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From JIT to Seru, for a production as lean as possible

Agostino Villa^{*}, Teresa Taurino

Politecnico di Torino, Dept. Engineering Management and Production, c.so Duca degli Abruzzi 24, Torino, Italy.

Abstract

Lean Manufacturing is not especially new. It derives from the Toyota Production System or Just In Time Production (JIT), but even before from Henry Ford and other predecessors. Based on analysis of mass production systems in USA, Toyota engineers began to incorporate Ford production and other techniques into the JIT approach: they recognized the central role of inventory. JIT is fit for a stable, but not “volatile”, business environment such as that which the electronics industry belongs. That means short product life cycles and fluctuating production. Seru Seisan, a new production organization, was developed to cope with this environment. Outside Japan, however, few people in the academic and practical area are aware of such production management mode. This work gives an interpretation of the evolution from JIT towards Seru Seisan such as to attract the interest in this labor organization that appears to be promising.

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1. Introduction

Lean Manufacturing is not especially new. It derives from the Toyota Production System or Just In Time Production, but even before from Henry Ford and other predecessors.

The lineage of Lean Manufacturing and Just In Time (JIT) Production goes back to Eli Whitney and the concept of interchangeable parts, end of the XVIII century. Eli Whitney is most famous as the inventor of the cotton gin. However, the gin was a minor accomplishment compared to his perfection of interchangeable parts. For the next 100 years manufacturers primarily concerned themselves with individual technologies. This changed in the late

^{*} Corresponding author. *E-mail address:* Agostino.villa@polito.it

1890's with the work of early Industrial Engineers, the most famous of whom is F. W. Taylor, who began to look at individual workers and work methods. Studying Taylor's theory incompleteness, Frank Gilbreth added Motion Study and invented Process Charting, and Lillian Gilbreth brought psychology into the mix by studying the motivations of workers and how attitudes affected the outcome of a process. These were the people who originated the idea of "eliminating waste", a key tenet of JIT and Lean Manufacturing (Villa et al. 2009).

The Allied victory and the massive quantities of material behind it caught the attention of Japanese industrialists. At Toyota Motor Company, Taiichi Ohno and Shigeo Shingo, began to incorporate Ford production and other techniques into an approach called Toyota Production System or Just In Time. They recognized the central role of inventory. Toyota soon discovered that factory workers had far more to contribute than just muscle power: discovery probably originated in the Quality Circle movement.

The Toyota production system (TPS) has long been regarded as a powerful approach for managing manufacturing factories. However, in the early 1990s, the TPS was found not to work when it was applied to Japanese electronics companies. TPS is fit for a stable, but not "volatile", business environment such as that which the electronics industry belongs. That means short product life cycles, uncertain product types, and fluctuating production. Seru, a new production organization, was developed to cope with this environment as described by Strecke et al. (2012), Liu et al. (2010), Miyake (2006) and Yin et al. (2006).

In 1992, many short conveyor lines dedicated to one specific product were taken apart from a long multi-product conveyor line in one of Sony's factories for producing video-cameras. With continuous improvement, these short lines become increasingly shorter and constant innovations take place in the layouts (Liu et al. 2010 and Miyake 2006). These changes have benefited Sony considerably, enabling the company to meet the dynamic market demands because the corresponding manufacturing system could be constructed, modified, and reconstructed rapidly and frequently. In 1994, K. Tatsuyoshi, a former staff of Sony, first coined the term of "Seru Seisan" for such an innovation of the production management mode (Yin et al. 2006). Seru Seisan has been attracting considerable interest in academic research and production practice in Japan. Outside Japan, however, few people in the academic and practical area are aware of such advanced production management mode. We hope this work will provide a comprehensive interpretation of the evolution from JIT towards Seru Seisan such as to attract the interest in this labor organization that appears to be promising under several aspects..

2. Managing production flows through "push" or "pull" approaches: preliminaries

All foremen in large enterprises and production managers in small and medium industries, have some urgent goals: (a) deliver on time the finished products; (b) but also retain the minimum of materials and components within the department (i.e., keep the as low as possible Work In Progress - WIP); (c) but also guarantee the customer the minimum delivery delay (sometimes referred lead time); (d) and finally obtain the maximum rate of capacity utilization (typically expressed in terms of percentage of time worked). In short, a "squaring the circle", practically impossible to obtain since the objectives are not only very different, but most are between them "in conflict." In other words, a person in charge of production cannot always guarantee delivery by the date requested if it has no margin of capacity to use (this thing that prevents a high use of machining centers) and if it did not provide sufficient materials and components to be used for the final assembly (which requires the presence of sufficient WIP).

In order to approach this complex task, the foreman experienced that any logic for sequencing jobs as well as for planning production flows depends on the structure of the production system. In particular, there are two aspects which distinguish the usable approaches: (i) the connections between the work centers, that is, the presence or absence of intermediate buffers that can decouple the operation of each center from that of the other; (ii) the direction in which the controls are propagated from one center to another. First, the presence of a buffer between two work centers, being able to contain a sufficient number of pieces, allows the downstream center to work even in case of stop of the upstream center and not to induce stops even in the opposite case: thus the two centers can operate independently of each other. The second aspect is related to the way of transmitting internal work orders from a center to those connected to it, upstream or downstream.

If the transfer occurs from downstream to upstream, the system operates in "pull" condition, with "dragging" production from one center to the next, which then acts as a "client" of the former, in turn, considered to be "supplier". In the opposite case, in which the transmission of internal orders takes place from upstream to downstream, the system is managed in a "push" condition, i.e. the production is "pushed" from the center upstream towards the center of the next, assuming that both be planned what and how much to work.

The "push" logic, in its most schematic form, could require no internal buffers. Having picked up some orders to be delivered, orders for domestic production can be programmed to the initial center of the line, and the delivery of each order may be provided depending on the timing of the different work centers. Starting from the initial center, it would then set up a flow of materials and components to the next ones, at fixed intervals or by transfers dependent on the size of the different lots. However in case of the "push" system, some defects can be envisaged. Taking into account a production line, different processing times at the different stages of the line can slowdown production: indeed, any line is always conditioned by its bottleneck. To avoid this drawback, internal buffers are necessary as well as a certain decoupling between consecutive work centers. If so, the necessity of a well timed transfer of internal orders to all centers, with strong coordination among them, is mandatory.

The "pull" management logic of a production system, in its simplest form, consists of a generalization of the EOQ method of storage management. By focusing on the center at the line end, it can be assumed that the demand for the finished products, corresponding to a withdrawal from the final warehouse, requires the production of a similar number of products, thus activating the same center terminal of the line (with a periodicity dependent on the rule reorganization of stock products). From the moment the center starts to work, absorbs components and materials contained in its buffer, up to activate in turn the work center upstream. This chain of work orders propagates along the whole line, in which the flow of materials and components is "attracted" to downstream by orders flowing upstream. The JIT management systems are based on such a "pull" method for controlling the flow of materials: however, in industrial practice, some changes to the schematic form described are adopted, including the use of small lots transfer. The following Figure 1 shows an illustration of the "pull" logic. In its simplified organization, the JIT system could be affected by some defects: necessity of internal stocks waiting for work at input buffers of machining centers, such that their amounts be proportional with the re-ordering frequency; potentially occurrence of stops of work centers induced by empty buffers, with consequence propagation of stoppages to up- and downstream centers.

To control stage by stage the transfer of materials and components via the JIT chain it is not the only method of implementation of the "pull" logic. In fact, a possible approach for a line is to check the work-in-process (WIP) within the entire line, not at each center: that can be achieved if, upon receipt of a delivery order for a batch of finished products, the internal order is sent to the initial center of the line. Once activated the initial center, it would also set up a flow of materials and parts from this to the next centers. Using this logic, it becomes possible to maintain a constant internal WIP (hence the name CONWIP - Constant Work In Process), pursuing one of the goals of most interest to the operator of the line.

In the following, all above three production management systems will be illustrated, to allow a direct comparison of their respective organization.

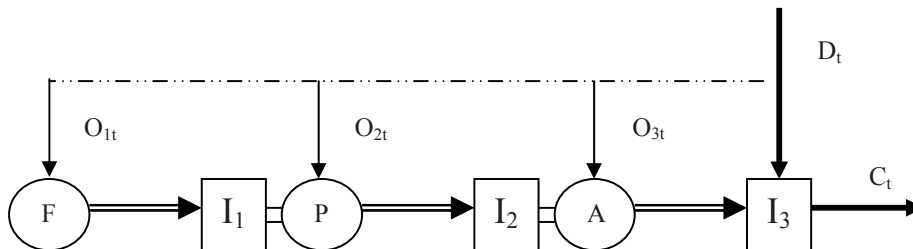


Figure 1. Scheme of a push-managed production line.

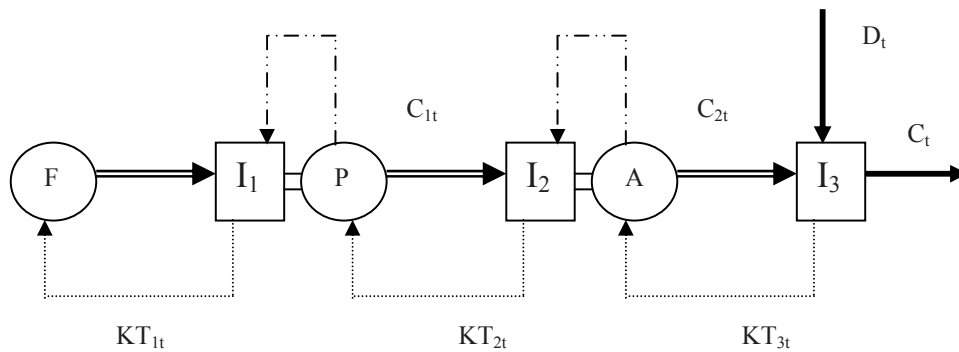


Figure 2. Scheme of a pull-managed production line. Notations: D_t exogenous demand for product type t ; C_{it} = “withdrawal Kanban” at stage i for product type t ; P_{it} = “production Kanban” at stage i for product type t

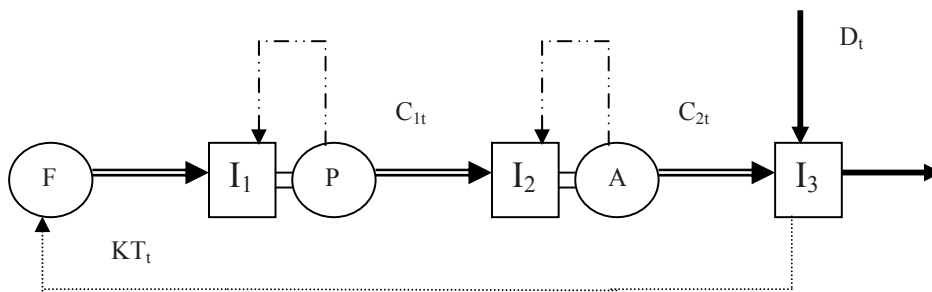


Figure 3. Scheme of a CONWIP-managed production line

3. JIT: controlling inventories for production fluidification

While the main “push” approach, i.e. MRP-based procedure, is really like a tactical planning process, which can be translated into an algorithm that builds production orders to be sent to the different stages of a line, based on the “product tree”, its description of the components of various levels and the required raw materials, JIT can be thought as a “philosophy” of management that has the objective to reduce as much as possible waste: that means waste that follows to excessive levels of stocks, the presence of unnecessary operations, the production of parts not of sufficient quality.

The JIT philosophy was originated in the Japanese automotive industry. After World War II, Japan, rebuilding, had a domestic car market too small for an efficient application of the principles of organization of work of Fordism: this pushed the Japanese manufacturers, including Toyota first, to design and develop a different system of tactical planning of production flows, which was more efficient in the production of small-mid batches. This system, applied in Toyota already in the fifties, showed his real operating efficiency during the oil crisis of 1973 when, among all companies, only Toyota was able to make a profit. A clear rationale for this philosophy showed that the JIT is a system that is especially effective for diversification of production, through the management of flows (Ohno 1988).

In this philosophy, the Kanban (or “tag order”) is the operational tool when you want to manage the handling of components and materials between the centers of the line: the planning and control of these movements are the practical logic JIT. Kanban is not the only key word logic JIT: it is also associated with other terms, such as

"kaizen," or continuous improvement, and "quality circles" or groups of employees involved in continuous monitoring of production, by themselves implemented.

The JIT approach has also been named "zero inventories" by Hall (1983). Then this analysis is now focused on this "famous" characteristic of JIT: the reduction of stocks.

Reduce inventory, however, is a real improvement if you understand what the real reasons for the accumulation are, remembering that accumulations are of different types. The most frequently cited are the "cycle inventory", due to the set-up delays and, in the case of raw materials, to the time of delivery. To reduce stocks of this kind should reduce the time of set-up: this is not just a management problem, but technological, as it can result in changes to the operations to be performed to the work center. It is certain that reducing set-up reduces the production lots, with benefits on WIP and lead time. Another builder of stocks is the delay in the presence of defective parts: it is a basic of JIT that WIP and improving the quality objectives are linked. Referring also to emergency stocks, particularly significant in the case of raw materials, these are contained only in the face of specific agreements with suppliers: it is a good rule of JIT production system managed to have a reputable supplier deliveries and possibly localized deposits in the vicinity of enterprise customer. Such an arrangement makes safer to agree on periodic deliveries, lower procurement costs and transport, smaller batches with each delivery, allowing reduced inventories. A similar reasoning applies to stocks online: here the problem to be addressed is the coordination between the various stages of the line, so you can use small batch transfer.

The main rule to reduce inventory is therefore the reduction of the lots, and especially to keep a production as constant as possible (it mentions the word "leveling" or smoothing of production). Key action is the reduction of the time of set-up, as can be understood from a simple example described by Brandimarte et al. (1995) and De Toni et al. (2013).

Consider a line on which are machined N products, each with production rate p_i , constant demand d_i , and time set-up s_i . Since it is assumed constant demand, the production system works in conditions of steady and periodic state, where the pattern of stocks is repeated cyclically, as shown in the following Figure 4, relative to two different products.

The period T_c of each repeated cycle should be chosen so as to minimize the storages: evidently longer cycles accumulations generate more, and thus require larger warehouses. On the other hand, reducing the cycle time allows also to use smaller batches provided more frequently (such as to smooth production). From Figure 4, it is understood that the cycle time is at least equal to the sum of the machining time T_i of each lot and set-up time s_i (the sign of greater than or equal must be considered in order to take into account any additional idle times):

$$T_c \geq \sum_{i=1}^N (T_i + s_i) \quad (1)$$

$$p_i T_i = d_i T_c \Rightarrow T_i = m_i T_c, \text{ where } m_i = d_i / p_i \quad (2)$$

The minimum cycle time will therefore be obtained by canceling all time storage: this involves producing during a cycle exactly what is required for each product.

To reduce the cycle time, and therefore, stocks, should therefore be reduced m_i , which means to increase the production and reduce s_i , i.e. set-up faster.

$$T_c = \left[\sum_{i=1}^N s_i / (1 - \sum_{i=1}^N m_i) \right] \quad (3)$$

Beyond the "icons" of Kanban, Kaizen, zero inventory etc., the JIT philosophy presents an absolute need: to control all the activities that take place within a production system in order to ensure that each operation takes place within one degree of variability as short as possible.

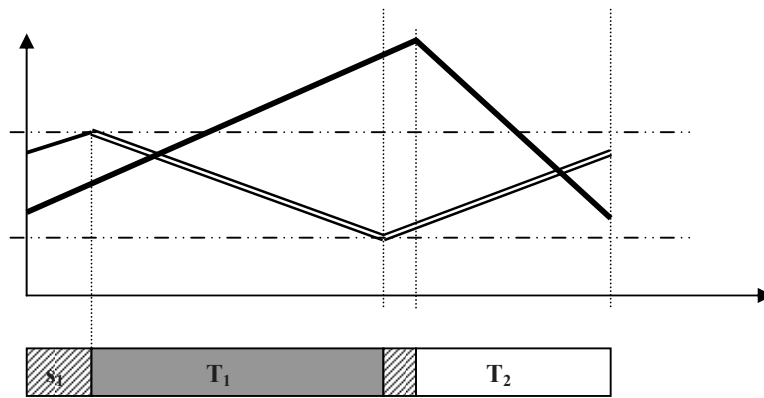


Figure 4. Performance of stocks for two products processed on a single line

From here, the various practices of "good governance" that are activated together.

- i) Total Quality: priority of an enterprise managed JIT is to eliminate waste and rework of defective products, in order to obtain a constant flow.
- ii) Standardization of components and methods: thus facilitating operations control and their results.
- iii) Balance workloads: at various stages of the line, produces a uniform daily demand for each stage, and facilitates the planning of flows and stocks.
- iv) Preventive maintenance: since machine downtime generate random variability and may cause the block and accumulation of stock.
- v) Reports of trust with suppliers: the objective of minimum stocks requires a close relationship with suppliers to get frequent deliveries and guaranteed quality.
- vi) Flexible work force: i.e. operators with sufficient knowledge of the process implemented by the line, willing to move from one stage to another in situations of block as this may result in the bottlenecks.

3.1. Some critical comments on JIT

From a reading of the above, you might think that the JIT philosophy can be the panacea for every production environment, providing an answer to every problem. In reality, especially the last considerations aim to present some "rules of use" of a control logic, not their application or the result thereof. Even in Japan, despite a much disciplined workforce, the full application of JIT occurred only in part, and often requires a significant effort and enterprise workers. This is because often, especially in the western industrial systems, the conditions necessary for the effective implementation of JIT philosophy are not clear. The main conditions are listed below:

- Firstly, the sequence of products to be processed (if preferred, the schedule) must be repetitive and invariant for periods long enough, so that transients resulting from changes do not produce significant percentage variations of flows.
- It must be possible to plan production flows and sequences in which the set-up times are short: this may require major changes in technology usually used and the organization of the system.
- It must be possible to use a wide standardization of all materials, components, equipment, tools, and so on.
- You should be able to have flexible workers: this requires incentives that facilitate the involvement (what today is called "loyalty").
- You must be able to activate supply contracts particularly guaranteed.

All these conditions create a work environment in which you can establish relationships of motivation and collaboration, which requires a commitment especially by the management.

4. CONWIP: Simplifying Kanban circulation but paying further constraints

As seen in describing the JIT system, the logic of kanban is to use the level of the buffer downstream a stage to control the production stage itself, so that when the buffer fills, the production of the type of piece by the upstream stage is stopped. In practice, the kanban ensure that there is no production except in response to the lack of parts in the downstream buffer. You might recognize a strong analogy with a supermarket: only products that have been sold will be replaced on the shelves. This method of control, however, has a drawback: the use of pieces (materials, components, products) as "vehicles of information" means that any operation of the upstream stage is conditioned by the presence or absence of items in the downstream buffer. This conditioning may not be a situation of efficient work: just think of the convenience to have some pieces in the buffer usable as a "lung" to prevent the unexpected block of a machine causes the interruption of the work to the next machine.

In order to apply with this logic it has been recently introduced an amendment to the circulation system of kanbans: the system CONWIP (Constant Work In Process) described by Enns et al. (2008). This innovated production management logic is simple: each time a batch of finished product is delivered, products of the same type are sorted in line to be processed as quickly as possible, sending a kanban at an early stage. This same kanban is attached to the new batch until its delivery to the finished goods warehouse.

- To state a simple (non optimized) CONWIP model, three most stringent constraints are required:
- The line must be balanced, i.e. all stations must have the same average process times.
- All stations must consist of a single machine, such to avoid any complexity of the parallel processing and jobs passing one another.
- Process times must be random and be such to be modeled accordingly to a specific probability distribution known as the exponential distribution. The exponential distribution is the only continuous distribution that has a special property known as the memoryless property: it means that if a processing time on a machine is exponentially distributed, the knowledge of how a part has been in process gives no information about when it will be finished.

With these assumptions, consider the situation in which you are riding around on a pallet that circulates through the line.

Suppose there are N (single machine) stations, each with average processing time t . Suppose also that there is a constant level of jobs w in the line.

Thus, the "raw process time" is $T_0 = Nt$, and the "bottleneck rate" for the line is $r_b = 1/t$.

Since the above three assumptions guarantee that all states (job storages) are equally likely, each time you arrives at a station, you would expect depending on average $(w-1)$ other jobs in the line, equally distributed among the N stations. So the expected number of jobs ahead of you upon arrival is $(w-1)/N$. It follows that, since the average time you spend at the station will be the time for the other jobs to be processed plus the time for your job to be processed, the "average time at a station", i.e. the time for processing other jobs plus the time for processing your job, is given by: $ATS = [1 + (w-1)/N]t$.

Now assume that the $(w-1)/N$ jobs ahead of your requires an average time $[(w-1)/N]t$ to be completed (neglecting any semi-finished product...). Then, since all stations are assumed to be identical, we can compute the "average cycle time" by multiplying the average time at each station by the number of stations N :

$$CT = N[1 + (w-1)/N] = Nt + (w-1)t = T_0 + (w-1)/r_b$$

The related "throughput" is obtained by applying the Little's law: $TH = WIP / CT = w / [T_0 + (w-1)/r_b]$

This set of formulas can be used to estimate, although in approximate form, the WIP and the average rate of production of the managed system through CONWIP.

Most important: this logic separates the flow of parts from that of information, because it transmits the request for production from one end of the line. Intuitively, the logic CONWIP should perform better than the pure kanban

control in case of variability in flows, in that it has partially decoupling buffer. However, the additional constraints that must be respected in a real plant for CONWIP application could limit its real usefulness in several manufacturing departments, mainly in mechanical ones.

5. Seru-Seisan: decentralizing JIT through personnel qualification improvement

Seru Seisan (“seru” means cell, and “seisan” means production) appeared to be an innovation of the production management mode in Japan recently as described by Miyake (2006) and Yin et al. (2010). It emerged from a very complicated environment of mixed factors both in and out of Japan:

- a) Change of demand to high variety and low volume.
- b) Low flexibility of the conveyor line.
- c) Long period of economic stagnation in Japan after 1991: managers gradually realized that high-cost automation could not always bring the sound effect as expected because of unstable customer demand.
- d) Low employee morale resulting from work circumstance and enterprise culture: high specialization, as well as the strict takt time, on the conveyor line, results in a monotonous work environment.
- e) Limits of the Toyota Production System, i.e. there is insufficient evidence at present to show that the Toyota Production System can achieve as great efficiency in other industries as in the auto industry; and, if compared with huge components in the auto industry, parts and products in electronic industry, especially television, digital camera, computer, printer, duplicator, DVD players and washing machine, are extremely small in appearance and lightweight. Hence, in the electronic industry, manual operation and transport is easier.
- f) Fierce competition in the international marketplace: i.e. facing the huge challenge from other East Asia countries, many Japanese manufacturing industries, and the electronic industry in particular, launched a battle to cut down cost by establishing factories abroad or innovating their manufacturing systems.

The main idea underlying Seru-Seisan organization is that the long line is removed and replaced by many short ones. The layout of cell production requires equipment with dissimilar functions used in the whole manufacturing process to be included in one cell. From the view of the source of flexibility, a cell is configured for a group of similar parts/ products, so the flexibility can be obtained within the certain part/product family. In a Seru, however, movable workstations, light equipment, and continuously cross-trained workers contribute to the quick configurations for several dedicated product types.

Indeed, “cell production” (also denoted “cell manufacturing”) has been implemented in diverse business industries in the US and Europe for decades. Conventional job shops are clustered into several manufacturing cells with cellular layouts theoretically based on Group Technology principles.

Cell manufacturing and Seru Seisan both have high flexibility, but the mechanisms behind the two systems are different. Seru-cell production no longer treats each product separately as job shop does. Instead, it groups similar parts or products into a part/product family according to the characteristics of the parts/products, the similarity of process, and the manufacturing methods. All of the equipment is grouped by the similarities of products rather than the function of machines.

However, Seru Seisan is mainly applied in the electronic industry in Japan. It is suitable for processing light and small products, such as electric products which are mainly manufactured manually or with simple equipment. Seru Seisan is difficult to implement on heavy products with complex processes.

In summary, some main characteristics can be recognized, by looking at a few presentations of the Seru-Seisan approach (Strecke et al. 2012):

- All or most production processes of one product are completed in a Seru. Under Seru Seisan, each Seru is dedicated to one or several specific product types, occasionally cooperating with other Serus.
- Then, Seru Seisan must be a human-centered production management mode. The cross-trained worker is the essential factor for Seru Seisan.

- In addition, Seru Seisan system is a low-automation system. Manufacturing enterprises in Japan had placed large investment on automation equipment until it was curbed by the economic stagnation in the 1990s. When dismantling the conveyor line into Serus, from the view of cost, it is unfeasible to duplicate the expensive automation equipment for each Seru.

Serus can appear in various layouts. In practice, various layouts of Serus such as U-shaped, L-shaped, and I-shaped lines, can be easily found. An example is presented in Figure 5, with reference to a “divisional Seru”, where the conveyor line is dismantled into many short lines, each short line is dedicated to one or several specific product types; workers usually shuttle among several workstations to complete all processes assigned to them.

Even if just only outlined, the Serue-Seisan organization shows already some advantages and disadvantages: among the *main advantages*: 1. high flexibility; 2. short lead time; 3. low inventory; 4. good morale; whilst among the *main disadvantages*: a. finite ductility on the size of a Seru; b. huge investment on training for multi-skilled workers; c. slight increase in variable production cost (tools, equipment, transports); d. high pressure on workers.

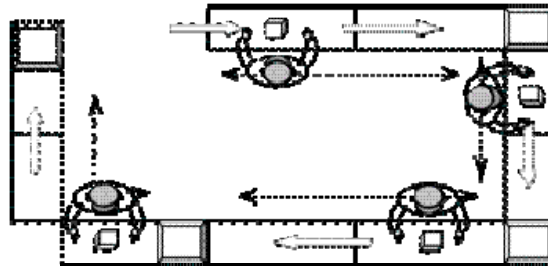


Figure 5. Example of Seru (cell). Source: Miyake (2006).

6. Final Remarks: Problems to be further investigated...

Instead of including a “standard” conclusion, the authors prefer to propose to the readers some aspects and problems to be further investigated, mainly concerning the dualism between Cell Manufacturing and Seru-Seisan, the two production management organization that appear to be promising for the future.

First of all, it's necessary to analyze similarities and differences between Seru Seisan and conventional cell manufacturing.

Then, the theoretical basis of Seru Seisan has not been ascertained until now: this prevents from a formal comparison with other approaches.

In addition, the researches on cell manufacturing mainly focus on four aspects: cell formation, layout planning, production planning, and production scheduling and control. ... What's for Seru-Seisan?

Finally, the impact of the two labor organization on personnel: it seems to be the most important issue in a crisis period as the one we are living today.

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