KANBAN SHARING AND OPTIMIZATION IN BOSCH PRODUCTION SYSTEM

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Keywords: Kanbans, Cellular manufacturing system, Information and resource sharing, Optimization, Bosch production.

Abstract: Information sharing and optimization is a key factor for effective knowledge management, which is based on data exchange, communication and technological infrastructures and standardization, being essential in order to remain competitive in the today's global market scenario. In this context, human functions are also relevant, and in this work we refer to the interaction of both in the optimization of Bosch Production System. Therefore, the aim of this paper consists on presenting the minimization of kanbans, when sharing this information in a proposed cellular manufacturing environment in Bosch production, in order to enhance workflows and material and work in process management as well as human interactions and production performance and productivity.

1 INTRODUCTION

Knowledge management (KM) is concerned with the analysis and technical support of practices used in an organization to identify, create, represent and enable the adoption and leveraging of good practices embedded in organizational processes. Effective knowledge management is an increasingly important source of competitive advantage, and a key to the success of contemporary organizations.

KM focuses on some core components including: people, processes and technology and an important concern aims at taking an organizational focus, in order to optimize organization aspects and workflows.

In order to accomplish effective KM information sharing (IS) is a key element. Increasingly important information is enabled through kanbans technology implementation, and in this paper we aim at optimizing it, in order to enable an improved knowledge management scenario in Bosch production.

Information sharing and optimization is a key factor for effective knowledge management, which is based on data exchange, communication and technological infrastructures and standardization, being an essential element to remain competitive in the today's global market scenario. In this context, human functions are also relevant, and in this work we refer to the interaction of both in the optimization of Bosch Production System (BPS). Therefore, the aim of this paper consists on presenting the minimization of kanbans, when sharing this information in a proposed cellular manufacturing environment in Bosch production, in order to enhance workflows and material and work in process management as well as human interactions.

Kanban, a Japanese word, means a board or card with visual information. In TPS (Toyota Production System) kanbans are used to conduct the information flows in the manufacturing system in order to pull the material flows from upstream to downstream. The operations of various types of kanban systems were documented thoroughly by Monden (1993) and published even before the TPS has caught the attention of the majority of U.S. manufacturers.

In order to better summarize this contents, this paper is structured in 5 sections. Next, in section 2 we will briefly refer to Lean a Just-in-time (JIT) management and related technologies. In section 3 we present a literature review about some work carried out in this areas and in section 4 the implementation of kanbans and related technologies to Bosch production is briefly described and some important advantages are pointed out comparing the proposed scenario with the existing one. Finally, in section 5, some conclusions are reached.

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2 LEAN AND JIT MANAGEMENT

Levy (1997) defines lean production as "a tightly coupled flexible system" centered on JIT, delivery and low inventories. To achieve this requires the elimination of defects, supply production problems and other delays in the product pipeline. It also requires high levels of responsiveness to changes in demand from customers. To this end, continuous improvements are necessary in component quality, in production control, reduction of lead times (as well as lot sizes and set-up times) and shortening of product development cycles.

To work effectively lean production requires a high coordination between suppliers and customers, rapid flows of products and information and JIT deliveries.

It is difficult for a modern manufacturing system to make the many different kinds of available products in low quantities, with high quality and low cost at just the right time. Moreover, in order to survive in the global competitive market manufacturing enterprises must increase their productivity and profitability through greater shop floor agility. As the manufacturing environment from mass production through to flexible and lean manufacturing moved towards an agile manufacturing philosophy, there was a drastic impact on all manufacturing-related activities (Kidd P.T., 1995, Cheng K., 1998). Therefore, manufacturing systems must adapt themselves at an ever-increasing pace to incorporate new information technology and new products as well as new organizational architectures.

A kanban system facilitates lean principles in a simple and effective way. While reportedly successful in many manufacturing firms, the conventional kanban systems using physical cards suffer from human errors, limited tracking capability, and so on. To make the information flow leaner, software providers add new features to their existing programs for manufacturing systems to computerize kanban activities. As Web-based technologies advance rapidly, developing an entirely Web-based kanban system appears to be feasible and promising.

Kidd (1995) established that a kanban system typically performs efficiently and effectively in shop floor control when the demand is repetitive and stable. It also applies to adjacent suppliers, customers, and even within a global supply chain to facilitate just-in-time (JIT) delivery (Cheng K., et al, 1998).

In the past decade, lean manufacturing concepts have shown significant influence in the way jobs are performed. Eliminating non-value added activities in response to customer's true demand, i.e., value, makes manufacturers leaner and eventually stronger in the marketplace.

Levy (1997) summarized lean thinking into value, value stream, flow, pull, and perfection. Among them, the pull concept is the key to carrying out a smooth flow of value stream. It aligns production targets throughout the system with end customer's demand and hence minimizes inventory and work-in-process (WIP).

As lean manufacturing gains popularity globally, the impact of implementing pull or kanban system becomes clearer. Mortimer (2008) summarized the major advantages of implementing pull system, including: (1) shorter lead time, and hence, higher flexibility to demand changes; (2) reduced levels of inventory and other wastes: (3) capacity considerations that are restricted by the system design, and (4) inexpensive to implement. Moreover, Hirano (2009) compared the pull-and-push systems in terms of production planning and control and conclude that pull system is more efficient, easier to control, more robust, and more supportive of improving quality. In general, implementing kanban system for pull concept contributes to a higher level of customer satisfaction by providing products with lower cost, shorter lead time, and more stable quality, while the supplier enjoys a more manageable production environment with lower WIP and inventory.

From the viewpoint of implementing kanban system in practice, the "paper card" system is known to be simple and effective, and requires little investment.

Fax and e-mail are commonly used as the means of dispatching kanbans among distant sites, when delivering physical kanban is no more considered efficient. For production control, the number of kanban can be adjusted within a range to meet the capacity requirements. Using demand leveling, the pull system remains stable when demand fluctuates in a certain range. When the product variety, demand fluctuation, capacity requirement, or distance between facilities drops out of the acceptable range, the kanban system becomes too complicated and difficult to manage. As a result, mistakes arise, and significant workforce can be wasted on managing and maintaining the kanban system.

Beside the effectiveness of information delivery, visibility is another critical issue of the paper-based kanban system. Within a workstation or production cell, the conventional kanban system enhances visibility of workflows by the paper cards.

"Seeing" the flow of value stream is the key to building a lean system. Information technologies provide the tools that can greatly enhance the visibility of a kanban system. Therefore, e-kanban system with real-time data transaction and monitoring becomes the natural solution for eliminating the weaknesses of the kanban systems.

While reportedly successful in many manufacturing firms, the conventional kanban systems using physical cards suffer from human errors, limited tracking capability, and so on. To make the information flow leaner, software providers add new features to their existing programs for manufacturing systems to computerize kanban activities. As Web-based technologies advance rapidly, developing an entirely Web-based kanban system appears to be feasible and promising.

Ohno (1988), Monden (1993), and Slack (2007) stated that a kanban system, when well applied in organizations has as main advantages: eliminating waste, enhancing control levels in the shopfloor, through the decentralization and simplification of operational processes; lead time reduction; improvement of the company's reactive capacity to its clients; stock level adjustment to regular oscillation of demand; reduced wip stock; elimination of intermediate and safety stock; and production lot size reduction and all these aspects and advantages motivated this work.

2.1 JIT and Kanban Calculation

"The JIT production system is a market-oriented production system that rests entirely on the foundation of serving client needs. JIT, or "Just in Time" refers to the timing of production flow; goods are delivered to the manufacturing lines just in time to be used, just in the immediately quantities and just to the production process that need them. Saying "in time" is not enough, since parts can arrive at processes a week or to two prior to their use and still be there "in time". That is why the most important word in Just-In-Time is the first word "just". Goods need to arrive within minutes, not days or weeks, of their use on the production line. Only then can we eliminate waste in such forms as overproduction, waiting for late deliveries and excess inventory" (Hirano, 2009)

In the literature several different kanbans calculation formulas exist, namely the ones put forward by Shingo (1989), and Monden (1993).

In the opinion of Shingo (1989), the determination of the number of kanbans is far away from being as important as the improvement of the production system in order to minimize the number of kanbans. Shingo (1989) presents a simple formula for the determination of the number of kanbans necessary:

$$K = \frac{Q + \alpha}{n} \tag{1}$$

K = number of kanbans;
Q = quantity of products in batch production;
α = minimum security stock level;
n = quantity of products transported on a pallet.

Monden (1993) presented a wider formula for kanbans calculation:

$$k = \frac{d\,(te + tf)}{c}\,(1 + \beta) \tag{2}$$

k = number of kanbans;
d = demand on the planned period;
te = waiting time, defined from the time since the necessity of production is defined until effective production starting time;
tf = time it takes to produce a container (one kanban) of products;
β = safety factor (around 15%);
c = container capacity.

3 LITERATURE REVIEW

In the late 1980s and early 1990s, researchers started to intensively investigate the mechanism and benefits of kanban systems. Various studies were carried out, such as simulation analysis, analytical modeling, system re-design, and so on (Askin, R. G., et al, 1993, Slack, 2007).

Various types of kanban systems and related techniques have been developed at Toyota (Monden, Y., 1993, Shingo, S., 1989). The system can be applied internally on a shop floor and also externally between distant facilities.

E-kanban systems have been developed based on existing ERP (enterprise resources planning) systems, electronic data interchange (EDI) connections, and web-based technology (Cheng, K., et al., 1998, Wan, H. et al, 2007, Ming P. T. and James T. Lin, 2004). In order to support the kanban activities, providers of ERP systems started to extend their products with pull or kanban modules. A few other e-kanban systems have also been developed recently by software providers, including Datacraft Solutions, eBots, SupplyWorks, among others (Monden, Y., 1993).

Even Toyota, the creator of the kanban system, has adapted an e-kanban system for sending external pulling signals to distant suppliers (Ohno, T., 1988).

The paper presented by Ming P. Tsai and James T. Lin (2004) presents advantages, limitations, and challenges of web-based kanban systems. They developed an experimental program based on popular web programming platform and technology, based on PHP+MySQL. The server-executed program features cross-platform compatibility, real-time tracking and performance monitoring, and greatly enhanced information contents compared to physical kanbans.

Therefore, human errors were minimized by the automated transactions; nevertheless, the interfacing and data maintenance still required further research efforts (Hung-da Wan, F. Frank Chen, 2007).

Rothenberg (2004) reported that some printing companies that implement the Lean Production methods have been successful using the 'pull' or kanban in some specific segments of their business. Generally, in business it is important to implement a kanban system to produce only the quantity ordered, and managing production under Just-in-time principles.

Lean and JIT technology can also greatly profit from cell systems and Hyer (1984) collected data on 20 U.S. firms. A detailed questionnaire was employed to gather information on the costs and benefits of cellular manufacturing. A large majority of the respondents reported that the actual benefits from implementing cellular manufacturing met or exceeded their expectations. Specific savings generally occurred in reductions of lead times, throughput times, queuing times, setup times, work in process, labor costs, material handling costs, and in easier process plan preparation.

4 BPS AND KANBANS

The main activity of Bosch Car Multimedia Portugal, Lda. Is the production and assembly of car-radios. The production process of this enterprise is, in general, divided in two main areas: An upper level, composed by the automatic insertion area of components and an area for storing the material needed in this area.

The lower level is composed by the manual components insertion area and by several storage areas.

The automatic components insertion area integrates several assembly lines, which are dedicated to the production of Pressed Circuit Boards (PCB), namely: Main Boards, Switch Boards, Antennas and Tuners.

The production process starts in the automatic components insertion area, where the automatic assembly of the PCBs takes place, after which it passes to the final assembly, where the manual components insertion process is carried out in PCBs.

4.1 Existing Scenario

The production programming is performed in the Bosch Production System (BPS) in two steps. First an annual plan is established and next a monthly based plan is prepared. Based on these plans, the daily production programming is determined in detail. The information about the daily production programming is managed by the kanban system, by using information cards. Through this system, which is based on pull production principles, the previous process produces just the quantity to be used in the subsequent process, therefore, eliminating the necessity of planning the production on all production processes and thus avoiding overproduction.

In the BPS, the type of kanbans used for caring out this work was the cards attached to the material containers.

The material received from the storage area is removed from the supplier package and put in standard boxes, which are passed to the production lines by the “Milkrun”. The kanban card goes attached to the boxes, identifying them.

In the entry point of each production line, in the automatic components insertion area there is a kanbans board, as illustrated in Figure 1, where the batches of each product are defined and a rule about production planning.

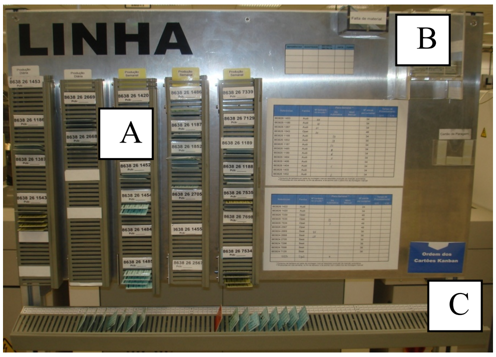

Figure 1: Kanban board.

This kanbans board is divided in three important areas. One area refers to the composition of the batch for each product, indicated by letter A.

Another is the kanbans buffer (B) and finally the planning ruler, indicated by a letter C.

The kanban systems works as follows: first each time kanbans arrive to the board, coming from production they are inserted in the batch composition area of the corresponding product.

Next, at the time the number of batches is reached, i.e., when this area is full, for a given product, the cards are placed in an existing box (buffer). In this same box there is a red line, and once it is reached indicates that someone responsible has to pay attention to this information (Figure 2).

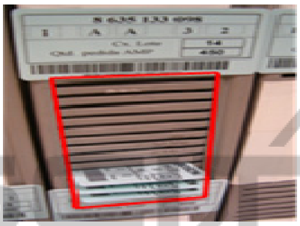

Figure 2: Product lot size.

Once the kanbans are put into a box they are used based on the First In First Out rule, so that the first kanban inserted into the box is also the first one coming out from it.

After being removed from the buffer, the kanbans are put into the programming ruler placed on the bottom of the board, where the production programming of the three daily production periods is expressed, based on the production times referred on each kanban. This ruler is divided into several 5 minutes based spaces. Notice that the kanbans distribution on the programming ruler is performed by a production line worker each time a new work period starts.

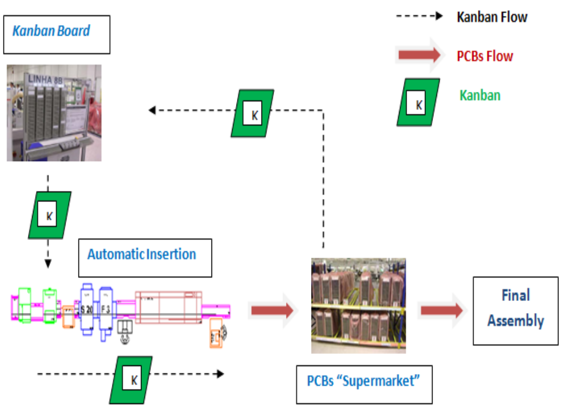

Figure 3: Kanban flow in the production line.

After all the previously described steps, the kanban follows to the production line, being attached to a container on the end of the line, from which it follows to the supermarket, where it is going to wait for being necessary on the manual insertion area. Once the containers are transported to the final assembly area the kanbans are placed back on the board in order to start a new production cycle. Figure 3 illustrates the kanban and the PCB flows in the production line.

In order to illustrate the kanban calculation let us consider an example about a PCB product, which we are going to refer as a "Type I". The daily based requisites (PR) of this product are around 1560 units/day, which corresponds to the quantity that BPS has to produce on a daily basis.

The standard number of pieces (SNP) is 120 units. This means that one box with 120 units will correspond to a kanban.

Production is based on a model that includes three work periods per day (24 hours = 1440 minutes), including intervals of 90 minutes (including breaks) and intervals of 187 minutes, including stopping periods, namely due to line stopping, due to technical problems or related to quality requisites. This conducts to an effective production time (NPT) of 1163 minutes (1440 min – 90 min – 187 min = 1163 min).

The processing time of one piece is 30 minutes and the production line cycle time is 15 seconds.

Let us consider a client that needs the product type I every day. So, the quantity removed within the period (WA) for the products are: 1560 units/day. The recharging time (RT loop) for the product type I is of 830 minutes.

Table 1 presents the values previously referred.

Table 1: Product type I main values (a).

	PR	SNP	WA	NPT	RT loop	LS	ST
Tipo I	1560	120	1560	1163	830	1560	18

Based on the values presented in Table 1 we can now calculate the values of RE, LO, WI, TI and SA, shown in Table 2.

Table 2: Product type I main values (b).

	RE	LO	WI	TI	SA	K
Tipo I	10	12	0	0	13	35

The time gap coverage (TI) is zero, due to inexistence of difference between the time shift model of the customer (Tc) and the supplier (Ts). The value of withdrawal peak coverage (WI) is also zero once the quantity removed in the periods; the withdrawal amount (WA) is the same as the lot size (LS).

Therefore, we have 35 kanbans for the product type I and 33 kanbans of product type II.

Based on a demand on the first month of 24.780 units, the number of kanbans necessary at the end of the month will be 554 units. Next we present a graphic expressing the number of kanbans necessary at the end of each month on a six month period.

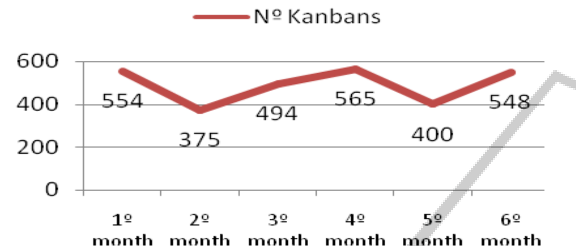

Figure 4: Number of kanbans for six months.

At the end of the six months period the total number of kanbans necessary was 2.936 kanbans.

The Kanban system is an information system to control harmoniously the production quantities in every process (Monden 1983).

The term kanban has sometimes been used as being equivalent to “JIT planning control” or even to the whole of JIT, However, kanban controlled is a method for operationalizing a pull-based planning and control system. It is sometimes called the “invisible conveyor” which controls the transference of material between the stages of operations (Slack et al, 2007).

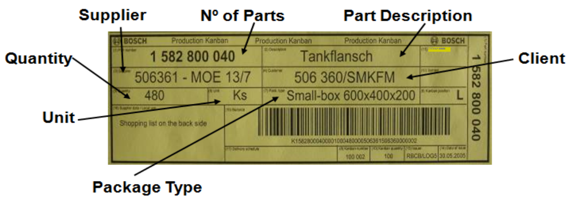

Figure 5: Kanban example.

Shingo (1989) stated that the determination of the number of kanbans is yet very far away from being as important as the improvement of the production system in order to minimize the number of kanbans.

Besides that, several formulas have been put forward for determining the number of kanbans which consider forecast factors, namely demand forecast, and also products processing and waiting times between processes.

The BPS formula used to calculate kanbans (K) is as follows:

$$K = RE + LO + WI + TI + SA \tag{3}$$

Where,

$$RE = (PR \times RTloop) / (NPT \times SNP) \tag{4}$$

$$LO = \frac{LS}{SNP} - 1 \quad \text{, If LS>SNP} \tag{5}$$

$$WI = \frac{WA - LS}{SNP} \quad \text{, Only if WA>LS, else WI=0} \tag{6}$$

$$TI = \frac{PR}{NPT \times SNP} \times |Tcustomer - Tsupplier| \tag{7}$$

$$SA = \frac{PR \times ST \times 60}{NPT \times SNP} \tag{8}$$

RE - replenishment time coverage
LO - lot size coverage
WI - withdrawal peak coverage
TI - time gap coverage
SA - safety coverage
Tc - shift time model of customer (minutes);
Ts - shift time model of supplier (minutes).
PR – requirement per period [pieces/period];
RT loop – replenishment lead time [minutes];
NPT – working time [minute/period];
SNP – standard number of parts per kanban [pieces];
LS – lot size [pieces];
WA – withdrawal amount [pieces/period];
ST – safety time (hours);

At the entry point of each production line, in the automatic insertion area is planned to exist a laser machine for printing codes (bar code 1D and data matrix code 2D). In the existing scenario only three lines are already integrating the laser machine, but in the future, in order to enable the BPS to satisfy the total demand, a total of 12 lines, and each one integrating a laser machine will be necessary to implement. These codes are important for enabling the operators to identify the PCBs, in the on going processing along the processing system, and in the screening and programs selection on machines in the automatic and in the manual insertion areas, therefore contributing to the improvement of production control and to the final product quality.

These lines are characterized as common production lines, where the product enters on the beginning of the line and subsequently passes from one work centre to the next one, without skipping or re-entering any one, and maintaining, therefore, a typical straight forward production flow (Baker e Trietsch, 2009, Black, J. T., 1991).

Due to some relevant inconveniences detected on the existing BPS lines there was a need to propose another kind of production system to supply the automatic insertion area, which is going to be described in the next section. Figure 8 shows the location of the production lines, which are 7 and each one includes the laser machines as well as a common local stockage area.

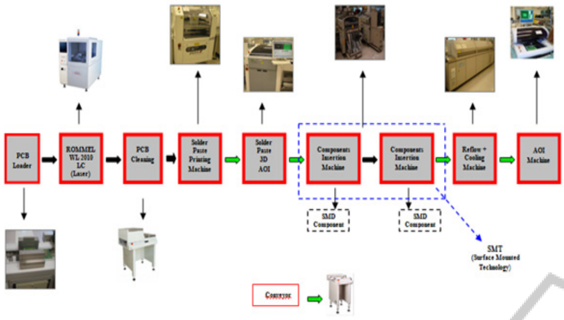

Figure 6: Production line phases.

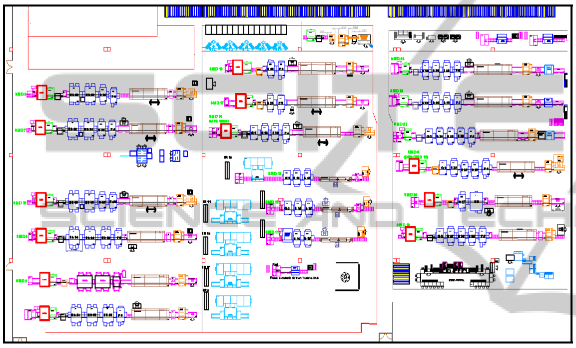

Figure 7: Kanban-line system layout.

4.2 Proposed Scenario

The existing BPS scenario composed by production lines revealed some significant disadvantages for the company, namely in terms of the high investment that had to be made for acquiring the 12 laser machines. Another disadvantage about the lines arises from the lack of flexibility of those production systems, as they do not enable to rapidly adapt to changes in order to satisfy different kind of client demands and different products, and the consequent changes on the product design and processing requirements (Black, 1991).

Another problem arises from the fact that if one machines stops working this may cause the complete production stopping (Slack et al, 2007).

Therefore, the company presented a new proposal, which considers modifying the production system to a cellular manufacturing system. In this kind of system instead of having one laser machine per line, and 12 lines, we only have to integrate 7 lines, disposed as a cell, and the corresponding 7 laser machines. So, we reduce in 5 lines and 5 laser machines, in the new scenario. Therefore, the company has to buy only 4 new laser machines, to complete the 7 necessary for serving the automatic insertion area, as 3 of them already exist. So, in case of maintaining the production lines scenario the company would have to buy more 9 laser machines, instead of 4, which would represent a big investment requirement.

The proposed cell configures typical characteristics of manufacturing cells, including some typical aspects that characterize the so called just in time cells (JITC) and the quick response manufacturing cells (QRC).

The JIT cells are well known under the scope of JIT principles and objectives, namely, zero defects, zero setup times, zero stocks, zero extra manipulations, zero breakdowns, and zero deadlines and also unit lot sizes (Singh, N. et al, 1996).

Nowadays it is convenient to use JIT cells, as they are wel suited for integrating group technology features and principles (Suri, R., 1998), therefore, being able to adapt very well to products families production, which is quite adequate in the BPS, in order to fulfil the requirements of producing PCBs product families. PCBs belonging to a same family share several kind of similarities, namely related with, processing and manipulation requirements, up to geometrical and dimensional and/or materials related similarities.

Once BPS faces a growing necessity to satisfy a wider range of product specifications and differences, it turns out increasingly more important to be able to easily and fast adapt and change the production system and processes in shorter time periods and this flexibility and quick response are some of the most relevant characteristics enabled by manufacturing cells (MC). (Hyer, N., 1984). Moreover, MC also enable reaching better product quality levels at the same time as productivity is maintained at competitive levels and material transportations and stock levels are minimized (Singh, N. et al, 1996).

Regarding the relation with clients, this kind of manufacturing environment also suits very well, as cellular the quick time model also aims at enabling reduced production and delivery times of products combined with offering a widened range of product differences, in order to meet the costumers needs and product specifications, in increasingly more reduced due dates (Suri, 1998, Slack et al, 2007).

The proposed layout for the automatic insertion area is presented in Figure 9 and shows the location of the proposed manufacturing cell. As we can observe, this proposal led to the need of an additional area of about 529 m2, for implementing the cell.

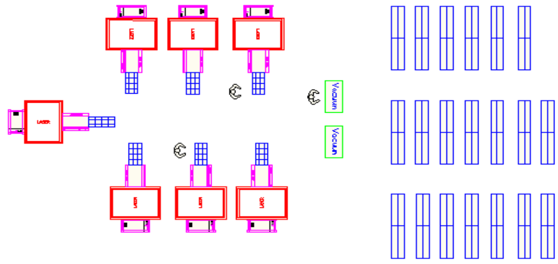

Figure 8: Cell.

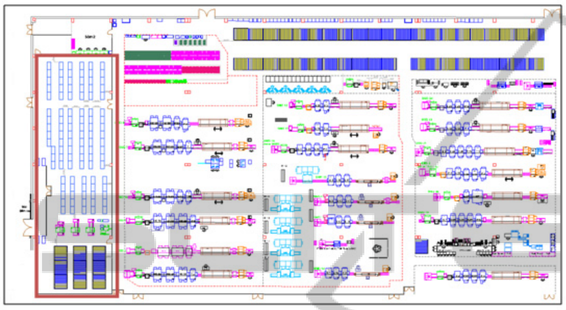

Figure 9: Automatic insertion area layout.

When the final assembly need material coming from automatic insertion area the containers placed in the stockage area, located at the end of the automatic insertion lines are transported, through milkruns, to the final assembly, were the final PCBs processing step takes place. Therefore, only when the containers are transported to final assembly kanbans are released in order to go back to the kanbans board and start a new cycle.

In a similar way, when the automatic insertion area requests material to the cell the materials grouped in the local storage area (the so called supermarket) located at the end of the manufacturing cell, are transported to the lines, where the automatic components insertions in the PCBs takes place. Therefore, every time a kanban returns from the supermarket to the board it is incorporated in the corresponding product area in order to constitute a new product batch. Once the product batch level is reached the corresponding cards (kanbans) are put on its buffer, which is a box, where the cards are being removed accordingly to the FIFO rule.

After being removed from the buffer, the kanbans are placed into a programming rule, located at the bottom of the kanban board, where the production programming is establisher for a rage of three daily working periods, based on the production times referred on each kanban. After leaving the programming ruler the kanban follows through the whole line and cell being attached to a container at the end of line and the cell and moving towards the supermarket, where it waits until it is necessary in the automatic and in the manual components insertion areas.

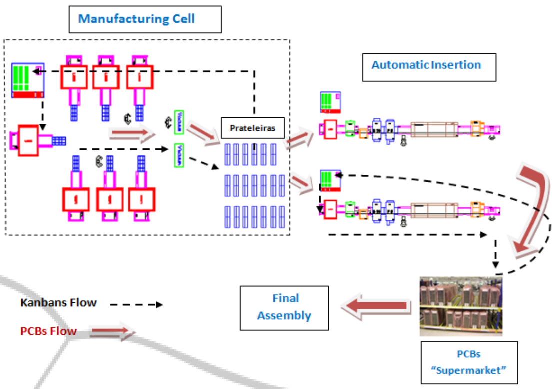

Figure 10: Cell kanban system.

In order to enable to establish a better data comparison the same PCBs example used for the line case is going to be used for the proposed cellular manufacturing case.

In the proposed scenario only the NPT and the RT loop values are different. This is due to proposed manufacturing cell environment, which enables setup and processing time's reduction. Therefore, the net production time (NPT) increases but the replacement time reduces and at the end we obtain a reduced product processing time (25 minutes) and cycle time (9 seconds), as shown in Table 3.

Table 3: Cell parameters calculation

	PR	SNP	WA	NPT	RT loop	LS	ST
Tipo I	1560	120	1560	1330	659	1560	18

With these values we were able to calculate the associated RE, LO, WI, TI and SA values as follows.

Table 4: Cell kanbans calculation

	RE	LO	WI	TI	SA	K
Tipo I	7	12	0	0	11	30

As we can observe in Table 4, the number of kanbans reduced from 35 kanbans to 30 kanbans. This corresponds to reducing 5 kanbans per day and, therefore, a reduction of 100 kanbans per month (20 working days), maintaining the product demand. Thus, in a range of 6 months we are able to obtain a significant reduction of around 600 kanbans.

The kanbans reduction is due, on one hand, to the increase on the NPT and to the reduction on the cell replenishment time.

Ohno (1988) referred that the number of kanbans reduction led to the reduction of the intermediate and final stocks levels, enabling a better adjustment to the regular demand variation. Moreover, Shingo (1996) stated that eliminating stocks reduces down to 40% on labour costs.

For the proposed cell scenario the same forecast analysis was carried out as for the line case, based on the same product data, covering a range of 6 months, and the results obtained are expressed in Figure 11, which shows that at the end of this planned period a total of 2.581 kanbans was obtained.

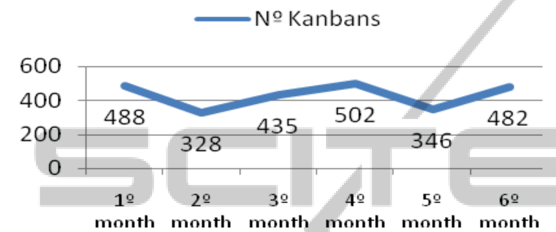

Figure 11: Number of kanbans in the proposed cell.

Comparing the results obtained for the proposed cellular manufacturing system with the existing line system we can observe that the total number of kanbans reduced significantly. At the end of the six months period analysed, the number of kanbans reduced from 2.936 in the line scenario down to 2.581 (less 355 kanbans) in the cell scenario.

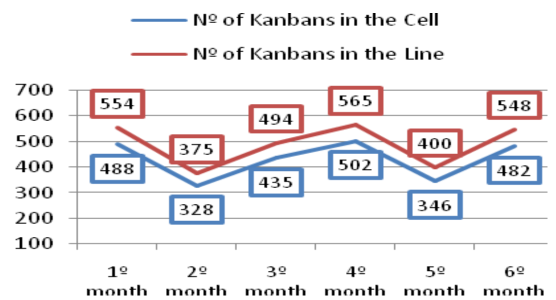

Figure 12: Total number of kanban comparison.

In Figure 12 we can observe the variations of the number of kanbans, along the six month period, in both scenarios simultaneously for a better comparison. Therefore, we were able to obtain a reduction of around 12 % of the number of kanbans necessary in the proposed cell scenario at the end of the six months (from 2.936 to 2.581). This is mainly due to the increase of the net production time (NPT) and to the reduction of the replenishment time (RT loop) in the proposed cell system.

As shown in Figure 12 it is expectable that product demand suffers some variations from month to month. Therefore, when a demand increase occurs is it normal to also have an increase in the number of kanbans necessary, and vice versa. Ohno (1988) stated that fluctuations of around 10 to 30% may be managed without significant changes on the number of kanbans necessary. Nevertheless, the real implementation is the most reliable indicator and the kanbans calculations will change accordingly to the company's nature.

On the other hand, regarding the production system itself, Black (1998) already stated that the main advantage, even in terms of the umber of kanbans, arises from the implementation of cellular manufacturing systems, instead of production lines, mainly due to it's increased flexibility, i.e., the greater capacity that this kind of production system presents to quickly react to changes, namely the ones caused by externally imposed changes, where variations on the demand is included, and also internal ones, related to product project changes and changes due to an increased variety of products.

The advantages derived from cellular manufacturing in comparison with traditional manufacturing systems in terms of system performance have been widely discussed by Askin et al (1993) and Singh (1996). These benefits have been established through simulation studies, analytical studies, surveys, and actual implementations and they can be summarized as follows:

- Setup time is reduced. A manufacturing cell is designed to handle parts having similar shapes and relatively similar sizes. For this reason, many of the parts can employ the same or similar holding devices. Generic fixtures for the part family can be developed so that time required for changing fixtures and tools is decreased.
- Lot sizes are reduced. Once setup times are greatly reduced, small lots are possible and economical. Small lots also smooth production flow.
- Work-in-process (WIP) and finished goods inventories are reduced. With smaller lot sizes and reduced setup times, the amount of WIP can be reduced. Askin et al (1993), showed that the WIP can be reduced by 50% when the setup time is cut in half. In addition to reduced setup times and WIP inventory, finished goods inventory is reduced. Instead of make-to-stock systems with parts either being run at long, fixed intervals or random intervals, the parts

can be produced either just-in-time in small lots or at fixed, short intervals.

- A reduction in flow time is obtained. Reduced material handling time and reduced setup time greatly reduce flow time.
- Tool requirements are reduced. Parts produced in a cell are of similar shape, size, and composition. Thus, they often have similar tooling requirements.
- Throughput times are reduced. In a job shop, parts are transferred between machines in batches. However, in CM each part is transferred immediately to the next machine after it has been processed. Thus, the waiting time is reduced substantially.

As a result of these characteristics, product quality is also improved: As the parts are transported individually from one work center to another within the cell, the feedback is immediate and the process can be stopped whenever any errors may occur.

5 CONCLUSIONS

Summarizing the above results presented with the study performed we may highline that several kind of advantages were able to be reached throughout the implementation of the proposed work. These advantages are mainly related to wip and inventory costs reduction, throughout decreasing the number of kanbans necessary, under the scope of Lean and JIT production principles, with are being used in Bosch Production System.

Another important improvement obtained was due to the proposed cellular manufacturing system scenario, instead of the existing line system. Therefore, it is possible to enhance the production system, by improving the production flow and consequently the production tasks management. Moreover it is possible to simplify materials acquisition and storage. Besides that, material handling and control is also simplified.

As a final conclusion we may state that kanbans sharing and minimization was possible through a manufacturing system layout change and improvement, by transforming lines to cellular manufacturing system. Thus, improving several other related aspects in the BPS, related to a better production system arrangement and materials and production flow, also enabling to facilitate the production planning and control tasks and material acquisition, storage, manipulation and control. Moreover, this study consists on another contribution in the Lean, JIT and kanban domain showing that these principles enable to better control production process, enabling better tasks performance and enhance productivity and production quality in manufacturing environments, by enabling better work integration among operators, through a closer interaction and information and responsibility sharing, which is a clear achievement within the proposed manufacturing cell. As a consequence, reduced production time and material and wip flow is also reached, through the reduction of waste and distances between work centres within the manufacturing system, which was also visible in the proposed manufacturing cell.

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