A CASE STUDY ON OPTIMIZING PARTS SUPPLY IN MANUFACTURING BY REUSABLE CONTAINERS

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Abstract

This case study analyzes the manufacturing system of a company producing and marketing branded power tools. The production process applies containers to transport parts within the manufacturing plant from the warehouse to the production floor as well as between several stages of production. The same containers are also used by manufacturer's suppliers to deliver parts to the manufacturer. As the containers are re-used in the production process they have to be cleaned and inventoried. Then they are allocated to internal flow of material or they are made available to suppliers so that they can furnish parts to the manufacturer. The production process is controlled by a Kanban system such that the flow of containers is also regulated in this manner. However, so far the containers were not tracked within the manufacturer as well as at the supplier. Consequently, it happened that containers were not available in the right amount so that the supply of parts from the supplier was disrupted. The purpose of this study was to evaluate methods to optimize the handling of these containers at the manufacturer. Among them is the determination of a safety stock of containers. We present the results of the findings.

Key words: Reverse Logistics, Reusable Containers, Production Control, Kanban, Parts Supply, Closed-Loop System, Case Study

1. INTRODUCTION

Within the area of supply chain management the field of reverse logistics has considerably grown in the last two decades. Reverse logistics integrates backward flowing material (products, packaging) into supply chain management. The forward direction of the supply chain comprises the movements of material to be processed and assembled to create a product or to carry the product or parts of it. The backward directed flow consists -among others- of collecting, transporting, and recycling of products and materials in order to reuse them in new production processes or to dispose them in an environmental less critical way. The logistics activities associated with the backward directed flow are called reverse logistics. See also Kroon & Vrijens (1995, p. 56), Fleischmann et al. (1997) on issues in reverse logistics.

In most production processes multiple flows of material consolidate to a single flow at the time the final product is completed and then from this node on the flow diverges when the products are distributed to wholesalers, retailers and consumers. The reverse direction of the supply chain may origin at various points of the forward chain, i.e. at the consumer for returned products, at the retailer for unsold products, at the manufacturer for reworking the product. Besides the logistics of the product there is also a logistics of packaging materials. These are items used to transport the products within the production process, i.e. to protect the parts supplied from one company to another. Packaging also enables transport and marketing to the consumer, like color-printed cardboard boxes that are common for consumer goods. The transport items may be disposable, like cardboard, or they are reusable, like beer crates. Notably, also cardboard is reused by recycling it. The difference to reusable transport items is that these are designed to be used many times for the same type of transport until they are depleted. Hence, reusable containers have to be returned to their origin in order to be reused again. There it is called a closed-loop system.

Transport items are used within a single stage of the supply chain like within a manufacturing plant or they pass multiple stages like the product's packaging that is added at the manufacturer and passes one or more distributions stages till the final user of the product.

This paper presents a case study. We examine the manufacturing operation of a manufacturer of power tools. At its main production facility parts of the various products are produced. These parts are manufactured in several steps and then they are assembled to components and finally to the product. Parts and components need to be transported between several shop floors. The factory uses containers of several sizes for most of these transports. The containers are reused after parts have been removed. Besides own manufactured parts the company also buys parts to be built into its products that are manufactured by suppliers. Some of these components are supplied to the manufacturer with the help of the same containers that are used for their internal production logistics. So, empty containers need to be transported to suppliers. After the supplier has filled them they are shipped to the manufacturer. There, containers filled with parts are transported using inner factory logistics to the respective production units.

Timely supply of parts to the productive units is affected by the availability of empty containers at the suppliers as well as at the plant's production units. Within the manufacturer's facility it is relatively easy to react to missing containers and deliver them to the productive places. At the suppliers missing containers can cause serious disruptions of the production process. The aim of this paper is to explore procedures to increase availability of containers within the plant and at the manufacturer's suppliers. Its purpose is to provide guidance on which activities are effective to solve a real world application.

2. REVIEW OF THE LITERATURE ON THE MANAGEMENT OF REUSABLE CONTAINERS

We use the terms returnable transport items or returnable containers as well as the terms reusable interchangeably. Reusable containers differ from single-use packaging (one-way packaging) as they are constructed to last longer and to be multiply used for the same type of transport and handling activity within a production plant or a transport from one facility to the next plant. In a broader sense, the idea applies to pallets, casks, etc.

As reusable containers are multiply used they need to withstand mechanical abrasion and wear-out by the transport and handling equipment. They also need to be cleaned, i.e. washed. Plastic containers are widely used for multiple transports.

Due to low price cardboard boxes are very often the preferred solution for single-use applications. However, single-use containers are subject to create large amounts of waste that need to be brought into a recycling process. So, single-use packaging is confronted with environmental concerns, their use is regulated by laws, and they are to some extent commercially unattractive. As this case study is concerned with a system of reusable containers we will not cover single-use transport items.

Regarding the design and operation of a manufacturing system using reusable containers there is the need to consider relevant aspects associated with reusable containers. Main issues are the costs of reusable containers and the control of their flow and of their availability.

The cost associated with a reusable container system are cost of the containers themselves, cost of adapting handling devices to these special containers, and -in addition to the cost of transporting full containers- the cost of transporting empty containers back to their origin or to a central point where they are sorted, cleaned, inventoried and dispatched to the place of their next use. See also Tewede & Clarke (2004).

The literature reports on shrinkage of containers due to theft, misplacement, usage in unplanned manner, damage, and end-of-life. Therefore, a portion of the literature addresses the tracking of containers to gather information regarding the current location of containers. See Welcome (2011). Maleko & Reimche (2011) and Maleki & Meiser (2011) describe how to model returnable container logistics with automatic identification technologies. See also Thoroe et al. (2009) for practical insights.

The cost of containers is determined by the amount of containers needed. This is a function of the overall volume of the production, lot sizes, and the travel times of the containers (forward and backward). Turnquist & Jordan (1986) consider the question of determining the fleet size of containers where the travel time of containers (or loading, dispatching, cleaning, or equipment downtime) is stochastic. They develop equations to determine the fleet size given a probability of a shortage of empty containers in order to balance the investment in shipping containers to the cost of container shortage. Kelle & Silver (1989a) consider the case of non-returning containers (e.g. loss or damage) with a certain probability so that new containers have to be purchased from time to time. The situation is common for consumer goods sold in returnable containers like for beverages or in industrial goods for liquid gases. Kelle

& Silver (1989b) propose forecasting methods for the requirement to acquire new containers as the time from issue to return of an individual container is not known and containers may be lost. For example, for fast moving consumer goods packaged into reusable containers the return cycles can be very long and they are very different from consumer to consumer. If supplier and customer are not directly linked by a manufacturing process the cycle time of returning containers has a large variability. Carrasco-Gallego & Ponce-Cueto (2009) develop a forecasting algorithm for this situation.

Rosenau et al. (1996) consider a returnable container system as an investment and evaluate such a system by capital budgeting procedures since cost and benefits should be evaluated in the long term. Hence, during the design phase of a reverse logistics system initial costs as well as long term costs have to be evaluated against the benefits. Twede & Clark (2004) describe costs and benefits of reusable containers. Barker & Zabinsky (2008, 2011) develop a framework for reverse logistics network design that can be helpful for network design. Böröcz (2009) focuses on the cost of one-way and reusable packaging. Also Lai et. al (2008) describe a returnable packaging network design problem.

Simulation is a widespread tool to analyze logistics systems. Hellström & Johansson (2010) analyze the problem of shrinkage in a closed-loop system by a simulation study regarding alternative control and tracking methods. Also the papers of Jarupan et al. (2003, 2004) develop a simulation model. Klug (2011) simulates container demand in an automotive supply chain. Nomura & Takakuwa (2006) use simulation to determine the number of containers to supply an assembly line. Containers are moved on a fixed route in a plant. Closed loop systems between to factories often suffer from a mismatch between the volume of parts delivered (in containers) and containers returned. See Yildis et al. (2010). Sobottka et al. (2014) analyze the consequences of superfluous container cleaning. Less cleaning phases can increase availability of containers. De Brito et al. (2005) review case studies in reverse logistics. Their review provides a source of practical approaches to reverse logistics issues.

In the remaining section of the paper the case study of a real world application is presented. It addresses the problem of increasing availability of reusable containers flowing within a manufacturer and between the manufacturer and some of its suppliers in a closed-loop system.

3. ANALYSIS OF THE MANUFACTURING SYSTEM

3.1. The Company and Its Market

The company operates a plant that manufactures electric power tools – hand-held tools as well as stationary tools. Products are designed for professional users. They are widely known for their high quality and reliability. Products are sold all over the world in far more than 100 countries. All the products are manufactured within a single large plant. This part of the company generates more than 300 million euros of turnover per year.

The portfolio of products is highly differentiated within power tools. There are many specialized tools for a single application but with different specifications, mainly due to strength of engines or the type of power supply (cord or accumulator). The total number of different products exceeds well 500. This variety is necessary to fulfil the needs of the users expecting high end tools to be well adapted to specific applications. Products close to each other we refer to as product line.

3.2. Organisation of the Plant

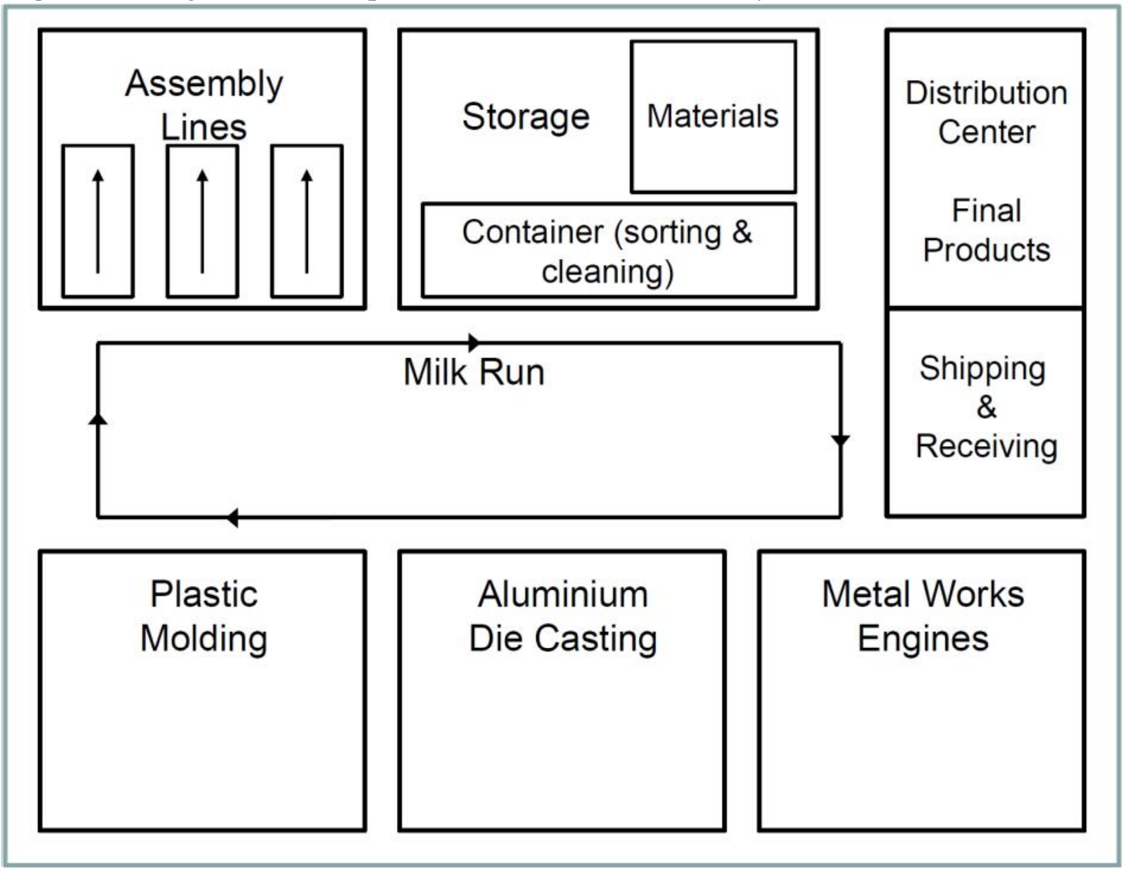
The company operates a single, large plant to produce its total portfolio of electric power tools, like drills, hammers, saws, grinders, screwdrivers, etc. [1] So, the plant is permanently required to be able to manufacture the whole portfolio upon demand.

The plant can be separated into two main sections, the component plant and the assembly plant. The component plant produces parts and components to be assembled to the final products. Main sections of the component plant are aluminium die casting, injection molding, rotor (turnery) and engine production. Within assembly operations, parts and components are assembled to the final products and then packaged to be ready for sale, stacked on pallets and brought to the company's distribution center. As not all parts are produced by the company itself, like electric cords or packaging material, these parts are sourced at specialized suppliers. Due to the wide assortment of the company, the components section is very large and consists of different shops. Similarly, the assembly operation falls into many units according to the product lines. There is an assembly line for each product line, e.g. one for the family of compact, i.e. small one-handed, angle grinders having about 23 variants, another one for the line large angle grinders.

The total floor size of the plant is about 80.000 square meters. Figure 1 sketches a diagrammatic plan of the layout of the plant.

[1] Only some tools are manufactured exclusively by selected suppliers. Outsourcing is very common in this industry as the total demand of very specialized products is too low to reach profitability.

Figure 1. Diagrammatic Representation of the Plant's Layout.



Source: Author

The plant is organized as a job-shop manufacturing in the components area and as flow-shop manufacturing in the assembly area. Within the job shop area, parts have to be transported to different manufacturing units and finally they are transported to the assembly area.

Since the demand is sufficiently large and there are set-up costs, parts and components are manufactured in lots. Lot-sizing is also done in assembly operations. For example, the assembly line for compact grinders assembles 200 units of type A and then 100 units of type B according to the production plan.

However, the demand of a single variant is not high enough to establish a dedicated line to a single variant of product to be produced continuously. This is due to the strategy of the company to provide the customers with very specialized machines. Hence, the markets for machines of special applications are relatively small compared to mass-market, e.g. do-it-yourself retailers' standard assortment.

The manufacturer is highly integrated as most parts and components are produced in-house. This is especially the case for the engines, the transmissions, the drill chucks, for instance. As the manufacturing process is highly integrated there are many successive steps in the manufacturing of a product within the plant. Between the steps, parts and components need to be handled and transported. The company decided to solve this problem by standardized containers. These containers hold parts and components for transport and for storage of lots until the production process is continued. The plant applies 7 different types of plastic containers. They differ in size (length, width, height). Some containers hold inserts to carry special parts. The containers with inserts are only used on the site. These inserts help to protect the parts from damage and facilitate their handling and storage. Containers are also used by some of the suppliers who place parts into the containers to be delivered to the manufacturer.

The production process is centrally planned upon customers' orders or it is initiated to restock the distribution center. Given the demand of a specific product, the assembly and manufacturing process is controlled by a Kanban system. Kanbans are attached to the containers. Thereby, the flow of parts is directed and stations receive order to perform a productive task. Most movements of containers are centralized, i.e. containers are consolidated in specific areas from where they are picked up, transported together with other containers, and sent to the next station. As there are considerable distances between the components section and the assembly section they are transported by a "train" – it is a so called milk run process. Routes of the train within the factory are predetermined (fixed route process).

3.3. Circulation of Reusable Containers

Reusable containers are either empty or they carry parts. When carrying parts the containers move parallel to the production process. When they are emptied they are collected to be prepared for next use. Therefore they are consolidated at a central location where they are sorted according to type (size), cleaned by a machine, and then inventoried. Upon demand they are transported to the next place of use by the milk run transporting process.

Containers are of modular size and compatible with euro pallet size. For example, four containers of size 600mm x 400mm cover a EUR-1-pallet that has dimensions of 1200mm x 800mm. Other containers used in the system are either 400mm x 300mm or 300mm x 200mm. Their heights are between 120 mm and 420 mm. The milk run train is adjusted to transport these containers. Figure 2 depicts a reusable container.

Figure 2. Example of a Container, Size 300mm x 200mm x 120mm.

Source: Author

Empty, cleaned containers are brought either to an internal manufacturing unit, e.g. within the molding area, or shipped to a supplier. The supplier orders empty containers to refill his stock or to be prepared for a larger production run of parts. A supplier producing parts for the manufacturer fills these parts directly into the containers. Then, the filled containers are transported to the manufacturer. Upon arrival at the manufacturer the filled containers go into buffer inventory or are directly transported by the milk run process to the respective production unit where these parts are needed.

3.4. Problems of the Process Related to Reusable Containers

The main problem of the manufacturing process related to the use of containers is that there are instances from time to time when empty containers are not available for filling with parts at a manufacturing unit or they are not available when a supplier orders empty containers. According to the management there is a loss of containers due to shrinkage. Though containers are not tracked by the manufacturer, management assumes that containers are also lost at the suppliers. In reaction to missing containers –though nobody knows how many containers are lost or are damaged- the company buys new containers year over year. The following section presents and evaluates actions to increase availability of containers.

4. ACTIVITIES AND PROCEDURES TO IMPROVE THE CONTAINER PROCESS

4.1. Improving Discipline in the Plant

Management indicated that there are several reasons for missing containers. Containers are damaged, misused, misplaced, or misallocated. The latter happens if there too many containers at a single supplier or multiple suppliers reducing the amount of empty containers available.

Since some containers are not used in a planned manner they are not available for the production process. Management needs to communicate the importance that containers are to be used exclusively for transporting parts and not to be used in any other way. I.e., the usage of a container is authorized only by a Kanban. Containers without Kanban have to be returned to the central storage of containers. Defective containers should be taken out of the process and their number should be recorded. In order to monitor the stock at the suppliers the minimum requirement is to track the number of containers delivered to suppliers and the number of containers returned. This can be realized by the regular method of shipping notes that is in place for materials and products.

4.2. Dedicated Stockroom for Empty Containers

It is not known how many reusable containers are in place at the company. There is no record keeping of containers in place. Also damaged containers are not recorded. Thus, the total number of containers owned by the company is not known.

In order to create a plan how to manage containers it is necessary to determine the total number of containers in the system at the manufacturer and the suppliers. Instead of counting the containers, their number can be estimated with the help of the Kanban-production control system. The number of Kanban cards in the system points to a total number of about 30,000 containers. This number of containers is valid, as it is derived from manufacturing output that was realized by the number of Kanban cards circulating in the production system. Here, this number represents a lower bound of the total number of containers available in the system because it was estimated from the maximum observed output.

From the buying records it is derived that within the last 13 years the manufacturer bought about 20,500 containers. Hence, we estimate an average yearly loss of containers at 1,500 units assuming the effective number of containers in the system remains constant. Therefore, the average loss of total stock of containers reaches 5.2 percent per year. In the literature the percentage loss of returnable containers is reported to be on average at 10 percent or even more (See Hellström & Johnsson (2010).). So, the realized loss does not indicate a strong problem of misuse or damage of containers.

In order to increase availability of containers the idea is to have a dedicated stock of empty, cleaned containers that are ready for use in manufacturing or to dispatch to suppliers. Only authorized employees shall have the right to take containers from this stock.

4.3. Safety Stock of Containers

The production is scheduled and controlled by the use of a Kanban system. The production system is a combination of various manufacturing process types. There is job shop type manufacturing for the parts, e.g. the molding section. The assembly of final products from parts and components are performed at assembly lines. The various units are linked by the Kanban system with transports being consolidated by a milk run process.

Though, production is controlled by Kanban cards the number of Kanbans effectively in place in the production system at a point in time is not constant (variable Kanban system). It varies with the demand level. Therefore, the number of containers necessary to cope with the variable load of the production system varies.

Hence, the workload of the production system is fluctuating. In order to have enough containers available to be protected against stock-outs their number should exceed the average demand by a certain ratio, i.e. a safety stock of containers has to be determined.

The safety stock of containers to cope with varying demand of empty containers can be estimated from historical production data. As the packing of parts into containers is fixed, the number of containers necessary to keep up production can be calculated from historical production data. The volume of production follows a stochastic process. Hence, the number of containers required to enable manufacturing at each station follows a stochastic process. The processes can be assumed to have normally distributed variables. Therefore, the safety stock of containers required to cope with fluctuating demand of empty containers is (See Monden 2012, chapter 18. See Dickmann, 2009, p. 173, for the number of Kanbans of the parts process. Note that this number is estimated from the series of production processes of parts and not from flowing containers as this information is not available since containers are not tracked.):

$$S = z \sqrt{(\sigma_d^2 * \mu_c) + (\mu_d^2 * \sigma_c^2) + \left(\sigma_s^2 * \frac{\mu_d}{\mu_s} * \mu_c\right)}$$

z = service level factor
μ_d = expected demand of parts of a specific process (containers)
μ_c = expected cycle time of a process
μ_s = expected loss of containers
σ_d = standard deviation of demand
σ_c = standard deviation of cycle time
σ_s = standard deviation of loss of containers

The first part of the sum under the square root refers to fluctuating demand of containers during average cycle time. It estimates the variance of additional containers needed due to demand variation within the cycle. The second sum estimates the need of additional containers due to variability of the cycle time. The third part of the sum reflects the effect of shrinkage. It estimates the need of additional containers due to fluctuating loss of containers, i.e. damaged or non-returning containers.

Since there is no estimate of lost containers available we set it to the fraction of new containers from above. Given the service level to be achieved the formula calculates the additional number of containers (exceeding average demand of containers) required to cope with uncertainty of demand for containers. In our case the safety stock determined is estimated at about 12% of the total number of containers available. Hence, increasing the total stock of containers by this number should protect against losses of containers and fluctuating demand at the manufacturer.

Misuse of containers can be hindered if containers carry the logo of the owning company. In our case the manufacturer should brand its containers. This can be done successively when new containers are bought.

4.4. Improving Information Exchange with Suppliers

Though suppliers are integrated into the Kanban system of the manufacturer, it is not required for them to produce simultaneously. That is, they furnish parts by delivering them packed into manufacturer's containers and attach manufacturer's Kanban cards to them: However, they schedule production on their own. For example, they define their own optimal lot sizes and they produce in advance. This is possible as the types of parts they supply are fixed depending on the product the manufacturer is about to produce.

Some of the suppliers tend to increase production before mid of year and they slow down production at the end of the year. Hence, they build up inventory of parts. If a supplier decides to produce in advance he will need more containers to stock produced parts till the delivery to the manufacturer. A supplier reducing stock will order fewer containers from the manufacturer. Hence, the number of containers at the supplier will vary according to inventory level of parts at the supplier.

The additional containers due to suppliers scheduling cannot be estimated by the safety-stock formula from above as it considers the realized production rate at the manufacturer.

It is suggested to gather information on the suppliers' production plans. If the manufacturer has information about an increasing production at a supplier the manufacturer can potentially buy new containers to fill up his stock (depleted by defective containers). New containers should be scheduled to be bought in advance to the peaks of production at suppliers. In this case as production goes up in summer, the containers should be bought to be available before summer term.

Decoupling of container provision to suppliers and receiving filled containers should be maintained. Though it is economic to schedule deliveries of empty containers with the truck that brought filled containers, it is not necessarily a 1-by-1 exchange. That would prohibit advance production of suppliers hindering them to realize economically optimal production schedules.

4.5. Tracking of Containers

It seems attractive to track the flow of containers in order to have more information on the number of available containers at various sections in the plant and at the supplier. However, such a system comes at a cost. It was estimated that the initial investment of a software able to track the containers will be at a cost of about 10%-20% of the cost of the total stock of containers, i.e. about the average loss of containers within two to four years. In addition to the initial investment there are operational costs of bookkeeping, i.e. entering data. Therefore, it is doubtful whether this investment would pay off. So far, the fraction of lost containers is about 5%. However, this figure includes damaged containers as well. This portion of lost containers cannot be reduced by better tracking. Though the safety stock of containers is likely to be set to a lower value with a full tracking system the largest portion of safety stock is due to demand variability. Therefore, it is not recommended to invest in automated tracking systems before the other suggestions are realized.

5. CONCLUSIONS AND DIRECTIONS FOR FURTHER RESEARCH

Summarizing, within the whole plant hundreds of different products have to be produced. Therefore, a complex set of production processes including the materials flow has to be planned and managed. In addition, the supply of empty containers and their preparation for use has to be managed to realize a closed-loop system. It is found that the company should increase its safety stock of containers in order to cope with fluctuating demand and with lot-sizing and advance production of its suppliers. The benefits of reusable containers to receive materials ready for production from suppliers and to manage materials flow on plant clearly outweigh the costs of lost containers. Considering total cost of control it is suggested not to invest into an automated tracking system before other simple activities are realized: Implementing standards of container usage by manufacturing personnel, adjusting safety stock of containers, and exchanging information with suppliers regarding their production plans.

Regarding future research opportunities there are –to the knowledge of the author- no theoretical developments available on designing closed-loop manufacturing systems with variable capacity usage. Having a better understanding on how the optimal number of Kanbans and the optimal number of reusable containers can be determined the value of information generated by a container tracking system can be identified.

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