Routledge
Taylor & Francis Group

Asian Journal of Technology Innovation

ISSN: 1976-1597 (Print) 2158-6721 (Online) Journal homepage: http://www.tandfonline.com/loi/rajt20

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To cite this article: ChenGuang Liu , Jie Lian , Yong Yin & WenJuan Li (2010) Seru Seisan# an innovation of the production management Mode in Japan, Asian Journal of Technology Innovation, 18:2, 89-113, DOI: 10.1080/19761597.2010.9668694

To link to this article: http://dx.doi.org/10.1080/19761597.2010.9668694

Published online: 24 Feb 2011.

Seru Seisan- An Innovation of the Production Management Mode in Japan[1)]

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Summary

Seru Seisan, also called "beyond lean" in many Japanese manufacturing industries, is an innovation of the production management mode in Japan. Although an increasing number of manufacturing enterprises in Japan have been adopting this strategy with great success, it is not popular among manufacturing enterprises and researchers out of Japan. This paper provides a brief introduction of Seru Seisan to promote the strategy worldwide. First, a report on the origin of Seru Seisan and an analysis on its generation background are provided. Second, the differences between Seru Seisan and the conventional cell production are shown. The characteristics, advantages, and disadvantages of Seru Seisan are also investigated. A summary of the Seru modalities that appear during its evolution is presented as well. Finally, several key problems for further research on Seru Seisan are presented.

Keywords: Seru Seisan, production management mode, cell production, management innovation, Japanese manufacturing industries

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1) This research is supported by the National Natural Science Foundation of China (Grant: 10801110) and the Shaanxi Provincial Project of Special Foundation of Key Disciplines (Grant: 00X901).

1. Introduction

Mass production, symbolized by the conveyor line, is a kind of universal production management mode that has been widely adopted by numerous manufacturing enterprises all over the world. The long history and popularity of the conveyor line influenced peoples' minds. Implementing the conveyor line in manufacturing industries, especially in final assembly processes, became a constant thinking pattern. Hence, people could not imagine that a high performance production management mode was rising in Japan and gradually taking the place of the conveyor line in some manufacturing fields.

Over the past decade, several Japanese manufacturing enterprises have dismantled their conveyor lines and adopted Seru Seisan. The majority of these companies are successful in their innovations; examples of these companies are Canon, Sony, Panasonic (Matsushita), Fujitsu, NEC and Hitachi (Iwamuro, 2002; Noguchi, 2003; Kimura and Yoshita, 2004; Kono, 2004a; Takeuchi, 2006; Yagyu, 2003; Yin, et al., 2008a). The most successful application of Seru Seisan is Canon's. "Canon has evolved into a high performance organization by using Seru Seisan," Fujio Mitarai, the chairman and CEO of Canon, has said (Sakamaki, 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. The constrained international promotion of Seru Seisan can be attributed to two main aspects. First, almost all literature on Seru Seisan is written in Japanese. According to our review, the number of existing literature on Seru Seisan written in English is merely no more than twenty. These research results are usually not available and not suitable to international researchers. Second, the majority of Seru Seisan researchers are in Japan. Our investigation shows that the number of international researchers focusing on Seru Seisan is remarkably scarce. In order to accelerate its dissemination world widely, more international researchers are expected to devote to this field. From this pressing perspective, we aim to provide a systematic, comprehensive introduction of Seru Seisan to international researchers and practitioners. The present review paper is one main part of our work. The early version of this paper has been published in Chinese (Liu, et al., 2010) for discussion. We sincerely hope this work will provide a new and comprehensive interpretation of Seru Seisan to attract more international researchers.

2. The Origin of Seru Seisan

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 an 8-millimeter CCD-TR55 video-camera (Noguchi, 2003; Kimura and Yoshita, 2004; Takeuchi, 2006; Nonaka and Katsumi, 2004). After dismantling the long conveyor line, each product was completed on a single short line as on the original conveyor line. Figure 1 shows how a conveyor line is dismantled. With continuous improvement, these short lines become increasingly shorter and constant innovations take place in the layouts. 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, Kon 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).

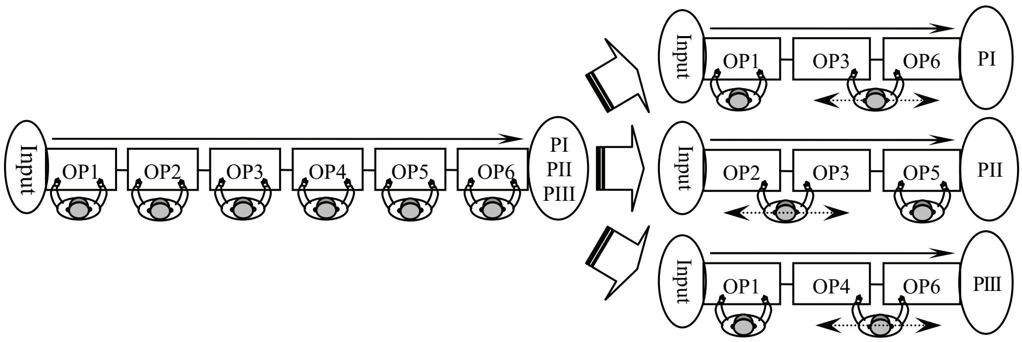


Figure 1: A Long Line is Divided into Short

Several Japanese manufacturing enterprises soon took after Sony. Canon dismantled their conveyor lines and adopted Seru Seisan under the influence of Sony's success. A 1997 investigation on the implementation of Seru Seisan in Japanese manufacturing enterprises revealed that 23.2% of the respondents had adopted Seru Seisan while 25.0% were planning to adopt the process (JSPMI-ERI, 1998). The percentage of Japanese manufacturing enterprises that adopted Seru Seisan should be remarkably higher at present. Seru Seisan has thus become one of the mainstreams of production management mode in Japan.

The first academic paper about Seru Seisan was written by Tsukada Shinohara (1995). From then on, a large number of reports concerning the implementation of Seru Seisan in Japanese manufacturing enterprises have appeared in many Japanese magazines and newspapers. At the same time, several Japanese academic journals， such as IE Review and Factory Management，published the application experience and academic research results about Seru Seisan. Recently, several books on this issue have likewise been published in Japan.

3. The Generation Background of Seru Seisan

Seru Seisan is an innovation of the production management mode in Japan. It emerged from a very complicated environment of mixed factors both in and out of Japan. The main factors are as follows.

Change of demand to high variety and low volume

Demand changes are embodied in two main aspects: product variety and product volume (Ohno, 1988; Fujimoto, 1999). From the standpoint of product variety, the diversified and personalized demand leads to high product variety. The shortened product life cycle also results in diversified products. Moreover, fluctuations in customer demand have negative effects on product volume.

The efficiency of the conveyor line will dramatically decrease when confronted with variable and fluctuating demands (Estrada, et al., 2000). Therefore, highly efficient but less flexible conveyor lines should be urgently replaced by manufacturing organizations pursuing high flexibility. In Japan, Seru Seisan is currently regarded as the most powerful approach in some manufacturing industries to deal with the dynamic environment with high product variety and low product volume (Mayumi, 2005).

Low flexibility of the conveyor line

The conveyor line is popular in the final assembly processes of mass production systems due to its high efficiency. Its other advantages include high productivity, superior product quality, low product cost owing to economy of scale, and low labor cost by low-skilled workers. However, the drawbacks of the conveyor line have usually been overlooked by the managers of many manufacturing enterprises (Johnson, 2005). The major demerit of the conveyor line centers on its lack of flexibility. Almost every conveyor line is designed for one or several specific product types. Therefore, measures should be taken to reconstruct the line when the product type changes. Meanwhile, it is essential to adjust the line in order to obtain high performance against the fluctuating demand volume.

Many Japanese manufacturing enterprises consider dismantling the conveyor line as a way to improve production flexibility because flexibility is a critical indicator of production system capability (Murase, et al., 2006).

Long period of economic stagnation in Japan after 1991

Before the burst of the "economic bubble" in the 1990s, manufacturing industries in Japan exerted great efforts to adopt a factory automation system and thus gained a large scale of automation systems. Conveyor lines, robots, and other high-tech equipment were applied universally. According to the United Nations Economic Commission for Europe (UNECE) and the International Federation of Robotics (IFR), the operational stock of multipurpose industrial robotics in Japan reached its peak at 413,000 units in 1997.

The "economic bubble" burst in 1991 followed the sharp fall of stock market and real estate. "The lost decade" came after when Japan suffered from a prolonged period of economic stagnation and malaise. The expansion of automation was curbed in the 1990s because manufacturing enterprises could not afford the additional enormous amount of capital investment required for automation during the economic recession. Moreover, managers gradually realized that high-cost automation could not always bring the sound effect as expected because of unstable customer demand. Therefore, the requirement for low-cost but highly efficient systems arose reasonably under the influence of an external economic factor and an internal performance factor.

The economic stagnation of the 1990s prompted Japanese manufacturing enterprises to dismantle their highly efficient conveyor lines and begin to innovate on their production management mode.

Fierce competition in the international marketplace

Globalization introduced plenty of opportunities that resulted in fierce competition among countries. From the viewpoint of industry structure, the competitive pressure brought by globalization on Japanese industries stemmed from East Asian countries such as China and Korea (Leggett and Wonacott, 2002). The low-end/mid-end electronic products made in these countries greatly weakened the competitiveness of Japanese electronic products in the international marketplace (Powell, 2002).

Additionally, the Japanese Yen sharply rose in value, from 145 Yen per U.S. Dollar in 1990 to an all-time high of 79.75 Yen in April 1995. Such a currency change made Japan suffer from huge pressure of cost from outside circumstances (Akino, 1997).

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 (Jiang and Willette, 2004).

Low employee morale resulting from work circumstance and enterprise culture

Managers and job designers of several manufacturing enterprises usually ignore the psychological factors of employees. The high specialization, as well as the strict takt time, on the conveyor line, results in a monotonous work environment. In such a circumstance, worker tolerance and enthusiasm decrease in the long-term. There is a strong desire to develop individual skills and promote team empowerment. An increasing number of enterprises have noticed the importance of employee job involvement and organizational commitment (Edralin, 2008). The requirement for a human-oriented design of work circumstance thus begins to emerge.

Undoubtedly, majority of Japanese workers are faithful to their jobs and treat the jobs as their careers. However, we have to admit that the culture of Japanese enterprises also leads to low employee morale to some degree. First, in the conventional payment system, employees are paid according to seniority rather than on performance. Remuneration is measured by the length of working experience in the enterprise, not work performance. This causes a loss of competition and spirit for some employees. Second, perpetual employment is a distinctive character of the employment system in most Japanese enterprises. Accordingly, the ones who would like to muddle along may not work hard, resulting in low employee morale in the whole enterprise (Sakamaki, 2006).

To satisfy the desire for enriched jobs, a large number of Japanese manufacturing enterprises have begun to exert more effort on improving the work circumstance and enterprise culture. This reform speeds up the progress of exploring the new production system beyond the conveyor line.

Limits of the Toyota Production System

The Toyota Production System has been regarded as the source of outstanding performance for Toyota Motor Corporation. It has also been implemented by various enterprises all over the world, and has become a milestone in the history of the production management mode. In Japan, besides implementation in the auto industry, the Toyota Production System has been adopted in other manufacturing industries including electronics, metal working, mechanics, and foods supply. This innovation has also reached the service industries. However, 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 (Liker, 2004).

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. This processing character of the electronic industry serves as a particular driver for a new production system when Toyota Production System fails to realize the expected high efficiency (Imaoka, 2005).

4. Distinguish between Seru Seisan and Cell Production

Cell production has been widely adopted in the US and Europe, and the term "cell production" has extensively appeared in the literature. As for "Seru Seisan" popular in Japan, "Seru" is a Japanese word for "cell" and "Seisan" is the Chinese word for "production" pronounced in Japanese. Although the terms of "cell production" and "Seru Seisan" seem identical in the literal sense, strictly speaking, they are dramatically different from each other in many aspects.

4.1 The Theoretical Basis of Formation

Cell production, the successful application of Group Technology, has been thoroughly studied over the past decades. 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 are grouped by the similarities of products rather than the function of machines. Conventional job shops are clustered into several manufacturing cells with cellular layouts theoretically based on Group Technology principles (Wemmerlöv and Hyer, 1986). All these changes contribute to overcoming the low efficiency of the job shop. In this way, cell production can effectively maintain the flexibility of the job shop and gain the efficiency of the Group Technology principle at the same time.

Compared with cell production, however, Seru Seisan is derived from dismantling the conveyor line with the objective of improving the low flexibility and retaining the high production efficiency of the conveyor line (Murase, et al., 2006). The theoretical basis of formation is still a source of heated debate on Seru Seisan in academia, and no final conclusion has yet been reached at the moment. Some researchers believe that the formation of Seru Seisan is based on the merger of the Toyota Production System and Sony's one-man production system (Kimura and Yoshita, 2004; Nonaka and Katsumi, 2004).

4.2 The Application Fields in Practice

Cell production and Seru Seisan have both been widely adopted in several manufacturing enterprises. Cell production is usually connected with the manufacturing process, whereas Seru Seisan is implemented in the assembly process. According to a survey organized by Wemmerlöv and Johnson (1997) on the 126 manufacturing cells of 46 American metal-working plants, each cell contains eight processing types ranging from forming, casting, heat treating, machining, assembly, finishing, testing, to packing, all belonging to the manufacturing processes. While in many cases, the most common Seru in Japan is assembly Seru. Such a Seru is widely used in the final assembly department and is usually comprised of assembly, testing, and packing (Isa and Tsuru, 2002; Japan Machinery Federation, 2005).

Cell production has been implemented in diverse business industries in the US and Europe for decades. However, Seru Seisan, an emerging mode in recent years, is mainly applied in the electronic industry in Japan (JSPMI-ERI, 1998; Isa and Tsuru, 2002). 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. According to the survey carried out by the Economic Research Institute of Japan Society for the Promotion of Machine Industry (JSPMI-ERI, 1998), about 75% of the respondents from electrical machinery and precision instruments industries had already adopted or are planning to adopt Seru Seisan. Comparatively speaking, almost half the respondents from the transport equipment industry revealed that they did not intend to implement Seru Seisan. However, there are several successful implementations of Seru Seisan in complicated manufacturing industries like Toyota (Japan Machinery Federation, 2005).

4.3 The Processing Equipment, Jigs, and Tools

In the conversion of the conventional job shop to cell production, all of the equipment are reorganized without any significant reformations in the structure. When dismantling the conveyor line into Serus, the equipment layout changes, and most of the equipment, especially the heavy equipment, are redesigned simultaneously. It is critical to redesign the big and heavy equipment orienting at light, movable, and low cost to guarantee that the reconfiguration of Seru can be easily performed (Yoshita, 2004).

In a cell, a part/product family is merely a group of part/product sharing a number of similar characteristics. However, parts/products are not identical to one another. Therefore, some equipment or tools are unused sometimes. In contrast, a Seru is usually dedicated to one product type; therefore, its equipment may be fully used. In this viewpoint, Serus enhance the utilizations of processing equipment, jigs, and tools.

Cell production increases the capital investment on installing the same kind of equipment in multiple cells such as jigs and tools. Similarly, in Serus, several duplicated jigs and tools to shorten fetching and returning time raise associated costs. However, considering the large amount of costs saved in other aspects, the investment on Serus declines in general. With most of the simple equipment for replacing the automated equipment developed within the enterprise, the investment is not comparable to that on the conveyor line and automated equipment. Correspondingly, the depreciation cost and maintenance cost on simple equipment decline compared with those on the conveyor line and automated equipment (Sakazume, 2005).

4.4 The Flexibility of the Manufacturing System

Cell production and Seru Seisan both have high flexibility, but the mechanisms behind the two systems are different. The layout of cell production requires equipment with dissimilar functions used in the whole manufacturing process to be included in one cell. The U-shaped line is usually used (Miltenburg, 2001; Aase, et al., 2003; Chiang and Urban, 2006). Under Seru Seisan, the long line is removed and replaced by many short ones. These short lines appear in various layouts, and the straight line, U-shaped line, L-shaped line, and more twisted lines are usually adopted in final assembly processes in response to the inconstant market demand (Iwamuro, 2004).

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.

4.5 The Evolution of Cell/Seru

Serus dismantled from the long conveyor line are continuously evolving. Several researches and production practices show that Serus generally appear in three main modalities of the evolution process: divisional Seru, rotating Seru, and Yatai (for details see Section 7). Yatai is a Japanese word for “street stall.” Some researchers consider Yatai as the perfect and the final object of Seru's evolution (Kimura and Yoshita, 2004; Nonaka and Katsumi, 2004; Kono, 2004b).

The cells, however, have not shown obvious evolving tendencies. Enterprises that have already implemented cell production even avoid adopting one-worker cells because they emphasize teamwork (Hyer and Wemmerlöv, 2002). Although there is no clear direction on the cell's evolution, cell production has achieved dramatic success in minimizing logistics cost within the plant, which is really high in the job shop.

These analyses reveal the existence of various differences between Seru Seisan and cell production. However, Seru Seisan is commonly confused with cell production in most cases. This may be one of the reasons that few researchers outside Japan are familiar with Seru Seisan, and the literature on Seru Seisan can rarely be found in international academic journals.

5. The Characteristics of Seru Seisan

Seru Seisan is distinguished from cell production and other production management modes via the following outstanding characteristics:

(1) The forming pattern of Seru is "reverse conversion." A key driving force for implementing Seru Seisan is to improve the flexibility of the conveyor line so as to meet the customer demand. To achieve this goal, the long conveyor line is dismantled into many Serus. However, the foremost motivation for adopting cell production is to enhance production efficiency by combining various job shops (Wemmerlöv and Hyer, 1986). Considering cell production with long history and extensive investigation, the conversion from job shops to cells is regarded as "conventional conversion." Correspondingly, the conversion from conveyor line to Serus is called "reverse conversion" (Yin, et al., 2008b). These two kinds of conversion patterns are illustrated in Figure 2.

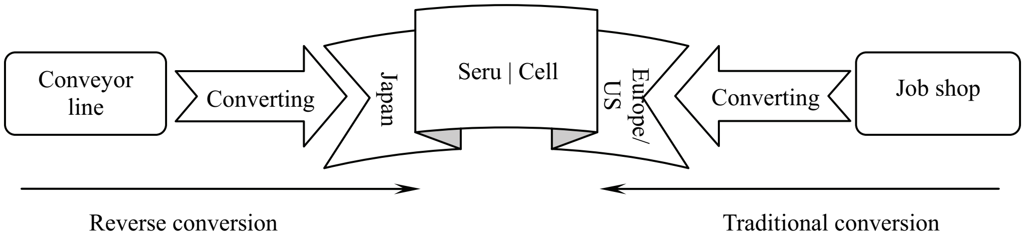


Figure 2: The Illustration of Two Kinds of Conversion Patterns

(2) 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. Such a manufacturing unit requires that all manufacturing resources, such as equipment, jigs, and tools, are located in or adjacent to it. Moreover, the workers are cross-trained and have multiple skills (Shinohara, 1995). Compared to the specialized worker on a conveyor line operating a given task, a worker in Seru can fulfill several tasks that are not always consecutive (Berggren, 1992; Sandberg, 1995; Jonsson, et al., 2004).

(3) Seru Seisan is a human-centered production management mode. The cross-trained worker is the essential factor for Seru Seisan. The ability of Seru Seisan to achieve satisfactory results is, to some extent, based on the performance of the cross-trained workers. The cross-training work should be started before implementing Seru Seisan. Furthermore, the training plan should not be confined to the tasks associated with the former and/or latter workstations. The utmost objective is to help some workers acquire all the skills for processing a product type or several product types (Shinohara, 1997; Tsuru, 1997). Such an objective can be achieved by job rotation in some cases.

Not every worker can perform all complicated tasks of one or several product types. Hence, the intelligence of each worker should be measured, and an individual training plan should be designed according to it. This plan can explore the worker's talent to the maximum. In general, the cross-trained workers have the capacity to work in several different Serus, so it is possible to adjust the worker assignment in response to the dynamic demand.

(4) 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. To avoid equipment conflict and to reduce cost, expensive automation equipment were replaced by simple equipment with similar functions, which could be easily duplicated and modified at low cost (Shinohara, 1995; Isa and Tsuru, 2002; Yoshita, 2004). As a result, the automation level of the whole production system went down. A representative example is a plant of Stanley Electric Inc. located in Northern Japan. During transformation, the plant replaced a costly piece of equipment worth 30 million Yen with a simple and cheap piece of equipment at a considerable low cost of 200 thousand Yen, only 1/150 of the original price (Yamada and Toshibumi, 2001).

(5) In Serus, product defects can be inspected and repaired timely. It is generally easier for cross-trained workers to discover defects and thus deal with the defects immediately (Miltenburg, 2001). Such an agile response to defects is associated with the workers' abilities

to a large degree (Lee, et al., 2010). To repair defects on the conveyor line may result in stopping the whole conveyor line or even the production system; however, repairing defects in Seru only affects the specific Seru. The cross-trained workers can also help one another to solve the problem efficiently.

(6) Seru Seisan can save floor space. The length of line is determined by the space between workers and the number of workers on line. The linear layout needs sufficient space, larger than other layouts. Academic researches and production practices have shown that Seru Seisan can save considerable floor space. One of the main causes lies in its changeable layouts to adapt to the practical situation. In Seru, the physical space between two adjacent workstations is sharply reduced. Face-to-face working not only ensures good communication among workers, but also saves shop floor. Moreover, light products are usually transferred manually from a workstation to another, and large ones are placed on carts that can be easily transferred (Iwamuro, 2004).

(7) 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. The more complicated layouts, like flower-shaped and heart-shaped, by joining separate Serus together, also appear in some plants. The layout of Seru can be quickly changed in a few minutes because the workers are multi-skilled and the equipment are movable. Whenever unexpected demand arises, the shape and size of Seru can be quickly reconfigured to meet this demand. Although the layout of Seru is diversified, the key standards behind the various outward appearances are unified. Such standards are the minimization of material handling, the minimization of floor occupation, and the avoidance of work-in-process inventory between workstations (Mayumi, 2005).

(8) Seru is a highly autonomous manufacturing organization. Laterally, Seru is an independent manufacturing organization with one entrance and one exit undertaking all or most processes of one or several product types. Vertically, the worker in Seru plays the managerial role to control and monitor production processes in order to keep operations smooth (Iwamuro, 2002). However, the autonomy does not mean that each Seru is isolated from others all the time and is out of control, because different Serus can be associated with one another by some factors and controlled by the same manager. Sometimes sets of Serus are concurrent to assemble one product type, or can be arranged to process one product jointly in a certain sequence.

(9) Seru is a continuously evolving learning organization. Continuous learning has been emphasized in adjusting to a new era of global challenges and competition (Asgari and Yen, 2009). In this context, workers in Seru are active to learn advanced acknowledge, share

information, and develop the capabilities to cope with uncertainties. Compared with workers on the conveyor line, who only receive orders and instructions from managers, the workers in Seru maintain effective communication and feedback with managers, and they can voice their opinions to managers to facilitate continuous improvement (Estrada, et al., 2000). If their ideas are accepted, the workers may be greatly encouraged and the relationship between workers and managers can be improved, which brings great benefit to the plant. The continuous improvement of Seru's performance does not come from the technical aspect unilaterally; continuous improvement in the aspect of management also plays a key role (Tsuru, 2001).

6. The Advantages and Disadvantages of Seru Seisan

Serus have replaced the conveyor lines of manufacturing industries in Japan such as electronics, auto-part, and information equipment. However, even with large-scale replacements, it is difficult or impossible for Seru Seisan to take over all kinds of industries because the conveyor line has irreplaceable advantages in some areas. When product volume is high and stable, the conveyor line can give full play to its advantages of high efficiency. Therefore, several manufacturing enterprises continuously adopt the conveyor line and do not intend to implement Seru Seisan. Just like other production management modes, Seru Seisan has advantages and disadvantages.

6.1 The Advantages of Seru Seisan

Seru Seisan has various advantages from different perspectives. The main advantages are as follows:

High flexibility

To pursue more agile and flexible production systems, manufacturing enterprises abandon conveyor lines and adopt Serus. Serus consist of movable workstations, light equipment, and multi-skilled workers. The installation and reconfiguration of Seru is more rapid and easy. Accordingly, Serus can cope with the demand fluctuation by adding or removing workers and workstations (Miyake, 2006). On the other hand, the layout and the number of workers of the conveyor line are usually fixed; the product output is fixed as well. The problem of under/overproduction usually arises in such a production system lacking in flexibility (Carnall and Ray, 1976; Smunt and William, 1985).

Short lead time

According to the responses from several manufacturing managers, designing, building, and installing the conveyor line may require several months, but a production system of Seru Seisan can be rapidly planned and installed within a few weeks, which results in a striking compression of setup time (Miyake, 2006). Parts are always preassembled before being transported into Serus to facilitate the process, thus decreasing the processing lead time. Worker participation in the prototype design and configuration of Serus also contributes to shortening the lead time. Since the number of workers is decreased and the distance between workers is closer, the amount of time needed to move between workstations is dramatically reduced. Some factors that slow down the whole conveyor line, such as part interruptions, worker's break and absenteeism, and defective part, only affect a specific Seru. The eliminated time during setup is a result of the decrease in the delay required to remove the remaining components/parts away from the conveyor line after completion, and to load new components/parts for processing a new batch (Johnson, 2005).

Low inventory

By replacing the conveyor line with Serus, both work-in-process inventory and final product inventory are reduced sharply. First, the Heijunka key principle, which results in huge work-in-process inventory on the conveyor line, is abandoned in Seru. Second, under Seru Seisan (such a production system), the product volume is decided on the basis of the real demand, therefore a huge final product inventory is avoided (Suzuki, 2004). Moreover, to reduce the blocking and starving situations between workstations caused by task time variability, the conveyor line always sets a large number of work-in-process inventories as buffers. However, the operating range of workers in Seru Seisan is extended so the workers can easily reduce blocking and starving situations by adjusting the operating range. As a result, many work-in-process inventories are decreased and the processing becomes smoother.

Good morale

With the shift from the conveyor line to Serus, workers no longer perform repeated tasks in a fixed speed all day. Under Seru Seisan, workers are cross-trained to master multiple skills, both operational and managerial. Decentralized powers enable them to make decisions on their own and explore their intelligence. As opportunity for communication increases, workers in Seru form a strong work team to improve their performance continuously. In Canon, workers are divided into four classes (3-class, 2-class, 1-class, and super-class) based on their skills. This ranking system promotes the workers to improve their performance consciously for the super-class. Since nobody else is more acquainted with the condition of inner Seru than the workers who operate it, workers are also invited to participate in other activities in their spare time to show their creativity, such as joining in the design of the Seru layout during installation or when reconfiguring an existing one, or taking part in the design of product prototype (Olorunniwo and Udo, 2002). Elements such as workstations, product carts, parts bins, transportation carts, and jigs are also selected or conceived by the workers to ensure the maximization of equipment efficiency and the enthusiasm of workers (Miyake, 2006).

The conversion from the conveyor line to Serus could result in several workers losing their jobs because the demand for workers will be brought down for cross-trained workers with multi-skills. However, the real need for workers in many manufacturing enterprises did not decrease after the adoption of Seru Seisan, and the motivation of workers increased dramatically. The key reason lies in reallocating workers to proper departments according to their characteristics rather than dismissing them. Once the worker is assigned to a position he or she is really interested in, enthusiasm is activated, resulting in increased devotion to the work and better performance (Sakamaki, 2006).

6.2 The Disadvantages of Seru Seisan

The above mentioned advantages interest numerous manufacturing enterprises into Seru Seisan, but the disadvantages of Seru Seisan should not be ignored.

Finite ductility on the size of Seru

When product volume rises slightly, Seru's capacity can be rapidly adjusted by adding workstations or establishing additional Serus. However, the stretch of Seru is limited; the number of workers in a Seru is usually restricted to about 15. When production volume rises to a certain extent, the excessive stretch or adjunction of Seru will take too much space, the efficiency will be lower than that of the conveyor line, and the investment will increase at the same time (Sakamaki, 2006; Miyake, 2006).

Huge investment on training for multi-skilled workers

The cross-trained worker with multiple skills is the core of Seru Seisan, so a large amount of money and time should be spent on training (Kimura and Yoshita, 2004). The content of training includes not only the usage of various jigs and tools, but also the operation methods of different product types. Fluctuation of demand requires this training to be a continuous course, therefore investment on training is also continuous in the long run.

Slight increase in variable production cost

With the conveyor line dismantled, heavy equipment are replaced by simple ones and tools allocated beside the conveyor line are duplicated and distributed to many Serus. Therefore, investments on simple equipment and tools increase. However, simple equipment are always designed and made by workers and engineers within the enterprise. As a result, the variable production cost will increase slightly in the early period of Seru Seisan implementation.

High pressure on workers

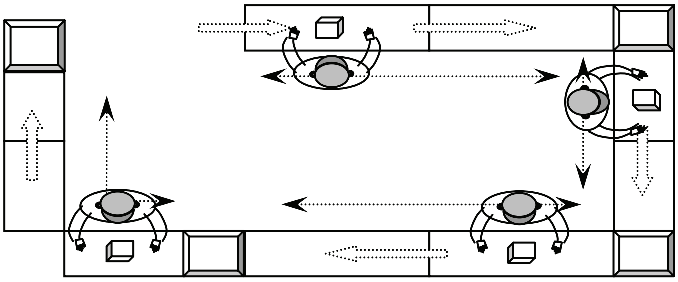
The workers in Seru need to attend several training courses to improve their skills. These workers, who have spent large amount of time and energy to acquire more knowledge and skills, are responsible for production, as well as quality control, and deal with the interpersonal problems when working with others. Workers feel higher pressure and fatigue in Seru Seisan than on the conveyor line, so some workers may be resistant to the implementation of Seru Seisan. This has been a crucial management problem for enterprises that have adopted Seru Seisan (Noguchi, 2003).

7. The Main Modalities of Seru

Whether under cell production or Seru Seisan, work cell/Seru is the most basic element to the whole production system. Several researchers, such as Akino (1997), claimed that during the process of Seru formation and evolution, the main and most common modalities of Serus are divisional Seru, rotating Seru, and Yatai.

7.1 Divisional Seru

Based on the systemic analysis on various constraints such as the complexity of tasks and technology factors, the conveyor line is dismantled into many short lines. After receiving cross-training, the workers are assigned to these short lines separately. On these short lines, workers also cooperate with one another as before, but each worker operates more processes than on the conveyor line. Each short line is dedicated to one or several specific product types. Hence, the workers usually shuttle among several workstations to complete all processes assigned to them. The expensive and complicated equipment are replaced by the cheap and simple equipment. This short line is called divisional Seru. Figure 3 is a U-shaped divisional Seru with four workers. The change of layout for the initial conversion from conveyor line to divisional Seru is not difficult; the key problem is the cross-training for workers.

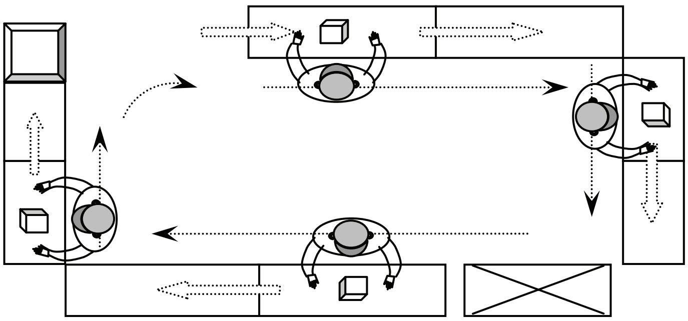


Note: Adapted from Iwamuro (2004, p. 63).

Figure 3: Divisional Seru

7.2 Rotating Seru

Along with the advance of cross-training, some workers are qualified to perform all required tasks from-start-to-finish for producing one or several product types and gradually become competent for some basic management tasks within Seru. These cross-trained workers, one by one in the fixed order, complete all production processes running from one workstation to another. After finishing one product, the worker returns to the start workstation and begins a new round. The Seru with such characteristics is called rotating Seru, which also can be named as “rabbit-chasing Seru” because of its resemblance to a rabbit-chasing game. Figure 4 presents a rotating Seru. Compared with the former modality, most workers in rotating Seru are fully cross-trained in technical skills. However, these workers still need a professional manager to take charge of managerial tasks because they lack comprehensive management knowledge.

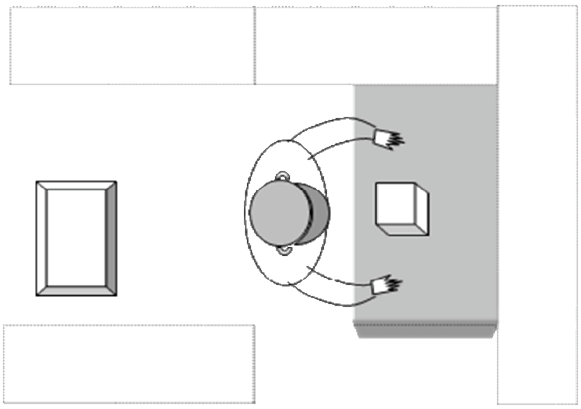


Note: Adapted from Iwamuro (2004, p. 65).

Figure 4: Rotating Seru

7.3 Yatai

Sometimes the rotating Seru may continuously evolve into Yatai — a single worker unit that can give full play to the worker's talents and potentialities. This organizational unit allows one worker can complete all tasks alone. The worker is not required to run from one workstation to another because workstations and necessary tools are accessible. The worker can get rid of the constraint from other workers and exploit his ability to the full. The worker in Yatai must receive full cross-training for a long period and become proficient in all technical and managerial skills. Flexibility and efficiency are two outstanding merits of Yatai. Hence, Yatai is regarded as the perfect modality to a certain extent. Constructing Yatai is the objective of organization innovation in many Japanese enterprises (Kimura and Yoshita, 2004; Nonaka and Katsumi, 2004; Shinohara, 1995; Kono, 2004a). Yatai is presented in Figure 5.



Note: Adapted from Iwamuro (2004, p. 67).

Figure 5: Yatai

From the above descriptions, we can see a common trend in Seru's evolution; that is, divisional Seru can be regarded as the junior modality and Yatai the advanced one. However, there is no strict criterion to rank them because divisional Seru may fit the production process better than Yatai on some conditions. Moreover, Yatai should not be considered as the final modality in Seru's evolution. The result of whether a divisional Seru will evolve into Yatai is determined by the combined effects of various factors in a certain environment. Therefore, for a specific enterprise, three modalities of Seru can be combined and applied according to the practical situation.

8. Further Research Problems on Seru Seisan

Seru Seisan is a new production management mode that emerged in Japan. Japanese manufacturing industries have achieved great success with regards to Seru Seisan, but the academic research on it is still rather sparse and sporadic. To accelerate the application of Seru Seisan in manufacturing industries all over the world, it is necessary to make a comprehensive analysis on previous practical experiences, extract its operational principles, and establish its operational theory. At the moment, some key problems on Seru Seisan should be investigated further as follows:

- The similarities and differences between Seru Seisan and conventional cell production. As described above, there are some similarities and differences between Seru Seisan and cell production. However, systematic research on comparison between them is scarce at the moment.
- The theoretical basis of Seru Seisan. It is well-known that the theoretical basis of cell production is Group Technology. However, the theoretical basis of Seru Seisan has not been ascertained until now. Although several researchers have claimed that the combination of operational principles in the Toyota Production System and Sony's one-man production system is the theoretical basis of Seru Seisan in literature (Kimura and Yoshita, 2004; Nonaka and Katsumi, 2004), this claim has not been widely accepted because of limited comprehensive analysis, analogical probation, and full field research.
- The operation theories of Seru Seisan. The researches on cell production mainly focus on four aspects: cell formation, layout planning, production planning, and production scheduling and control. Referring to the research experience on cell production, we think research on the operation theories of Seru Seisan can be developed from the same four aspects. These groups of research will constitute the core content of operations management of Seru Seisan.
- The way to realize mass customization by merging Seru Seisan and cell production. Mass customization has become the main production philosophy for the 21st manufacturing industry. However, research on mass customization is still restricted to several aspects like definition, success factors, and key technologies. Investigations on the manufacturing system and management method for realizing mass customization are very scarce to date. Existing manufacturing modes, whether job shop or mass production, cannot realize mass customization. We think that it may be an effective way to realize mass customization by merging Seru Seisan and cell production, because these manufacturing modes integrate the flexibility of job shop and the efficiency of mass

production. Achieving mass customization by merging Seru Seisan and cell production is shown in Figure 6.

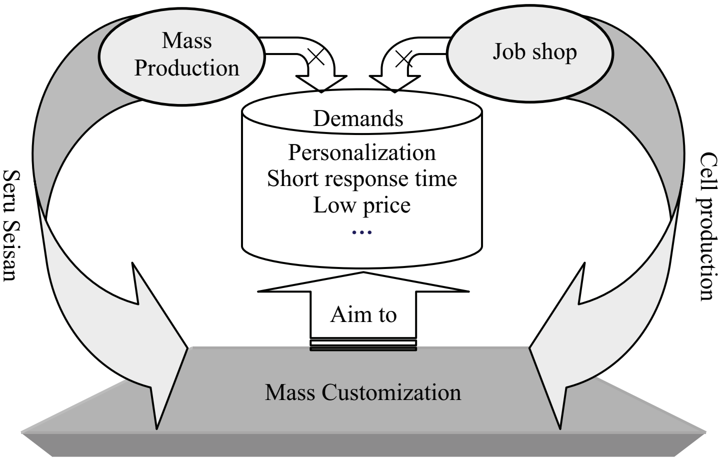


Figure 6: Realizing Mass Customization via Cell production and Seru Seisan

9. Conclusions

In the literature, several researchers have proposed tentative definitions of Seru Seisan from the viewpoint of Seru. Shinohara (1995) indicated that Seru is a Jiritsu manufacturing unit in which all required tasks for producing a product are completed by one or several workers who can operate several different types of equipment. Tsuru (1997) pointed out that Serus resulted from the dismantling of the conveyor line, and the batch size in each Seru can be adjusted by the multi-skilled workers to correspond with the fluctuation of market demand. Yin, et al. (2008c) summarized that a Seru is a manufacturing line (an assembly line in most cases) made up of equipment and workers dedicated to one or several product types, and represents three main characteristics: Kanketsu, Majime, Jiritsu. A group of researchers intended to explain Seru Seisan from the viewpoints of production line and support system. Yagyu (2003) showed that the production line of Seru Seisan is constructed by a group of equipment that is closely located for processing several specific parts or products and are under the charge of one or several workers. In giving full scope to the advantages of this production line, several fundamental support systems are indispensable. These support systems include production planning and scheduling system, transportation system, components supply system, management, and maintenance system.

On the basis of systematic analyses on the origin, generation background, characteristics, advantages, and disadvantages of Seru Seisan, we also propose a definition of Seru Seisan for academic discussion: Seru Seisan is an innovation of the production management mode based on the conveyor line in the Japanese manufacturing industry. It is a human-centered production system based on cross-trained multi-skilled workers. As the basic level, Seru is dedicated to one or several specific product types, and majority or all of the operations are completed within one Seru. It is an advanced production management mode with high efficiency, as well as the capability of adapting to the production situation characterized by low investment on equipment, high production variety, and low production volume. Seru Seisan should not only be considered as a production management mode; the core theory of such an innovation can be seen as a management principle applied to many other areas, such as the service area.

In this paper, we have provided a brief introduction of Seru Seisan from many aspects such as the origin, generation background, characteristics, advantages and disadvantages, and modalities of Seru. Key problems that require urgent solutions in the future were also presented. These investigations show that Seru Seisan, which has been called “beyond lean” in many industries, is an emerging production management mode in Japan. Seru Seisan has been widely implemented in Japanese manufacturing industries, but academic research on this area is still very limited worldwide. In view of the successful application and lack of existing research, this work was conducted to gain the attention of researchers out of Japan and invite more researchers to join the research teams on Seru Seisan.

Acknowledgments

The authors sincerely thank Professor Kazuhiko Yasuda of Tohoku University and Professor Ikou Kaku of Akita Prefectural University for their kind assistance and valuable advice in this study. The authors also express their heartfelt thanks to the anonymous reviewer for his/her constructive comments.

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