The Lean Manufacturing System and its Contributions to the strategy of a manufacturing company.

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Abstract. *The market has been demanding a high quality level from the companies in the products and offered services, besides the service of the demands in a fast and efficient way with defined prices for the customers. Inside of that reality, the companies suffer with the pressure of the contestants, being forced to act in advance to their actions. The Lean Manufacturing principles and tools that have been considered as strategic alternative for the companies obtain high productivity levels and quality, looking for the elimination of the wastes of their processes, considering that the wastes are the activities that absorb resources and they don't create value. The objective of that work is to present a case study where the manufacture contributes in a strategic way to the company, for that it should eliminate the seven productions wastes described in the Lean Manufacturing and to apply the takt time concept as an entrance parameter for the production just in time. It will also be shown the integration with the kanban, that makes possible the principles of the Lean Manufacturing. The case study will be an assembly line of components and its transformation in manufacturing cell, as a function capable to assist to the strategic objectives of the company.*

Keywords: *Production administration, Lean Manufacturing, Theory of Constraint, MRP II, Competitive Strategy*

1. Introduction

Many industrial sectors follow the increase in the competition among their participants, due to the globalization which allows the existence of suppliers and customers all over the world. The problem is how to do it with quality, speed, reliability, flexibility and yet, reducing the costs.

To survive in this highly competitive environment, the companies are been demanded to work in a very accurate way without margin waste. It conducts to a management with well defined strategic objectives and with a production system capable to attend these objectives.

The objective of this work is to introduce how a hybrid system of management can help the production function in the strategic management of the company.

The work is organized in five sections. Section 2 introduces the production function as part of the strategic management. Section 3 summarizes the Lean Manufacturing systems, Manufacturing Resource Planning (MRPII) and the Theory of Constraint (TOC). Section 4 shows a case study of the company Super S.A., where the production used to attend to an outdated management which allowed a lot of waste, and after the implementation of a hybrid system of management, the production function starts to cooperate with the strategic management of the company, and this way improving the general result of the company. Finally, section 5 introduces the conclusions.

2. The production function as part of the strategic management

Authors like, Oliveira *et al* (2000) affirm that the production has the challenge to develop new methodologies, or adopt the managerial systems that enable the company to survive in the market. It is confirmed by Corrêa e Gianesi (1996), when he resumes the position adopted by the managers until the 80´s, where the necessary attention to the changes that happened in the worldwide market were not been taken, especially relating to quality and variety of products. It was not identified in what ways the production should change in order to attend these necessities, considering that the problems in the production are solved, and directing its attention to other matters like distribution, packages and advertising. In this context Slack (1993) considers that the development of the Japanese industry, occurred partially due to its marketing abilities and the financial environment, but mainly because they realized the preponderant advantage that could result from the use of more sharpened manufactures.

Toyota from Japan was the company that realized the important role of the production and created the Toyota System of Production. Toyota's vice-president, Ohno (1997), comments that he only drew the attention to the Japanese industry, just after the first petroleum crisis, in 1993. With this crisis, it became clear that the western industry would not be profitable if they used the conventional production system, that is, the American mass production which worked so well for a long time.

Slack *et al* (2002), present the result of a study with Swedish companies that use a strategic management focusing on the production. This study concluded that the 184 Swedish companies (all manufacturing companies), have formulated a consistent production strategy with the business strategy and had reached higher performance levels that those which had not. It happens because a formal strategy of production management forces the organization to define operational policies that adjust themselves in a consistent way to the strategic objectives. The production inside the strategic management of the company is able to objectively contribute, with fives objectives of performance, as shown in Fig. 1.

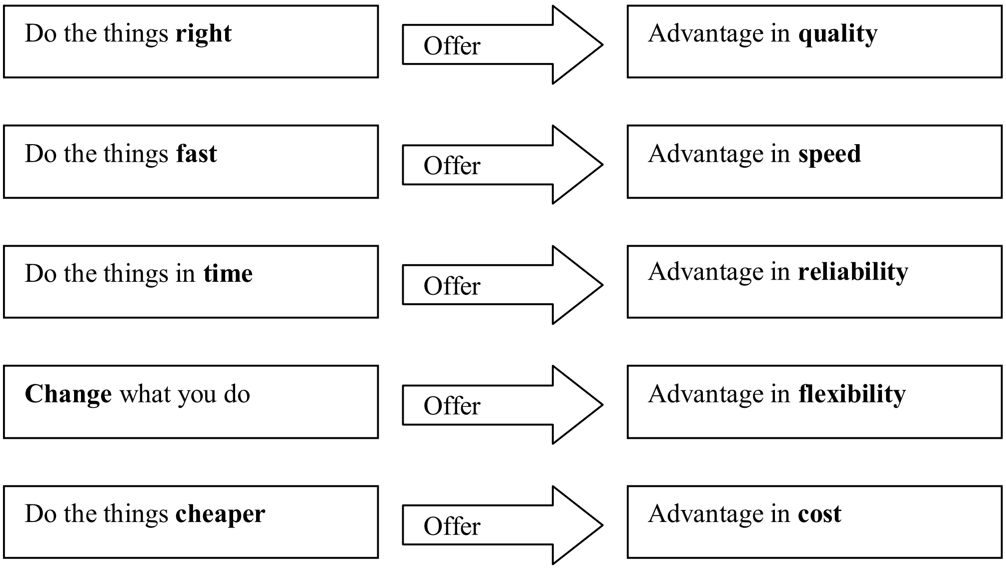

Figure 1. The five objectives of production performance

When the production function is the constraint of the system, the company needs to be guided to the production process, as Montgomery and Levine (1996) show in Figure 2.

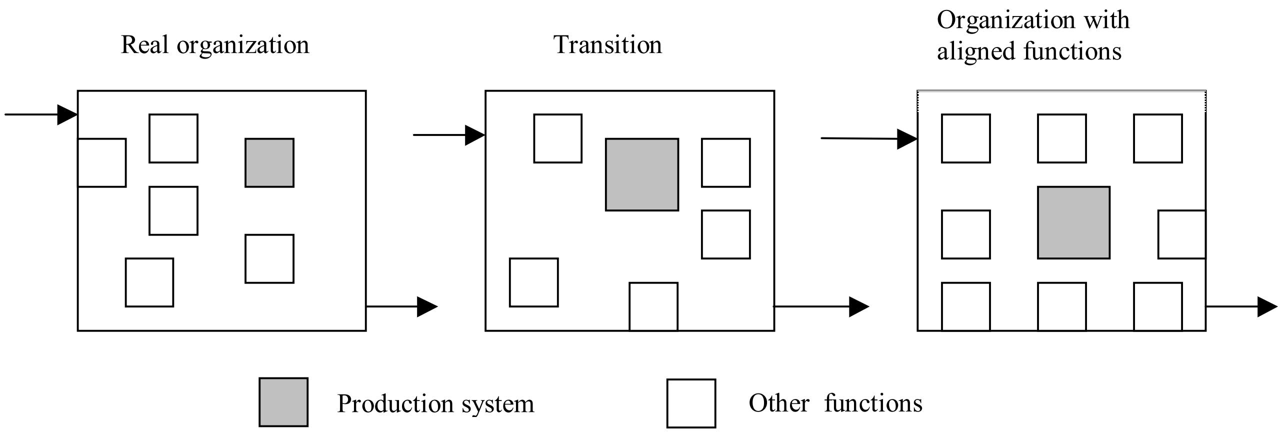

Figure 2. Companies with aligned functions

Knowing that the production is responsible for the transformation of what will be delivered to the customer, so it must become the centre of the organization, to meet the criteria of quality, speed, reliability, flexibility and cost.

3. The production management systems

In order to follow the five described criteria, the Lean Manufacturing (LM) combines the advantages of craft production with the ones from mass production, avoiding the high costs of the first and the inelasticity of the second. It employs teams of multi-qualified workers and must install highly flexible machines to attend the strategic objectives of the company.

According to Corrêa and Gianesi (1996), the company needs a system of calculation of necessities, in order to attend the time of delivery of the customers' orders. It also needs that the orders have a minimum formation of stocks, with a purchase and production planning in the correct moments and quantities. This way the system MRPII (Manufacturing Resource Planning) is an important computational tool to the management of the productive process.

The Theory of Constraints (TOC) is another important tool, because it considers that the entire company in the process to reach its goal presents one or more constraints. If it was not true, the system would produce an infinite quantity of whatever they want. The constraint is anything that limits the improvement of the system performance. The implementation of the Theory of Constraints in the company is important because it identifies and eliminates the constraints.

3.1 The Lean Manufacturing - LM

The Lean Manufacturing System is able to respond to the changes, using the tool of Just in Time (JIT) and the *kaizen* philosophy, minimizing the waste in the production. According to Lima *et al* (2004) introduces the following principles: **have** (and maintain) the correct items in the correct places, in the correct time and the right quantity; **create and feed** effective relation in the value chain; **work** focused on the Continuing Improvement and **search** for Excellent Quality. The companies can develop, produce and distribute products with less human efforts, room, tools, time and other expenses.

The Lean Manufacturing understands that waste is any activity that absorbs resource and does not create value, and recognizes seven types in mass production that must be eliminated: **Waste in over production,** when it produces in an anticipated way something that the demand might need, hiding problems in the productive process; **Waste of available time (stand by),** when the material waits to be processed, forming lines to guarantee high rates of equipment utilization; **Waste in transport,** once the movement of the materials do not add value to the product and they are necessary by constraints of process and of the installations, they must be well managed, aiming its minimization; **Waste in the processing,** is the waste in the realization of the functions or the steps of the process that do not add value to the product; **Waste in available stock,** this waste interacts with all the other wastes, because it works as a solution for the quality problems, equipment and installation maintenance (brake) and the preparation of the machines (*set up*); **Waste in movement,** they are the wastes in the operations of the productive process and it happens in the interaction among the operator, the machine and the material which are being processed; **Waste in producing defective products;** the defective products mean waste of material, workmanship, usage of the equipment, and the movement and storage of defective materials, inspection of the products, etc.

Inside the Lean Manufacturing, time is considered in the management of the system through the *takt time.* This one, by definition, is the relationship between really available working time by shift and the quantity ordered by the customer by shift, according to Equation (1).

$$Takt\ \ time = \frac{(work\ \ period - programmed\ \ stops)}{customerdemand}$$

Equation (1) *Takt time*

According to Alvarez and Antunes (2005), the lashing of the material flow along the time and the space of the factory are done based on *takt time*, being the main element modeling and representation for the process function in the Toyota System of Production.

Through the lean thinking is possible to work on the reduction and even on the elimination of the existing wastes in the company, according to Womack and Jones (1998), the lean thinking searches for the increase in the productivity with less human effort, less time, less investments of capital and less room, always looking for the customer satisfaction. The five principles of lean thinking, developed by Womack and Jones (1998) are introduced as follow: **Specify the value,** focus on identifying the value that the client wants to find in the purchased product or service. The customer must be provided with a specific price in the correct time; **identify the value flow,** are all the actions that add or not the necessary value in the elaboration of the product. These actions include information, troubleshooting and the transformation of raw material in available product to the customer; **Guarantee the flow,** create a continuing flow on small lots, or even in of unique lot, to attend fast the variety of products; **Pulled production,** it means that an initial process should not produce goods or service without the order of the customer of a posterior process, it reduces the inventory and make the problems more visible; **Search for perfection:** Rother and Harris (2002) affirm that there is no project perfect in the paper. As the project of continuing flow is implanted in the factory, details never seen before are discovered, and more wastes can be eliminated, there will be always improvement or degradation in what is defined. That is why the best way to keep the performance of the pulling processes in continuing flow is to keep improving.

3.2 *Manufacturing Resource Planning* - MRPII

According to Chen (2001) in a typical manufacturing environment, the master production schedule (MPS) specifies the quantity of finished product required in each planning period. The MRP is a production planning and purchase orders for lower-level components. MRP is continually evolving and expanding to include more business functions. The

MRP expanded from a material planning and control system to a company-wide system capable of planning and controlling virtually all the firm's resources. This expanded approach was called MRPII, see Fig. 3.

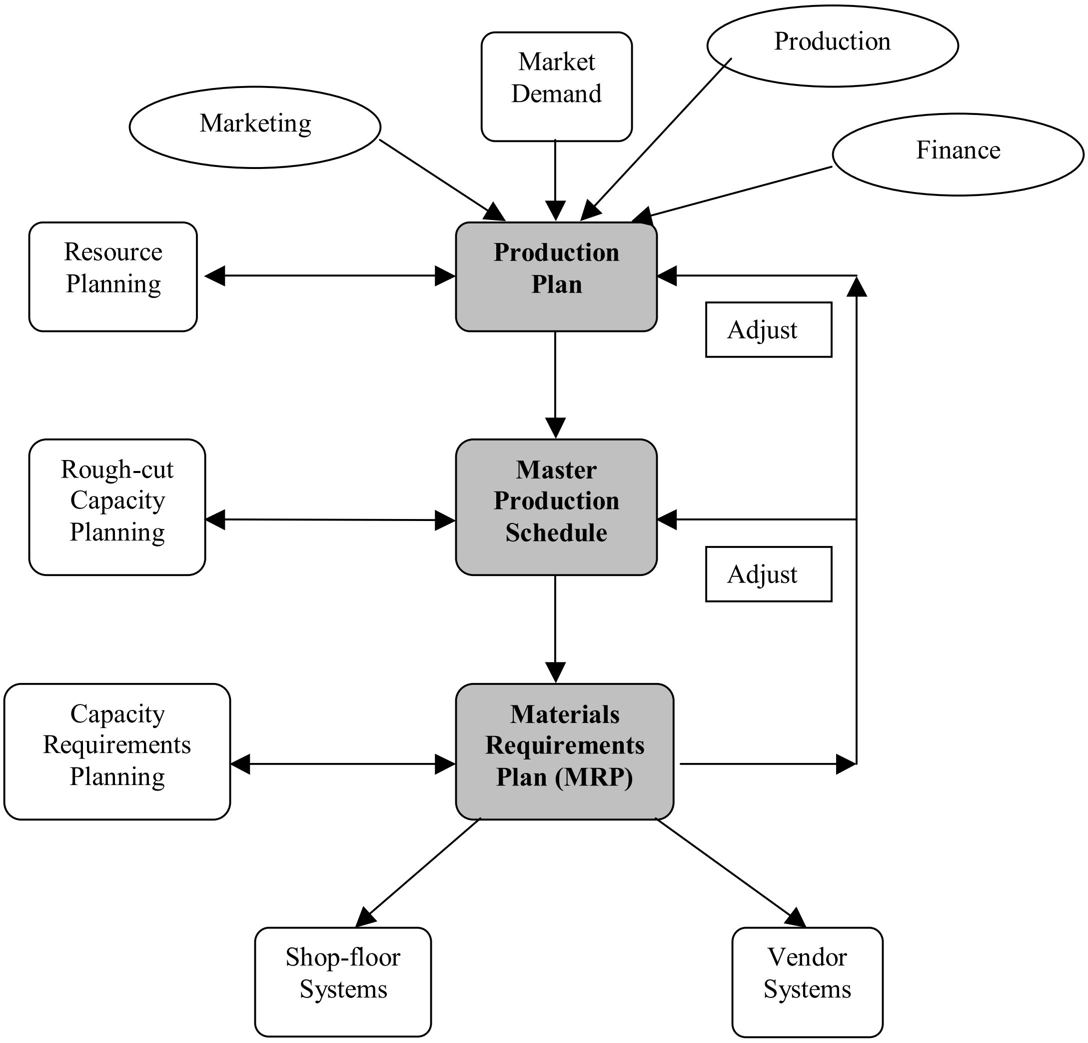

Figure 3. An overview of MRP II

Corrêa and Gianesi (1996) define the MRPII as a calculation system of necessities with the objective of allowing the accomplishment of the time of delivery of the customers' orders with minimal formation of stocks, planning the purchases and the production of items so that they occur only in needed moments and quantities. The major purpose of MRPII is to integrate primary functions (i.e. production, marketing, and finance) and other functions such as personnel, engineering, and purchasing into the planning process. Since it is a company-wide system, MRPII often has a built-in simulation capability that allows the firm to ask "what-if" questions.

In agreement with Plenert (1999), the Japanese JIT environment seems to be the least-cost production control tool, reducing inventory levels and reducing manufacturing lead times. Looking at MRP's basic philosophy, we should be able to focus our scheduling only on what materials are needed, and when they are needed. From the Plenert's experience during a one year research project in South-East Asia, he found that Japan rarely uses JIT outside of Japan, and uses MRP in more of its developing country factories than all other production systems combined, including JIT. Plenert (1999) shows the design and usage differences between MRP and JIT, see Tab. 1.

The most obvious shortcoming in MRP usage is its focus on labor efficiency. Labor is not the resource that we need to be efficient at, especially since it causes inefficiencies in our critical resource, materials. We need to minimize our routings, shortening lead times as much as possible. This does not mean that we only include the value added steps, rather, it means that we should minimize the non value added steps to make them efficient as possible.

Table 1. Differences between MRP and JIT.

DESIGN DIFFERENCES			USAGE DIFFERENCES		
Area	**MRP**	**JIT**	**Area**	**MRP**	**JIT**
Product flexibility	High	Narrow range	Production lead time	Very long	Very short
Order tracking	High degree	None	Production batch size	Large	Small
Data accuracy	High	None	Resource efficiency focus	Labor	Materials
Computational needs	Lots	Minimal	Inventory levels	Large	Minimal
Scheduling flexibility	High	Poor	Set up time	Averaged	Minimized
Shop layout	Flexible	Restricted			

3.3 *Theory of Constraints* - TOC

TOC is a group of principles applied to the organization management, Guerreiro (1996) introduces these principles below: **Balance the flow, not the capacity,** the attentions should be directed to the material flow, not to capacity installed of the resources. Identify the bottlenecks of the system, because they will limit the flow of the system; **The utilization of non bottleneck resource is not determined by its availability, but by any other constraint of the system,** this constraint can occur by limitation in the internal resources or by the limitation of the market demand; **Utilization and activation of a resource are not synonyms,** the utilization corresponds to the usage of a non bottleneck resource according to the capacity of the bottleneck resource. The activation corresponds to the usage of a non bottleneck resource in superior volume to the required by the bottleneck resource; **an hour spent on a bottleneck resource is an hour lost for the global system,** any time spent on the bottleneck resource, decreases the available time for the production; **An hour spent on a non bottleneck resource is nothing, only a mirage.** The entire system works for the bottleneck item, that is, any effort to reduce the *set up* time or to reduce the number of changes of tools in the non bottleneck resource only increases the idle time; **The bottlenecks control the gain and the inventory;** the bottlenecks determines the system flow, and also the level of stocks, because they are measured and located to isolate the bottlenecks of statistic fluctuation. The statistic fluctuations are the result of the occurrence of a series of random events, or out of control. The manufacture involves series of interdependent operations, in other words, certain operation can only be executed when the previous operation in the chain finishes. In this case, the statistic fluctuation does not have the average zero, but the delays tend to propagate along the chain. An example is in Tab. 2 below.

Table 2. Statistic Fluctuation

	A			B		
item	program	real	deviation	programa	real	deviation
1	0-10	0-12	2	10-20	12-22	2
2	10-20	12-24	4	20-30	24-34	4
3	20-30	24-32	2	30-40	34-44	4
4	30-40	32-40	0	40-50	44-54	4

The transference lot might not be and, frequently, should not be equal to the processing lot. The transference lot is always a fraction of the processing lot. The division of the lots allows reducing the transit time of the products, according to Figure 4.

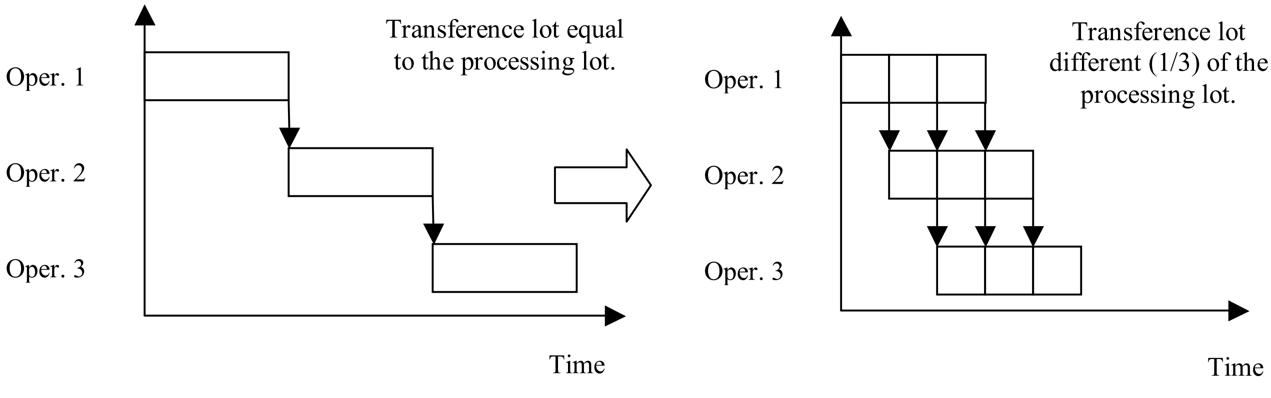

Figure 4. Graphic of lot division

The processing lot should be variable and not fixed, most traditional systems considers that the processing lot is equal in all the operations, they do not respect the situation of the factory and of each operation. TOC defines the size of these lots. **The programs should be established, considering all the constraints simultaneously,** and not sequentially. The *lead times* are a result of the programming and they can not be priority assumed.

4. The Case Study

The company Super S.A assembles a mechanic sub-group for the company Hiper S.A., it is made of: 3 terminals, 3 rivets, 1 base, 1 pivot, 1 washer and a trigger. Hiper S.A has a demand of 2.000 sub-groups per working shift, it implies in the *takt time,* calculated below.
Working time = 8 hs. / shift = 28.800 s / shift
Programmed stops per shift (coffee, toilet, maintenance, etc.) = 20 min / shift = 1.200 s / shift
Available time / shift = 27.600 s
Takt time = 27.600 / 2.000 = 13,8 s

The utilization of MRPII provides through the computer, the quantities and the moments in which the resources (materials, equipment, people, etc.) should be available.

The process can be improved by the *Kanban* production system, which must be applied to inform to the operators the quantity and the version to be manufactured. This production will be made available to the supermarket of the cell and it will be able to be transferred to the stock by the *Kaban* of movement.

Each operation is fulfilled in a distinct work station, and they are defined in Table 3.

Table 3. The operations

Operation	Description	Compon.	Time (s)
A	Assemble	7	17,5
B	Press	2	5
C	Assemble	2	5
D	Press	2	5
E	Assemble	3	7,5
F	Solder	4	20
G	Test	1	5
H	Pack	1	5

Allowing to establish Fig. 5, below:

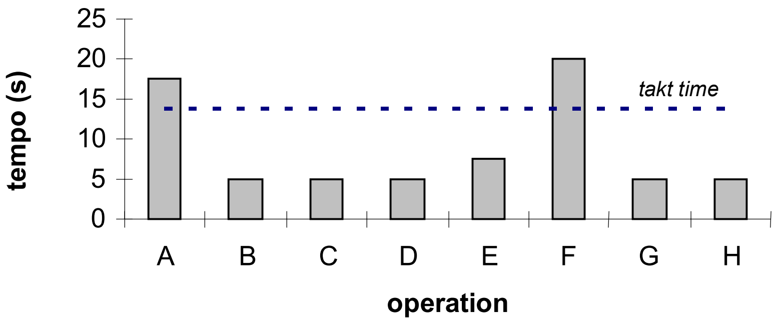

Figure 5. Graphic of the operations X time

In this situation it was possible the maximum production of 27600/20 = 1380 pieces / shift, considering that there is no waste, except the programmed stops.

To answer to the *takt time*, it was necessary to eliminate the constraints that did not allow it to happen. Reduce the time of the operations A and F, for less than 13,8s. In operation A, part of this (7,5 s) was added to operation B that passed to 12,5 and to operation F was divided in two, that is F (10 s) and F' (10 s).

With that, a new table was defined with the operations of assemblage of the sub-group, according to Figure 6:

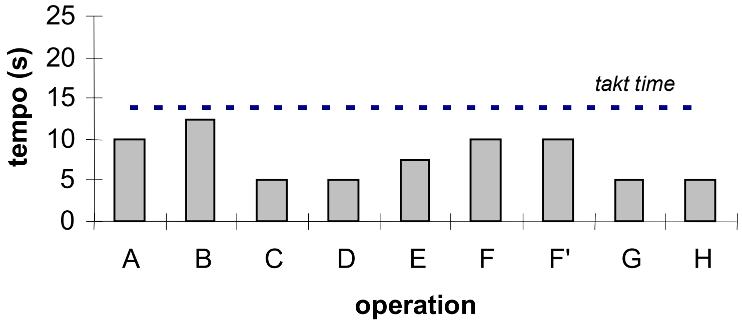

Figure 6. Diagram of the operations X time, modified

Now, it is observed that it is possible to group some operations, seeking the reduction of the work stations and respecting the limit of *takt time*. The activities C+D and G+H were grouped. This is demonstrated in the figure 7, below:

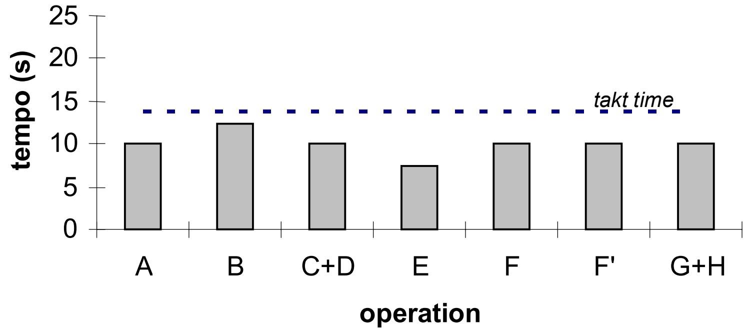

Figure 7. Diagram of operations X time, final.

By this diagram, it is observed a reduction in the quantity of work stations from the initial eight stations that will be converted to nine, and posteriorly will be reduced for seven.

The quantity of operators in the first situation where there was not a balanced production in a line, it was of 8 operators, one for each operation, creating intermediary inventory and idleness of the operators. For this last situation, we have the work in cell. In this one , each operator will execute the entire process, working as a dedicated cell, however with the resources shared by the other operators. Bellow is the calculation of the quantity of workers, according to the cycle time of table 4 and the number of workers of the Equation (2).

Table 4. Cycle time

Operation	Time (s)
A	10
B	12,5
C+D	10
E	7,5
F	10
F'	10
G+H	10
Cycle time	**70**

$$\text{Number of workers} = \frac{\text{cycle time}}{\text{takt time}} = \frac{70}{13{,}8} = 5{,}07 \text{ workers}$$

Equation (2) Number of workers

A problem with very dependent systems from the human factor is the aspect of absence from work. Imagine the first situation where the assembly line with eight operators and an operator is absent, to substitute him/her it is necessary to place another operator with 80% of productivity. Soon, if all the other operators have 100% of productivity, on that day the productivity of the line will be 80%. Whereas in the proposed cell system, there are five operators with 100% of productivity, and an operator is absent on that day, he will be substituted by another operator with 80% of productivity, so the total productivity will then be of 96%.

To implement the multi-functionality in the cell, it is necessary special training so that the operators know the involved operations.

There is a necessity that the operations occur in a patterned way, this way all the operators repeat the operations in the same way, assuring the repetition of the product.

5. Conclusions

The production function in manufacturing industry, supported by an information technology system like MRPII, when it applies the concepts of Lean Manufacturing and TOC, there is an important advantage in the actual competitive and globalized scenario of the business.

The creation of the cell production, through the introduced methodology, resulted in several improvements in the production of the company Super S.A.

There will not be the formation of intermediaries in stock, because each operator will execute the process in a continuing way.

The flexibility of mix and volumes also improves.

When each operator elaborates the entire product, it implicates in the improvement of the indexes of quality and productivity for two reasons: First reason, the individualized control on the operators' activities becomes possible, allowing correcting and training the ones with problems. Second reason, is that this way there is a higher commitment and satisfaction of the operators.

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