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THE LEAN WAY TO COMPETITIVENESS

Jordi Fortuny-Santos
Business Management Department, Universitat Politècnica de Catalunya
61-73, Bases de Manresa Ave. 08242 Manresa (Barcelona), Jordi. Fortuny@upc.edu
Spain

Lluís Cuatrecasas-Arbós
Business Management Department, Universitat Politecnica de Catalunya
31, Jordi Girona St. 08034 Barcelona, lluis.cuatrecasas@upc.edu
Spain

ABSTRACT
Different companies are relocating their production plants from Spain to other countries with lower salaries and taxes to better compete on the basis of lower costs. The aim of this paper is to show that, at least in some cases, the best decision to improve competitiveness is to transform process-oriented plants managed according to the principles of mass production into efficient plants managed according to the principles of lean manufacturing. In this paper, a set of key magnitudes referred to process time are calculated by means of a simple Operations-Time chart and then completed with inventories and costs. This methodology is used twice: the first time on a process-oriented plant, relocated in a low-cost country and the second time on the equivalent lean process in Spain.
Final conclusions show that a lean implementation is more efficient because it is reliable and it has neither activities without added value nor inventories. Relocation strategies bring important savings but they also entail new costs that not always make them so attractive.
Keywords: lean management, relocation costs, cellular manufacturing.

1. INTRODUCTION
Global relocation, delocation or off-shoring are names that describe the move of production plants from North America or Western Europe to countries with an advantage in cost (lower salaries, lower cost of the land, lower taxes…) or in legal regulations (about the environment, the number of working hours…) that finally help to cut costs [1, 2, 3, 4]. An almost recent example that happened in Catalonia could be the move of the Korean company Samsung to Slovakia [5]. This strategy is justified on the improvement of competitiveness based on lower costs but that make possible to lower the price of finished products. But sometimes these companies do not consider that global relocation involves new costs. For example, SEAT, a company of the Volkswagen group based in Catalonia decided to offshore part of its production to its plant in Slovakia but finally found that cars were most expensive there because of logistic costs [6].

As a consequence of this last experience, it is easy to see that it is necessary to consider whether relocation is the only way to cut costs –including the costs caused by the new situation- or there are better ways to bring down costs.

As lean management, which started up as the Toyota Production System, is famous for increasing the efficiency of companies by means of getting rid of all sources of waste and so reducing costs [7] it could be an option to be considered before setting up a new plant abroad.

2. METHODOLOGY AND FINDINGS

We considered a process with 9 operations (see Table 1) where operation P2 needs operation P1 to be finished before it can start (and so on) and where process M needs both processes P and D to be completed to start. These operations were performed on a traditional process-oriented layout with units moving from operation to operation in lots. The process was simulated using an Operations-Time chart and key parameters shown on the right column of Table 1 were found for a production batch of 500 units.

Table 1. Key magnitudes of the process on a process-oriented layout for a production batch of 500 units.

Operation	Time (s)	Number posts	Lot size	Findings about the process
P1	180	3	100	Total lead time = 85,000 s (23.6 h)
P2	90	1	250	First lot finished = 40,000s
P3	120	2	150	Last lot finished = 85,000
D1	60	1	200	Lead time last lot = 85,000 – 24,000 = 61,000 s
D2	48	1	250	Waiting time = 42,000 s
D3	84	2	250	Work in process = 885 units
M1	60	1	10	Bottleneck (P2) cycle time = 90 s
M2	84	1	5	Theoretical capacity = 96,000 units/year
M3	108	2	10	Real capacity = 7,200 units/month

The static parameters of the process are not enough for a full comparison so its capacity to cope with demand is also tested. With a demand like the one in Table 2, sales will be lost when demand exceeds the capacity of the plant (7,200 units), provided there are no inventories of the product while that inventories will pile up when demand is lower that the production rate.

Table 2. Monthly demand of the product simulated. Effects on inventories and sales of a production of 7,200 units per month.

Month	Demand	Inventory	Lost sales
January	8,500	-	1,300
February	8,000	-	800
March	8,000	-	800
April	7,500	-	300
May	6,000	1,200	-
June	8,000	400	-
July	6,500	1,100	-
August	6,000	2,300	-
September	5,000	4,500	-
October	6,500	5,200	-
November	7,000	5,400	-
December	8,000	4,600	-

As it was stated at the beginning, our process is going to be transformed into a cellular process, managed according to the principles of lean manufacturing. Demand is the starting point because the production pace (takt time) is set at the speed required by demand. According to this, takt time is set to 84 seconds. This is main parameter to balance the whole production line. Operations L1 and L2, performed by machines, can depend on a single worker. Operations P3, D1 and D2 can be put together in a U-shaped workcell. As the cycle time of these operations is 83 seconds, the cell will need 5 workers, everyone in charge of all three operations (what is called Nagare or rabbit run).

Operation P4, with a cycle time of 84 seconds, needs an employee. It can be placed isolated on the shop floor, connected to the previous an the next cells but when takt time changes (because demand changes) operation P4 will become a part of one of the workcells.

Finally, the assembly process M, with operations M1, M2 and M3 can be carried out in a U-shaped cell by means of three employees being two of them in Nagare, in charge of M1 and M3 with a cycle time of 84 seconds.

As we did with the process-oriented layout, the cellular process can be simulated with an Operations-Time chart. One of the features of lean management is the flow of parts. It means that batch-and-queue processes have been substituted by a regular one piece flow from operation to operation. Production batches (production orders) also tend to be lower if compared with traditional process-oriented plants, but we have simulated a production batch of 150 units and another of 500 units in order to compare to previous data on Table 1. Results can be seen in Table 3. Lean manufacturing achieves higher efficiency with less waiting time and higher flexibility with less employees.

Table 3. Monthly demand of the product simulated.
Effects on inventories and sales of a production of 7,200 units per month.

TRANSITION FROM A CONVENTIONAL PRODUCTION SYSTEM TO LEAN MANAGEMENT				
M a g n i t u d e s	**Conventional Implement.**	**Lean Manufacturing Batch 150**	**Batch 500**	**Total change**
Total Lead time (hours)	23.6	4	12.2	**- 48%**
Lead time for 1st unit (hours)	11.1	0.4	0.4	**- 96%**
Average stock in process (u.)	885	9	10	**- 99%**
Waiting time in posts (h.)	11.6	0.1	0.08	**- 99%**
Cycle time range (sec.)	90-42 = 48	84 – 83 = 1		**- 98%**
Number of workplaces	14	10		**- 29%**
Productivity (units per hour)	40	43		**+ 7.5%** [with **less** workers]
Flexibility	Non-existent	A lot		**+100%**

The dynamic performance of the cellular production system is also much better because this layout has been designed to cope with the changing demand without inventories.

Finally, costs of both strategies can be compared. The following cost types have been taken into account: 1. Cost of purchased materials and components (including regular transportation cost) (Cp). ; 2. Charges for rush courier services and overnight transportation (Cc), allocated to finished product; 3. Charges, as a proportion of the unitary costs, for the time lost in activities that do not give rise to finished goods or, otherwise, manufactured products are faulty (Ct); 4. Hourly labor cost (L) of each of the production employees (N). L can be split between low salaries and high salaries (Ll and Lh); 5. Wages of indirect workers (Iw) as a proportion of direct labor costs; 6. Indirect labor needed for external logistics and physical distribution to the market. If the market of the product is far from the off shored production plant, some of the employees in charge of distribution tasks will be located near the market, in countries with high salaries (Ieh) while the rest are in the low salary country (Iel); 7. Indirect employees needed in post-sales service and to deal with claims and customer guarantees, in countries with low and high salaries (Ich, Icl); 8. Costs due to equipments, machines, systems and facilities, and other cost that can be allocated to the product (Co); 9. Real state costs (Cr); 10. Daily costs due to stocks (Cs); 11. Stocks of finished products in transit from the production plant to the market. Their volume can be quantified as the production amount (P) dispatched per time unit (T) multiplied by the time the journey takes (J); 12. Safety stocks (SS) for urgent deliveries can be estimated as a percentage of the total lead-time that is enough for safety purposes (ts); 13. We must take into account the stocks of finished product (Sf) in the production plant, due to the time lag between production and sales (tl); 14. Cost of stocks of unsold products (Cu). A certain percentage

(U) of the total stock of finished goods will finally become obsolete, unmarketable or just unsold . We can consider it as a monthly percentage of the total amount of finished product inventories.

Equation 1 determines the basic cost (CB) of every unit of finished product.

$$CB = Cp + \frac{L \cdot N \cdot T}{P} + \frac{T}{P} \cdot \left[\left(Iw \cdot N + Iel + Icl \right) \cdot Ll + \left(Ieh + Ich \right) \cdot Lh \right] + Co + Cr \qquad (1)$$

The total production and distribution cost (CT) for every unit can be found according to equation 2.

$$CT = CB \cdot \left(1 + Cc + Ct\right) + Cwip \cdot WIP \cdot LT + Cs \cdot \frac{P \cdot J}{T} + Cs \cdot SS \cdot ts + Cs \cdot Sf \cdot tl + Cu \qquad (2)$$

If we solve equations 1 and 2 for both production strategies taking into account values according to our experience and values that come from the previous simulations, results show that basic cost is higher in the lean plant because of the lower salaries in the relocated plant. But when all costs al considered, costs are lower in the lean plant. Gross operating margin is also bigger in the lean plant because, in addition to lower costs, we have higher sales (there are no lost sales).

3. CONCLUSIONS

According to this case study, lean management and cellular manufacturing techniques contribute to a more efficient production plant by means of a reduction of waste -including reduction of inventories (work in process and finished goods) and reduction of waiting times-.

This philosophy and its implementation result in a flexible plant that can cope with demand without inventories of finished products and without lost sales, with motivated multiskilled employees that can carry out more than one single operation, adapting production cycles to takt time (the speed of demand). There are no lost sales because the capacity of the plant is enough to produce what has been scheduled.

These benefits of lean manufacturing can offset the advantages of relocation, because relocation only focuses in low salaries but doesn't consider a whole optimization of the production process. What's more, sometimes delocation entails costs that were not expected. Finally, the combination of low costs and higher sales results in much higher profits.

According to these figures, a lean manufacturing strategy can be better, at least in some cases, than an off shoring strategy to improve the competitiveness of the firm.

The method described in this paper (description of all operations, simulation, deduction of inventories and delays, and calculation of 14 types of cost) has proven to be a useful decision tool when a company is considering the possibility of moving abroad.

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