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A STUDY ON SERU PRODUCTION SYSTEM

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Abstract: Big, complicated, mass-produced products have long been made on the assembly line. And the assembly line, at its core, hasn't changed much since Henry Ford put it into swing. In the early 1990s. High-tech products began to have much more variety and much shorter lifecycles. So the Japanese companies who dominated the electronics industry, like Canon and Sony, uprooted their assembly lines and switched to a production method they call seru. Seru production is an innovation in Japanese manufacturing since 1990s. Its essence is converting traditional assembly conveyor lines into some mini-assembly units, called seru, a Japanese word for cellular organism. A seru production system is economically sound for manufacturers to improve sustainability and to increase profits simultaneously. In this paper we will study the development of a multi – objective optimization model to investigate two-line conversion performances. We will also study examples, effects and training process for seru method in the industries around world.

I. INTRODUCTION

"Seru is like going back to trade manufacturing, before Henry Ford's assembly line innovation. A focus is on extremely highly trained workers, emphasizing both speed and quality," said Stecke, who teaches operations management and flexible manufacturing strategies in the Naveen Jindal School of Management at UT Dallas This type of cellular manufacturing is distinguished by the ability to configure the cells quickly and its use of the cells for assembly, packaging and testing rather than only fabrication. Seru uses highly skilled and flexible workers to achieve the responsiveness required by the changes in demand and the fast development of an innovative product. Seru has acquired a reputation as the next generation of lean in Japan for several years but is still largely unknown outside Japan (Shinobu, 2003). With combined strengths from Toyota's lean philosophy and Sony's one-person production organisation, Seru is a more productive, efficient, and flexible system than Toyota's Production System. It has been successfully applied to electronics and auto components industries. Many leading Japanese companies such as Sony, Canon, Panasonic, NEC, Fujitsu, Sharp, and Sanyo have dismantled their assembly conveyor lines and adopted Seru (Gotou, 2005). In fact, by applying Seru, the average productivity of Canon is now higher than that of Toyota (Weekly-Toyo-Keizai). Seru has many benefits. It can reduce lead time, setup, Wip inventories, finished-product inventories, cost, required workforce, and shop floor space. Seru also influences profits, product quality, and workforce motivation in a positive way (Takeuchi , 2006). A seru has three characteristics : firstly, Kanketsu, which means all tasks are completed in a Seru; Secondly, Majime, which means all required resources are placed closed to reduce unnecessary movement; Thirdly, Jiritsu which means self management and learning organisation. There are three types of Seru: Divisional seru, Rotating seru and Yatai. As seru has continuously achieved big success in not only Japan but Korea and China, more and more attention have paid to performance indicators of seru. Several papers analyse the performance of line-seru conversion affected by operation factors. Jhonson adopted a previous theory to illustrate why assemblyserus have a better performance than traditional conveyor assemble line. He studied the stimulation models to observe the marginal impact when the operational factors are changed in the conversion. By using human memory ability they analysed the cross-training of workers quantitatively and found that information support system is benefit for improving the cross training effect. Yu et al proposed a 64-array experiment and used three non-dominated solutions to find operational factors or interactions between them which may improve the performance. They suggested several insights about the formation of assemble serus and load serus based on the experimental results. For the methods to achieve better line-seru performance, many researchers use a multi-objective model to optimize two line-seru performances: the total throughout time and the total labour hour. In this paper we will also study what is seru production and why do Japanese manufacturers like to introduce it. We will also discuss on a trend in Japan to improve the performance of traditional assembly line by adopting seru with some examples.

II. BIRTH OF SERU

Sony (2005, 2009) began to adopt assembly conveyor line in 1955 to accommodate rapidly increasing market requirements. Until 1992, conveyor lines were widely used in Sony's manufacturing factories and had contributed greatly to Sony's production. In between 1955 and 1992, Sony also tested other manufacturing approaches such as one-person production organization and TPS. Sony experimented with OPO in 1963. By 1967, it became the second most important manufacturing tool for Sony after assembly conveyor lines. In 1983, a TPS Studying club was created. Later, a project named "Prodcution-innovation-86" began applications of TPS to Sony's production organizations. In the middle of 1980s, production of most high-volume, low-value-added Japanese products were shifted to low-cost countries. To products high-variety, low-volume, and high-value-added products, Sony applied TPS's mixed-products method to its conveyor lines. Unfortunately, the volatile hensyuhenryou environment made heijunka – a key lean tool to guarantee production flow – almost dysfunctional. Sony asked for help from a TPS expert, Hitoshi Yamada. Hitoshi Yamada is the founder of a Japanese management consultant company, PEC. He had been a pupil of TaiichiOhno, the father of lean production, for many years. In 1992, several short lines were created in one of Sony's video-camera, after dismantling a long assembly conveyor line. As did the original conveyor line, each short line produced the entire product. Since then, these lines became shorter and shorter and eventually evolved into-one worker organizations. These mini-assembly organizations brought huge benefit to Sony. They could be constructed, modified, dismantled, and reconstructed rapidly and frequently. In 1994, TatsuyoshiKon, a former staff in Sony's industrial engineering division, called this mini-assembly organization seru, a Japanese word for cellular organism. Since then, hundreds of Japanese companies adopted seru(Economic-Research-Institute).

III. WHAT IS SERU PRODUCTION?

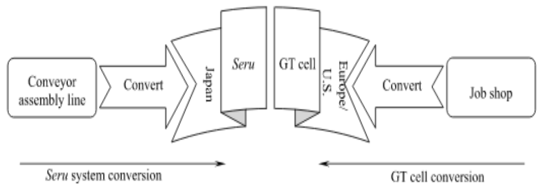

Fig. 1. Typical conversion of a job shop to a GT cell and a conveyor assembly line to a *seru* system

Since the 1990s, Japanese manufacturers were faced with a decreased market demand and increased product variations. To survive in such an extremely tough business environment the traditional high-volume conveyor assembly line was no longer fulfilled. Speedy adjustments were needed to handle transitions in product models and demands. A company's competitiveness was becoming dependent on whether or not it can respond to these transitions. In such an environment, there was a trend in Japanese industry toward converting conveyor assembly lines to more flexible manufacturing system. A seru production system is an innovative manufacturing system developed in Japanese industry. Its essence is tearing out traditional assembly conveyor lines and adopting them into mini-assembly units, called seru, a Japanese word for cellular configuration. Seru can be defined a manufacturing organization (an assembly unit in most cases) that consists of some equipment and one or more workers that serve one or more products. Seru production system was first investigated initiatives taken in the electronics industries by firms like NEC Nagano, Yamagata Casio, Olympus, Pioneer and Santronics, mainly on the cases in plants dedicated to assembly of printers, digital cameras, digital video cameras, and module parts for digital electric equipment . They claimed that many manufacturing managers in Japanese companies seem now to realize that the advantages of the conveyor lines no more pay off the adoption of this type of production system design. Since 1990s, Japanese companies have IkouKaku / Procedia Manufacturing 8 (2017) 723 – 730 725 actively introduced seru production systems, which handle small-lot multi-kind production more efficiently than the belt conveyor assembly line with the resultant advantages of a marked improvement in productivity, reduction on capital investment, shortened lead times, saving of manufacturing work space, improvement in product quality, and so no. On the other hand, as for the physical configuration of serus, quite often they are designed in resemblance of the U-shaped lines, which are notably developed from 1960s on as a means to build streamlined flow (by a layout configuration that assures a more rational materials flow than the functional or process layout), enable one-piece flow, reduce work-in-process inventory, and nature work in small groups as well as workers' multi-functionality. Naturally a question is could we say that seru is different to the traditional cellular manufacturing? There are also several researchers made comparative studies and listed up a lot of differences of seru and cellular manufacturing, to try to proof that seru is a new production system. However, it seems not so successful, because many similar technologies are used in both seru and cellular manufacturing system. It should be pointed that seru production system is not suitable to be used in all kinds of manufacturers. Sengupta and Jacobs found environments where the conventional assembly line outperformed assembly cells in a plant that assembles television sets. The environments occurred when conversion also results in an increase in task time or other loss of efficiency in the assembly cells. Adler and Cole claimed that the performance of the assembly cells used in Volvo's plant was inferior to the more traditional assembly line system. That means seru or cellular manufacturing system does exist in many configurations and more researches are needed to understand the factors that determine when and where certain configurations are applicable. Consider seru production system is following those previous innovations in past decade, it cannot be distinguished wholly to other manufacturing methods like as cellular manufacturing, assembly cell, short assembly line and so on. However it totally represents an improved production system and gives its own special characteristics in a whole imagination. Therefore a fundamental positive research on Japanese seru production systems to clarify the features of seru is very interesting and important. For example making an issue database where all of Japanese companies who adopted seru reported in literature are included. You can find the related information of those companies reported their sustainability in the literature.

IV. AN OVERVIEW OF SERU PRODUCTION SYSTEM

Publication Types	Number of serus
Magazine paper	164
Companies report	13
Newspaper	76
Book	21
Web site	415

Table 1. All of published material in Literature

Up to now, as shown in Table 1 there are 164 magazine papers, 13 companies reports, 76 news papers, 21 books and 415 internet sites have been collected. Those materials cover almost all publications on seru production systems in Japan. Fig. 1 shows the trend of publication of magazine papers. The horizontal axis shows publication year and 726 IkouKaku / Procedia Manufacturing 8 (2017) 723 – 730 vertical axis shows the numbers of publication. From Fig. 1 it can be observed that articles of seru were presented from 1992 and reaching a peak in 2004, and constantly presented after then. Consider those successful cases reported in literature are just a part of Japanese manufacturers who adopted seru production systems, we can say it is a trend of that the seru production systems are often adopted in Japanese manufacturers as a usually used improvement approach

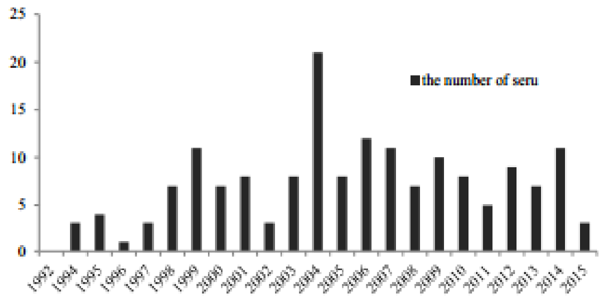

Table 2.The number of published magazine papers.

Unfortunately, very few reports of seru production system involving environmental impacts are reported in the past decade. By introducing seru production system from 1998 to 2002, Canon dismantled belt conveyor assembly lines of 20,000 meters in their 54 factories. 720,000 square meters of workspace had been saved . Especially in Canon Electronics Inc., a subsidiary company of Canon group, an environmental performance of 54,677ton CO2 emissions reduction had been achieved in 2002, which corresponded to more than 50% of their total emission. In 2001 after seru implementation, Ricoh has also successfully reduced its CO2 emissions by 13.8% compared with 1990 and achieved a recycling ratio of 100% at all production sites around the world. It can be considered that the environmental impacts are shown by total economic activities executed by the company, even throughseru production system can achieve a lot of effects of QCD (Quality, Cost and Delivery) but it is difficult to show how many for example CO2 emissions have been reduced by seru.

V. A MODIFIED MODEL OF THE LINE-CELL CONVERSION PROBLEM

Problem description

Kaku et al. (2008) compared three types of assembly systems: a pure cell system, a pure assembly line, and a hybrid assembly system that consists of an assembly line and several cells. For simplicity and without loss of generality, this paper studies a line-cell conversion problem shown in Fig. 2, i.e., an assembly conveyor line is converted to a pure cell system. All workers who formerly worked within the assembly line are assigned to cells (we name it as ‘‘assembly cell formation’’). A robust JIT-OS is the key for implementing a successful cell system. One important problem for designing a JIT-OS is to schedule or assign customer orders to different cells. We call this problem ‘‘assembly cell loading (ACL)’’. Unfortunately, Yin, Stecke, Li, and Kaku (2011) have proved that even a simple ACL problem is NP-hard. In this paper, we adopt a First Come First Serve (FCFS) principle that applied in many companies. An arriving product batch is assigned to the empty cell with the smallest cell number. If all cells are occupied, the product batch is assigned to the cell with the earliest finish time. Fig. 3 shows a FCFS cell loading example with six batches and two cells. The length of rectangle charts in Fig. 2 is the flow time of a product batch. We evaluate two line-cell conversion performances: throughput time and required labor hours, which have been reduced dramatically by seru users (e.g., 53% throughput time at Sony, 25% required workforce at Canon, respectively). Therefore, our problem is to decide how many cells should be formed, how to assign workers and product batches to appropriate cells to minimize two objectives, i.e., the total throughput time (TTPT) and the total labor hours (TLH).

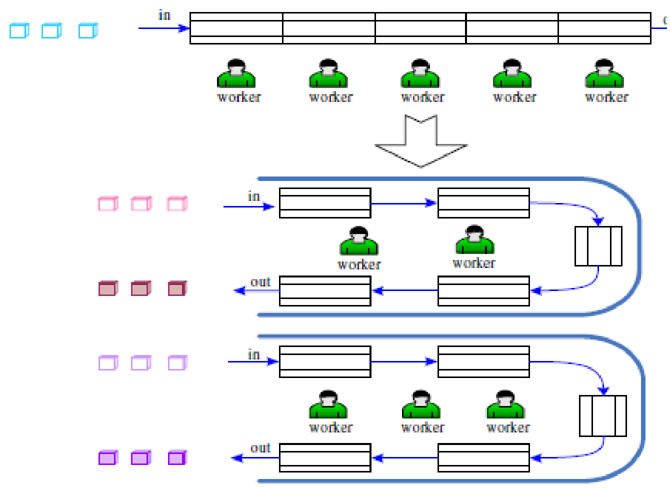

Figure 2. –Converting an assembly line to a cell system.

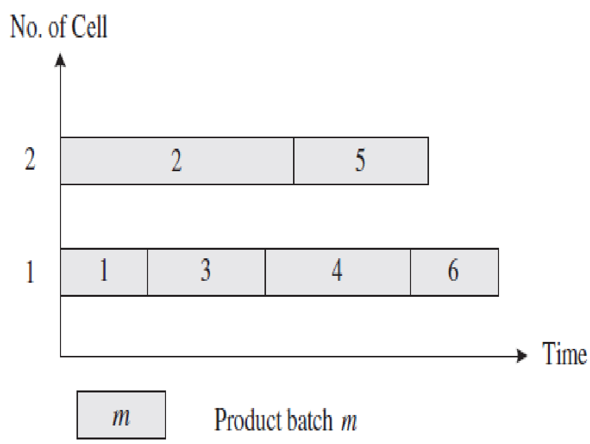

Figure 3.– An example of FCFS scheduling in a cell system

VI. ENVIRONMENTAL IMPACTS CAUSED BY SOME REAL CASES OF SERU PRODUCTION

It is a well-known fact that almost big companies have reported their sustainability every year. A very famous case of introduced seru production system is Canon, a big Japanese electronic company that the conveyor-belt assembly processes have been eliminated at all its plants worldwide. Driven by the applied expertise of individual employees, including their workplace and process knowledge, the Canon's seru production system has increased productivity dramatically. The seru production system also contributed to the introduction of supply chain management, allowing greater flexibility in high-mix low-volume production and changes in production volumes. It is can be observed from Canon sustainability report of 2007 and 2015 that Canon assesses the amount of CO2 emissions produced during the product lifecycle and carries out environmental assurance activities based on an annual action plan. The product lifecycle in Canon's business activities comprises four principal stages: 1) the manufacture of raw materials and parts by suppliers, 2) Canon's operational site activities (development, production, and sales), 3) transportation to sales outlets and other locations (logistics), and 4) customer usage. In 2006 Canon made a plan to make their products be more energy-efficient, smaller and lightweight, and to reduce the environmental burdens from customer usage and the manufacture of raw materials and parts by suppliers. As a result of higher product shipments CO2 emission volumes rose to total 6,851 thousand tons in 2006, 0 5 10 15 20 25 the number of seruIkouKaku / Procedia Manufacturing 8 (2017) 723 – 730 727 in which 3143, 950, 940, 1818 thousand tons were used in stage 1, 2, 3, 4, respectively, against stagnant growth in consolidated net sales as the result of increased competition and lower market unit prices. In 2014, Canon implemented measures aimed at reducing environmental impact in all stages of the product lifecycle. As a result, in the manufacture of raw materials and parts (stage 1), Canon reduced the amount of raw materials and parts to make products lighter and more compact, but increased production in the office business unit caused CO2 emissions to decrease by approximately 349 thousand tons compared to 2006. It is a great achievement. For the customer use stage (stage 4), the CO2 emissions from use have been reduced through the development of energy-conservation technologies. However, due to the economic recovery it was seen an increase in sales of industrial equipment with high environment impact, resulting in an increase of approximately 116 thousand tons compared to 2006. Regarding operational site activities (stage 2), Canon reduced CO2 emissions by approximately 6,000 tons year on year by energy-conservation activities, which included making equipment operations more efficient at production sites and eliminating waste at sales sites. However a large increasing of CO2 emissions in stage 2 were seen approximately 298 thousand tons compared to 2006. Finally, in logistics (stage 3), Canon tremendously lowered CO2 emissions by approximately 628 thousand tons compared to 2006 by promoting a modal shift, improving transport efficiency and changing transport routes. As a result, total lifecycle CO2 emissions for the entire product lifecycle in 2014 amounted to approximately 6.29 million tons, a decrease of approximately 563 thousand tons over 2006.

VII. CROSS-TRAINING TO OBTAIN MULTISKILLED OPERATOR

Multi-skilled operators are necessary to implement seruproduction. In seruproduction, an operator's need for job enrichment is effectively satisfied. Therefore, seruproduction has been generally acknowledged as human-centered production (Kaku et al., 2008; Liu et al., 2010; Stecke et al., 2012).In implementing seruproduction, if multi-skilled operators can upgrade to fully skilled operators,they become a vital resource for a factory. Also, operators receive generous remuneration when theyobtain the highest skill level, such as S-class in Canon (Yin et al., 2008; Stecke et al., 2012).

A. Determine the necessaryskills for training.

The main goal of implementing seru production is to meet the high-variety and low-volume market demands. With diversified product demand, technologists and managers should analyze products from the perspective of tasks, and then determine the assignment of tasks to specific operators. Technologists and managers should communicate thoroughly with the operators so that each operator can clearly know what he or she needs to do to efficiently produce products. Compared to mass production, the task range for each operator in seruproduction is much larger. To train an operator, if the factory adopts divisional serus, thetraining should focus on extending the task range to the adjacent tasks based on his/her currentspecialized task. If the factory implements rotating serusor yatais, training needs to cover all skills required in the entire production process.

B. Set distinct objectives

To aid smooth production under a predetermined schedule and quality objective, managers should inform each operator of his/her objectives according to the planned delivery time and required product quality, such as when a given skill level should be mastered. The objective of operation balancing should be made clear to the operators, especially in divisional and rotating serus. In divisional serus and yatais, if the products to be processed are precision products, the task precision criterion should be recognized clearly by the operators during cross-training. In general, a training objective is established by a manager according to production demand. Inorder to strengthen motivation and efficiency of operators, setting specific objectives for operators requires managers to communicate fully with each operator. Full communication not only allows managers to know each operator's views and capabilities, but also helps the operators have greater enthusiasm to achieve their specific objectives.

C. Formulate a comprehensive training plan.

For cross-training activities to run smoothly and successfully, a comprehensive training plan is essential. Real-time supervision and control of implementation of the cross-training plan is necessary. Corrective measures should be taken when a deviation is detected. A cross-training plan should be made once a factory decides to implement seru production. After the analysis of products and process features to implement seru production is completed, training for basic skills should be launched as early as possible. Real-life scenario-based training and management knowledge oriented training also should be carried out, as the design of the organization and engineering of a seru production system are launched gradually. Cross-training should be persistently promoted, which assists factories to deal with constantly changing market demands.

D. Select effective cross-training methods.

In practice, one reason for not meeting expected results is imperfect cross-training methods. For new operators, it is better to learn from appropriate books and workbooks rather than to attend classes for cross-training. The detailed diagrams in a book are helpful to understand how to prepare required operations. Instead of only theoretical training, real-life scenario-based training should be emphasized. For factories that can afford to establishlife-like serussimilar to those in production, operators should be cross-trained in these trainingserus. To reduce production cost and shorten delivery time, on-the-job training is usually used forsome simple operations. For some complex operations for which operators cannot meet the trainingrequirements in a short time, it is suitable and effective to carry out off-the-job training timely onthe basis of implementation of on-the-job training (Iwamuro, 2004).

E. Use advanced training approaches.

Operators in seruproduction are responsible for some managementand problem-solving functions in addition to normal operation assignments. As a result, along with training for the necessary operating methods, training courses should also highlight thepurpose and meaning of the operations. That is, conventional know-how training should be supplementedwith know-why training (Iwamuro, 2004). The conventional know-how training approachtrains operators to master specific operating methods from a technical perspective. Know-whytraining emphasizes the purposes and meanings of operating methods.For a factory that intends to implement seruproduction, facing changing market demands andthe requirements of a production process for continuous improvement, cross-training for multi-skilledoperators should be done with long-term adherence. Compared to other production modes,the investment in cross-training for multi-skilled operators in seruproduction is larger. A factoryimplementing seruproduction should place importance on cross-training formulti-skilled operators,and regard it as an important strategic task. Senior managers should give adequate attention tocross-training for multi-skilled operators.Research results from the literature show that job training is valuable for workers. The influence ofjob training on job satisfaction has been illustrated in many works (Nordhaug, 2004; Georgellis andLange, 2007; Steven, 2007; Leppel et al., 2012). Factories that have implemented seruproduction show that job satisfaction increases significantly from job training activities (Sakikawa, 2005, 2006).However, some problems that can arise in conducting cross-training for multi-skilled operators deserve attention. Since multi-skilled operator-oriented cross-training requires operators either to master more skills or to improve their skills to higher levels, it puts more pressure and burden on operators. Operators who have less desire for career development may resist cross-training. In orderto advance cross-training to meet the demand of smooth production, managers should squarely face these negative attitudes and problems and take measures to solve them timely.

VIII. SUSTAINABLE EFFECTS BY USING THE SERU PRODUCTION SYSTEM

Today, sustainability has become an essential part of manufacturing strategies. Sustainable development in manufacturing goes beyond environmental preservation to protect the environment and its resources while satisfying human needs and boosting progress. The implications of these actions must be considered to ensure that future generations are able to satisfy their needs. Sustainable manufacturing refers to the set of technical and organizational solutions contributing to the development and implementation of innovative methods, practices and technologies, in the manufacturing field, for addressing the world-wide resources shortages, for mitigating the excess of environmental load and for enabling an environmentally benign life cycle of products.

A seru production system, which integrates lean and agile production paradigms [5], has many benefits. It can reduce throughput time, setup time, required workers, WIP inventories, finished-product inventories, cost, and shop IkouKaku / Procedia Manufacturing 8 (2017) 723 – 730 729 floor space. Therefore, seru production system can be used to increase the productivity and competitive advantages. In the past we have constructed a mathematical model to convert an assembly line to seru type production system to show the feature of seru production system, in which how many cells should be formatted and which workers should be assigned in each cell have been discussed. We also have discussed how to evaluate the performance improvement of seru production system.

However, it has not been discussed in those researches why could seru production system reduce environmental negatives, such as CO_2 emissions, waste generations and so on. As an undergoing research in this paper, we used the proposed model in to explain that seru production system has significantly reduced its impact on the environment

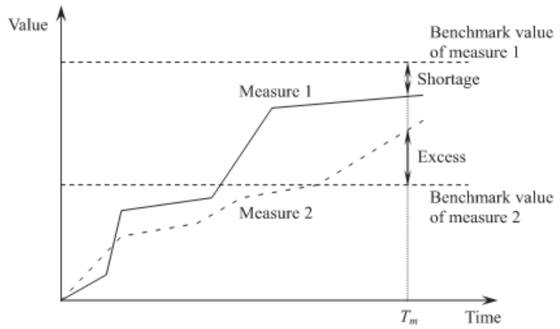

Figure 4 – Performance Results

IX. CONCLUSION

Seruproduction is a manufacturing philosophy based on an innovation of assembly conveyor lines and originally developed in Japanese manufacturing industries. A large number of successfulimplementations show that such an advanced production mode can achieve the integration of the flexibility of a job shop and the efficiency of mass production, as flexible manufacturing has done formachining. From the viewpoint of environmental performance, it also has some essential features ofsustainable manufacturing. In seruproduction, many practical methods are actualized to improveenvironmental performance. For example, small simple movable equipment are usually used in placeof big complex fixed equipment, which helps to reduce carbon dioxide emission. In Canon, carbondioxide emission dropped by more than 50% after seruimplementation (Sakamaki, 2006). In thissense, seruproduction methods would appeal to industry and academics interested in the area ofsustainable manufacturing.

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