan. This is comparable with a design process in general.

Bellgran and Säfsten [3] distinguish 5 main phases in the design process of production systems and each phases is worked out in more detail, fig 2(a). The management and control phase is about the preparation of the design process. Preparatory design is about gathering knowledge and data to be able to write the requirement specifications for the design specification phase. In this phase the production system is designed. The next phase, realization and planning, the system is built and the start-up is planned. The start-up phase is the final phase in the structured way of working. The start-up is carried out and evaluation will be done.

2.2. Lean during design

The Lean philosophy embraces methods and tools to support its implementation. These methods and tools are meant to improve existing manufacturing systems. When they can be implemented during the design process, it should result in a Lean production system from the beginning, that needs less improvement actions during lifetime.

Tomphkins e.a. [2] do mention the impact Lean has on facilities planning, but they do not relate it to the design process itself. They mention the Future State Map as an important tool, but almost all tools/methods can be useful to create a new Lean manufacturing system.

3. The design support tool

In the case that concerns this paper, a new production system is being designed that should comply with the theory of Lean Manufacturing. This means that the Lean philosophy has to be taken into account in the design steps. As a consequence, the in- and outputs per design step are created with the focus on Lean. The tools/methods can be seen as actions that should be taken at the different design steps to ensure that the created output per step is as Lean as possible.

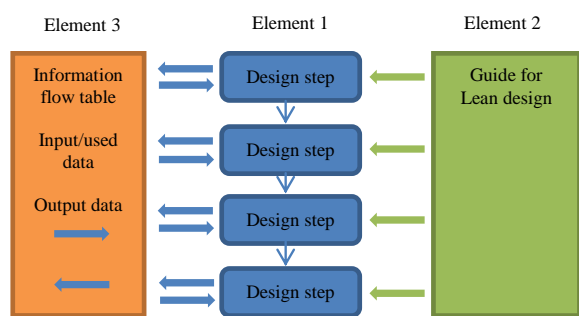


Fig. 1. Three elements of design support tool.

The design support tool consists of three related elements with a strong interaction, fig. 1. The first element of the tool prescribes the steps in the design of a new Lean production system. The second element consists of guidelines/actions for

Lean design. The third element illustrates the flow of different types of information during the design process. Next the three different elements of the design support tool will be discussed.

3.1. First element; Steps in design of production systems

The structure of Bellgran and Säfsten [3] can be used to design new Lean production systems, but it needs some adaptation to the Lean philosophy to be sure that the final production system is Lean. The focus has to be set on 4 of the main phases of the structured way of Bellgran and Säfsten; preparatory design, design specification, realization and planning and start-up. The management and control phase is of course from Lean perspective also very interesting, but is more related to the management of a company. Since Lean cannot survive without support of the management of a company, the management should already be Lean minded before starting to design a new Lean production system.

Most of Lean manufacturing ideas should be implemented in the conceptual part of the design specification phase, if the new production system has to be Lean from the very beginning.

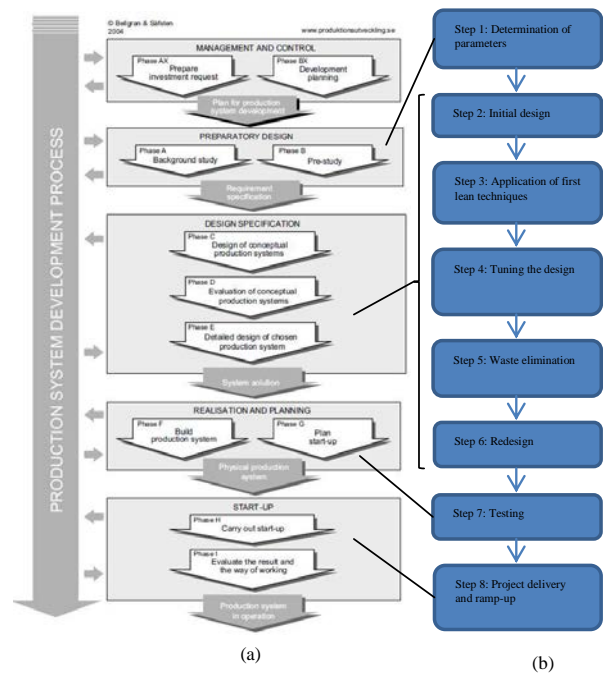


Fig. 2. (a) Description of a structured way of working with production system development by Bellgran and Säfsten (2004). (b) Steps in design of new Lean production systems, related to the structured way of working.

Fig. 2(b) shows the relation between the structured way of developing a production system of Bellgran and Säfsten and the design steps necessary to come to a Lean production system, based on literature and the industry survey [1].

Before starting to design the production system, the requirements that should be met must be determined. Parameters are important in the requirements. For Lean the customer demand, available time and therewith the Takt time

are the most important parameters. The Takt time plays a crucial role in further decisions. In traditional production the speed of production is determined by summing up the cycles of each machine. In Lean manufacturing the speed of production is determined by the demand rate of the customer. In this step also the processes, production volume and variety, and evaluation of customer needs, must be determined.

The second step generates the conceptual design of the production system. The actions to be undertaken at this stage involve choosing proper technology and layout, understanding of customer needs, proper organization of work and striving for flexible production. Understanding of customer needs and requirements is one of the most important aspects in terms of lean design. The system should be designed in such a way that it will be able to fulfill those needs and requirements. To be able to do so it is crucial to prepare the Value Stream Map (VSM) at this moment. It will be useful now and in the next design steps. The finalization of the second step should be done by calculating the corresponding production cycle times, which are a source of data concerning the conceptual design.

The aim of the third step is the application of the first Lean tools to the design. The Value Stream Map from step two will help to identify unnecessary activities and reduce the non-value adding activities, which is one of the tasks in this phase. At this moment it is also necessary to implement Heijunka and Just-in-Time (JIT), i.e. pull system, one-piece flow etc.

In step four the designer should take a closer look at reducing waiting times, identifying and finding solutions for bottlenecks, and defining proper amounts of operators and machines in the production system. All of this can be done with the help of the information and the results of actions from previous steps. JIT is a technique for reducing waiting times, while the bottleneck analysis will facilitate improvements in the production efficiency. At this stage the proper amount of machines and operators for achieving the Takt time can be computed.

The main goal of step five is to eliminate waste. In order to do so a number of actions must be carried out. First of all it is essential to identify the seven main wastes. Next find the possible places of occurrence and take actions to remove them. It is also important to minimize the disruptions and breakdowns of the machines. This can be done by implementing Total Productive Maintenance (TPM), preparing maintenance schedules etc. Some of the Lean tools that could be useful in this step are standardization of work, poka yoke, Kanban cards and visual management.

The redesign of the conceptual production system is done in step six. After this step, there will still be some minor changes to take place, but this redesign is going to be the basis for the final design. All the data gathered previously give a clearer picture of how the production system should look like. Therefore the first action of this step is to implement this information, as far as it is not implemented already. It is also the time for comparing old cycle times with new ones. The progress needs to be analyzed. The redesign needs to be evaluated concerning Takt time and further requirements.

The seventh step is dedicated to testing, assuming that the physical production system is built between step six and seven. It is time to check how the system works in reality,

finding the remaining issues and fixing them, revising whole value stream etc.

The eighth and last step in Lean implementation during production system design is the final release of the system and its ramp-up. At this stage the last Lean tools should be applied. The continuous improvement philosophy, Kaizen, must be translated into action.

3.2. Second element; Guide for lean design

As follows from section 3.1 actions can be taken to make sure that the resulting output of every design step is as Lean as possible. Several action examples are already given in the previous section. These actions originate from the guide for Lean design, that will be presented next. It is going to be in the form of a flowchart that will give hints and show directions that can be used during the production design process.

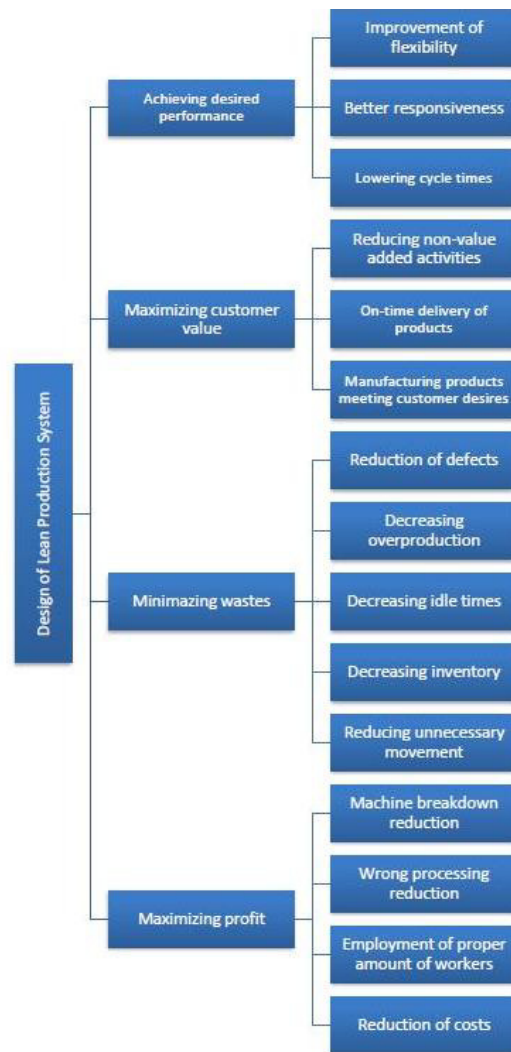


Fig. 3. Guide for Lean design (levels 1-3).

Fig. 3 shows the guide for Lean design, in the form of means-ends hierarchy. This figure is not yet linked to the design steps. The guide contains four basic improvement elements; achieving desired performance, maximizing customer value, minimizing waste and maximizing profit. These features are selected as the most important elements due to literature research, survey results, interviews with experts and common sense [1].

Every improvement element is split up into five levels. At level five the actual action to fulfill the basic improvement element is described. Note that this overview only shows three levels of depth.

All the remaining levels are worked out the same way up to level five. For example when talking about “Maximizing customer value” combined with “On time delivery of products” the remaining levels look like in fig. 4.

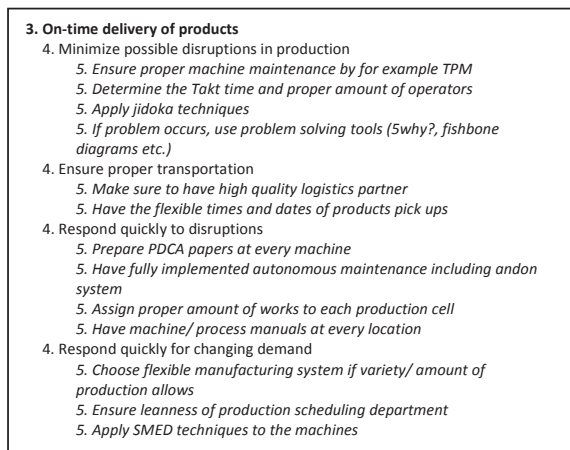


Fig. 4. Example “On-time delivery of products” worked out up to level 5.

The link between the design steps and the guide is shown in fig. 5. Each design step consists of several actions to be taken, which are directly related to the guide for Lean design. Here only design step five with its actions is presented.

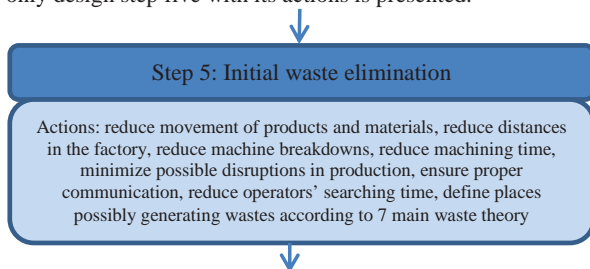


Fig. 5. Design step 5 and the actions that represent the guidelines for Lean design.

### 3.3. Third element; Information flow table

In general a design step needs input and generates output. An information flow diagram for designing new Lean production systems is made. This diagram shows the relationships between the design steps, the in- and outputs and the actions coming from the guide for Lean design. But it also

shows which input is when needed. Fig. 6 shows a part of the diagram. For example let’s assume that the design process is at design step three. The action that needs to be performed according to the guide for Lean design is “identify unnecessary activities”. The input is formed by the output of design step two; VSM analysis results. When this action is completed, it should be possible to provide output data, i.e. a list of non-value adding activities and cost efficiency analysis results.

In table 1 a summary of the information flow for design step five is presented. It is going to help to understand the information used in each step of Lean production system design, as well as the output of each step.

Table 1. Summary of information flow for step five in the design of Lean production systems.

Step number	Input/used data	Output data
Step 5	Output data from steps 3 and 4	List of wasteful or possibly generating wastes places and activities
	Value Stream Map	New distances between machines
	Analysis of distances in the factory results	New machine order
	Machine manuals analysis results	Maintenance schedules
		Manuals and PDCA sheets

### 3.4. The use of the design support tool

Previously the different elements and their relations were explained. Next the use of the design support tool will be discussed. In fig. 7 a workflow for using the design support tool for designing new Lean production systems is given. By following this workflow the design support tool is used as optimal as possible and it should result in a new Lean production system.

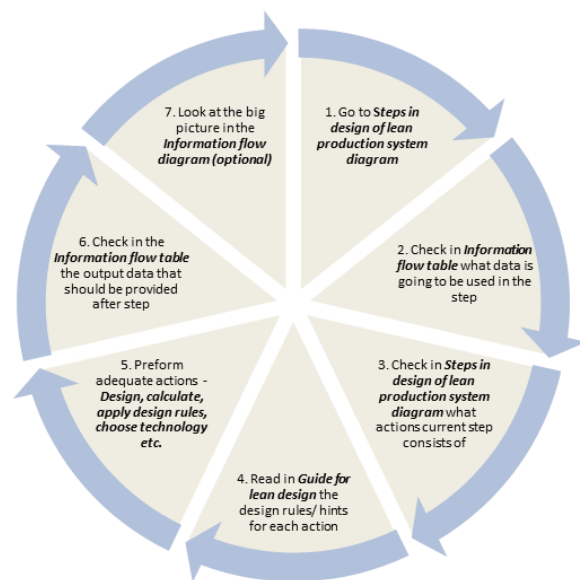


Fig. 7. Workflow for using the design support tool for designing new Lean production systems.

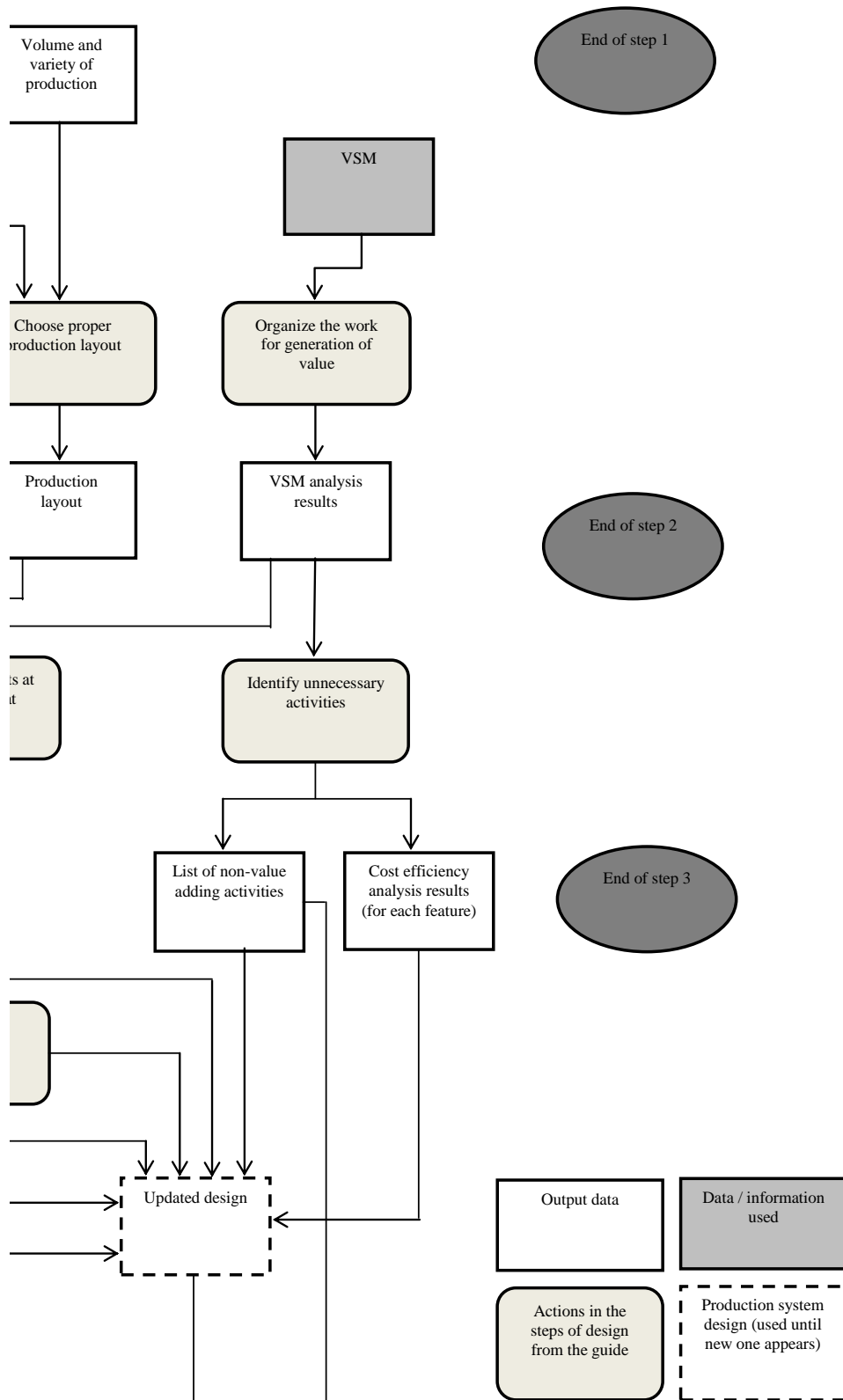


Fig. 6. Part of the information flow diagram.

#### 4. Conclusion and discussion

The goal of this project was to design a design support tool for Lean production systems. Some recommendations for future improvements can be made.

To be able to make a statement about the potential of the tool to offer a good support for designing new lean production systems evaluation and verification needs to be done. Although a small production system design exercise was done, it is not sufficient to draw conclusions. The complete workflow for using the design support tool was followed. It showed how the tool can be applied. The tool should be tested in a real life situation to be able to make a full conclusion.

Most Lean tools and methods are suitable for existing production systems. In this situation they were applied to non-existing (conceptual) systems. Further investigation is necessary to find out whether and how this will work.

Applicability of the design support tool for different types of production systems is not obvious yet. It should be further investigated whether the tool is applicable for production systems without a clear flow, for example jobshops.

Application of checklists should be taken into account. It could be useful to implement checklists at several phases within the design steps. This can facilitate, for example, finding the seven main wastes more easily.

To be able to use the tool also for redesigning existing production systems, the steps and guidelines need to be adjusted. When this is done the tool could be used for both – designing new production systems and redesigning or improving old ones.

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