Design For Lean Systematization Through Simultaneous Engineering

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Abstract. Lean Manufacturing philosophy has had an important role in productivity improvement in first rate industries. It came from the best practices applied by the Japanese automotive industry, targeting high quality, low cost, lower lead time and enhanced flexibility. Due to high competitiveness, there has been a great effort in its wider application. While product concept has had an important role on the efficacy of manufacturing, it must be said that there is still a shortage of elements for a proper product development with focus on Lean Manufacturing philosophy. Concern to design products that maximize specific characteristics by way of Simultaneous Engineering gave birth to DFX tools such as DFM. To this date no DFX tool has come up with enough subsidies to generate products that will support implementation of Lean as a whole. On the other hand, Simultaneous Engineering has not been used so as to involve Product Design with Lean Manufacturing. Present article proposes a set of guidelines, called Design for Lean, to systematize best practices for product development with focus on Lean Manufacturing through Simultaneous Engineering. They will target conceptual and detailed design phases.
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Keywords. design for lean, lean manufacturing, DFX, systematization, simultaneous engineering

1 Introduction

High competitiveness has triggered a wide usage of Lean in production. As its application has been so far generally restricted to manufacturing, losses still occur, mainly due to the fact that product concept has not been in line with that philosophy.

It is otherwise known that DFM has an important role in product design, to impact on the feasibility and the productivity of the manufacturing process.

Perhaps due to the fact that design teams are not so well acquainted with Lean, they have met difficulties in developing products that will effectively contribute with it.

In order to help enable a full implementation of Lean philosophy all the way from product design through its final delivery out of production, present tool is presented. This tool comes in a form of guidelines or wastes to be avoided as in the stamping case resulted from interviews with experts of the main automotive industry processes: stamping, welding and assembly. These guidelines are related to one or the other of the seven main wastes encountered in running production.

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2 Lean Manufacturing

It is understood by Lean Manufacturing everything which refers to having the right things at the right place at the right moment and in the right quantities thus eliminating wastes in a flexible and open to changes manner.

According to Womack [8], "Lean thinking is a way of specifying value, aligning the best sequence of actions which create value, perform these activities without interruption every time someone requires them and ever more effectively". So, according to the author, Lean thinking is a way of doing more with less, increasing efficiency. Liker [5] lists seven wastes identified through Lean thinking:

1. Overproduction: manufacture of items not yet demanded, creating the need of storage and transport more often than necessary.
2. Wait: workers merely watching an automated machine or waiting for the next step of a process, requests for parts in delay, production bottlenecks, etc.
3. Unnecessary transportation: need of long distance moving of a product in process between one step and the other or between unnecessary steps.
4. Over or incorrect processing: unnecessary manufacturing steps: inefficient process due to poor tools and production design requiring unnecessary movements which may cause low quality. Wastes when excess quality demanded.
5. Excess inventory: excess of raw material, product in process or finished product, causing long delivery times, obsolescence, damaged items, storage and transportation cost.
6. Unnecessary movements: whatever movements made by workers, be it to search or reach for parts.
7. Defects: production of bad parts. Any kind of rework, loss of products, inspection, does nor add value.

3 The Role of Product Development in the Implementation of Lean Manufacturing

3.1 Product Development Process

Once the purpose of this study is to propose a DFX tool to be inserted in the product development environment, it is necessary to choose a PDP model among the various available. Figure 1 shows the Rozenfeld, *et al.* model, which will serve as a base to have us understand in which development phases the tool will be applied.

With DFX, proposed tool will have its application in Conceptual and Detailed Design phases, with its requisites already defined in the informative phase.

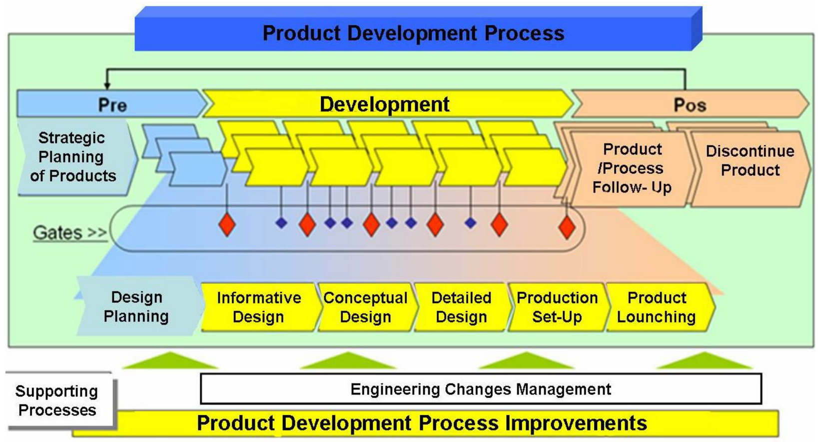

Figure 1. Model PDP adapted from Rozenfeld et al. [6]

3.2 Design for Manufacturing

Product concept has a considerable impact on final cost. It is during the production phase that design change costs are highest. To help the designer evaluate the impact of his decisions on the product's life cycle, auxiliary methods for design decisions called DFX (Design for X) were developed. Among most applied DFX is Design for Manufacturability.

For better results, this tool must be used the earliest possible in the PDP process, within Simultaneous Engineering environment.

3.3 Design for Lean Manufacturing – A New DFX Tool

At present the guidelines contained in DFM tool have supplied subsidies so that product development teams contribute, although modestly, with the implementation of Lean Manufacturing philosophy, mainly in what regards standardization. There is to be noticed, however, a strong absence of tools to support product development teams specifically in the task of contributing with the implementation of Lean Manufacturing in its entirety.

"Lean production must traverse product not only in its manufacture, but also in its concept in PDP, for that is how there is growth of opportunities to cause impact on manufacturing efficiency, cost and product quality" Rozenfeld [6 apud Womack 8].

But, then, what new approach would this tool bring with regards to the already known DFM? The answer is a set of specific guidelines for the development of products that is focused on the implementation of Lean Manufacturing philosophy in the manufacturing phase.

The development of products with focus on Lean Manufacturing must intrinsically think not just in the product manufacturing phase, but yes in all the concept cycle. According to Womack [7], one must search to utilize value engineering techniques in order to break down the costs of each production step, identifying every possible factor to reduce cost of each part. Afterwards, value analysis techniques are applied in order to reduce additional costs. In this phase, each step of the manufacturing process is analyzed in order to identify critical points which will get more attention so as to reduce costs even more.

Womack [7] makes an analogy between mass versus lean product development, in which, among other differences, resources needed for the development of the design are temporarily placed under a Design Manager, with no ties to their routine, or series, activities for the entire duration of the design. Whereas in mass production, resources needed for the design are placed in simultaneous development programs and under a functional department. As in the Lean system the available resources dedicate exclusively to their design and do not report to other departments during its lifetime, design duration is consequently shorter than in mass concept.

Through this development technique products can be produced quicker, with less work and fewer errors, which significantly contribute to Lean manufacturing. Following prerequisites have been identified to enable this concept:

- a team leader, responsible for design and engineering;
- a synergic work team under one single design leader;
- Simultaneous engineering – as the engineering department can not have enough knowledge of all relevant design areas, experts from other areas are to be brought in. Full benefits from simultaneous engineering to be harvested.

4 Simultaneous Engineering

The term simultaneous engineering can denote both a parallel cooperation and work discipline towards a set of common objectives in the development step or a form of design time reduction through the accomplishment of independent activities which can be made simultaneously.

According to Rozenfeld [6], one of the first attempts was to increase the degree of parallelism among development activities, seeking the simultaneous accomplishment of design and process planning activities. In this way, activities that were previously started after the former activity had been finished and approved, can be made in parallel.

Following benefits can be attained through simultaneous engineering:

- reduction of time for development of new products
- reduction of cost in the development of new products
- better quality of new products as per customer needs

So, through Simultaneous Engineering, one can make the product concept changes in the initial development process steps.

Our object is not exactly the reduction of product development time, but yes the assurance that the developed product meets essential requisites for the implementation of Lean Manufacturing philosophy. For that purpose it is necessary to determine what is its application that exactly corresponds to the goal market, which in our case is Lean manufacture.

Many authors like Bralla [1], defend that DFX tools can be implemented without the help of Simultaneous Engineering, once good designers should be able to consult their direct and indirect customers and apply design guidelines by themselves. That may be one reason why even today there is so much difficulty developing products focused on their internal customers and not just on the expectations of the final customer.

In order to assure the good result of its application, Simultaneous Engineering must be backed up by product development supporting tools, such as QFD, DFX, among other which are not exactly the focus of this work.

In the same way it is utilized to process and translate the needs of the final customer, QFD should be used as a coordination element of the information process, dictating the rhythm of product development and the sequence of activities of this process. This means that each phase of the development process should have the elaboration of the respective QFD matrix as its conductive element.

To our interest, Simultaneous Engineering is an important tool in what concerns bringing the customer needs to the implementation of Lean Manufacturing philosophy. In other words, through Simultaneous Engineering the product development teams work together with Lean Manufacturing implementation teams.

In order to render the utilization of Simultaneous Engineering effective in the phase of product development, of importance is the support given by the Informational phase supported by the QFD tool, to ensure consensus of the different definitions on the product. Through QFD, translation is made of the Lean Manufacturing goal specifications into product requisites, so that they do not negatively interfere with other important product requisites. This is easy to observe as Lean Manufacturing philosophy asks, among other things, less robust products and whenever possible with not so tight tolerances. Well, this requisite may very well work against some of the final customer's requisites, as for example efficiency, or product quality, or even against Lean principles themselves, once a stamped part with loose tolerance may generate the need of further adjusting operations in the welding steps.

5 Recommendations to the Product Development Team

Once the environment of this study is mainly the automotive industry it is only natural that study focus shall be on it.

As explained in the initial stages, this work's objective is to supply directives which will enable wider penetration of Lean Manufacturing philosophy through strong contribution of the product development team as well as other DFX tools. Therefore it has been decided to stratify the main steps of automotive production so as to supply orientation to each of them. Whenever possible, these orientations will be directly related to the seven main wastes mentioned in the Lean Manufacturing definition.

First step – stamping: If the manufacturing process of an automobile is analyzed as a whole we will notice that, what concerns product design, the higher the quality of a stamped part the lower is the investment needed. Higher productivity gains in stamping have been obtained through improvements by way of high flexibility equipment. Less complex geometry, right choice and adequate thickness of materials will allow following benefits, shown in table 1, according to the seven main wastes previously mentioned:

Table 1. Relation between benefit and avoided waste during stamping process

Benefit	Waste
Less complex geometry bringing lower tool adjusting time;	Over and incorrect processing;
Adequate raw material and thickness, bringing lower template numbers;	Defects;
Less complex geometry meaning less time spent on measuring and rework;	Over and incorrect processing;
Adequate raw material and thickness reducing stamping stages;	Over processing;

A stamped part of higher complexity along with robustness of the stamping process is however preferred over a lower complexity part. Reason is stamped parts must be welded and assembled giving thus shape to the vehicle. Therefore, design of stamped parts give indeed a great contribution to the reduction of manufacturing steps to follow.

Second step – welding: table 2 relates the main potential wastes encountered in the welding process as well as its consequences when they are not avoided, according do the seven main wastes previously mentioned:

Table 2. Relation between waste causes and consequences during welding process

Causes	Waste
Necessary process checkings to ensure good product quality to be delivered to assembly due to low design robustness;	Over processing and incorrect processing;
Amount/complexity of gadgets to ensure welding geometry;	Over processing and incorrect processing;
Number of welding spots to ensure product rigidity;	Over processing and incorrect processing;
Part degradation in storage due to high degree of ductibility and thickness;	Defects; over production;

Welding is the direct client of stamping, therefore quality of stamped product has a direct impact on the requirements of a robust welding process.

The environment in which the study was carried out is responsible for the production of two distinctive vehicle brands, to be called brand A and brand B.

Each of them demands a specific production line, which allows a direct comparison as to the robustness of both processes involved.

Brand A, due to its more robust part design, needs a leaner manufacturing process. As an example, a hinge to be welded to the car body has a rather complex design, thus requiring a more complex stamping tool. Stamping time as well as number of tools and their stages are however not necessarily higher and the welding operation to the car body can be performed through a simple gadget as it was designed so to have its positioning on the body ensured.

Brand B on the other hand has a simpler design, but demands a much more robust and complex assembling process as it not capable to ensure needed positioning by itself.

Third step – painting: Not to be dealt with in this study as it is a distinct process from the others.

Fourth step – final assembly: At this stage the vehicle has already had its body welded and painted, and is ready to receive up to a thousand components. This is the phase where the highest optimization potential has been identified for both brands. First, design decisions on large stamped parts (sides, doors and stringer) have an amplified impact during assembly as the welded components, here including car body, present geometric variations that will require a great number of adjustments in this manufacturing stage.

Table 3 shows the relation between waste causes and their consequences in final assembly, according to the seven main wastes mentioned earlier.

As happens with body welding, final assembly spends even more time and money with the attempt to geometrically position large components, mainly mobile parts. Due to the low design robustness of their primary components they do not feature many rigid points and thus must undergo a flexible positioning for assembling purposes. On top of this there are the process variations.

In order to facilitate the parts design and absorb variations along the process due to the addition of tolerances, it is a practice that the designer resorts to “fitting facilitators”, commonly known as oblongs and keyways. These artifices have an enormous contribution for us to have an unstable process, therefore creating a dependency on operator sensitivity (which so far cannot be measured) and on devices, patterns that eliminate this variable, creating tools and operations that do not add value. It is desirable an effort from the designer so that any and every subjective operation which depends on “the common sense of the operator” be brought to a minimum, for there is no way to standardize this requisite.

Another point observed was the amount of similar items, in special screws which in many cases could have their usage unified, therefore reducing the number of inventoried items, number of screws and also the amount of assembly failures by means of mistakes.

An important point to be considered when designing a stamped part is that it should come with tolerances such that when added to the tolerances of the other components there is no further difficulty put to the final assembly process.

Table 3. Relation between waste causes and its consequences during final assembly process

Causes	Wastes
Components with geometric variations received from internal suppliers;	Waiting time; over and incorrect processing; unnecessary moving;
Component with undefined positions in assembly operation (oblongs, keyways), requiring many adjustments at assembly;	Over processing and incorrect processing; unnecessary moving;
Parts that could have their assembly through fitting instead of screws, decreasing number of components, inventory, number of components and operations;	Unnecessary moving, excess inventory; defects; over processing and incorrect processing;
Lack of standardization of components that have very similar functions (screws, nuts), meaning high inventory, process faults, excessive equipment needed;	Unnecessary moving, excess inventory; defects; over processing and incorrect processing;
Inadequate raw material which deforms during process, requiring adjustments steps;	Defects; excess inventory; over and incorrect processing; unnecessary moving;

6 Conclusion

Through this study we can observe that the integrated development of products has an important contribution for the implementation of Lean Manufacturing philosophy in its entirety. The DFX tools available to this date like DFM are not sufficient, there being room for the creation of a new tool – DFL.

Simultaneous Engineering has an important role in the search for the development of products with focus on Lean Manufacturing, still underutilized, not only in the reduction of product development time, but mainly in the development teams interaction with their client areas.

Much has been done in the search for a Lean manufacturing, with contributions from product in a punctual manner and in isolated steps of the manufacturing process. Isolated changes of the product in search of cost reductions in the production process can bring as a consequence an excess of operations that do not add value along the production chain.

Present study has shown that the product development can present a positive contribution for the implementation of Lean Manufacturing philosophy, mainly if the guidelines here outlined are applied in the initial steps of the manufacturing process.

7 Bibliographic References

7.1 Journal Articles

[1] Edwards KL. Towards more strategic design for manufacture and assembly: priorities for concurrent engineering. Materials and Design 23, 2002

7.2 Book Titles

[2] Bralla JG. Design for Excelence. New York: Mc Graw Hill, 1996.
[3] Forcellini FA. Introdução ao desenvolvimento sistemático de produtos. Florianópolis, 2000. 110 f. Apostila (Disciplina de Projeto Conceitual) – Pós-Graduação em Engenharia Mecânica, Departamento de Engenharia Mecânica, Universidade Federal de Santa Catarina.
[4] Huang GQ. Design for X – Concurrent Engineering Imperatives. 1 ed. Dundee: Chapman & Hall, 1996.
[5] Liker JK, O Modelo Toyota. Porto Alegre: Bookman, 2004.
[6] Rozenfeld H, Forcellini AF, Amaral DC, Toledo JC, Silva SL, Alliprandini DH, Scalice RK. Gestão de Desenvolvimento de Produtos: uma Referência para Melhoria do Processo. São Paulo: Editora Saraiva, 2006.
[7] Womack PW, Jones DT, Roos D. A máquina que Mudou o Mundo. Rio de Janeiro, Elsevier, 1990.
[8] Womack JP, Jones DT – A Mentalidade Enxuta nas Emmpresas. 6 ed. Rio de Janeiro, Editora Elsevier, 1996.