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DETERMINATION OF BASE KANBAN LEVEL FOR MULTI-KANBAN MECHANISM IN A DISASSEMBLY LINE

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ABSTRACT

In this paper, we propose an application of a pull type production control mechanism for a disassembly line setting. We discuss complications and justify the use of pull type mechanism in a disassembly line. We introduce a multi-kanban mechanism for a multi-product disassembly line where demand for components can arrive at any level. We define the kanban routing rules to minimize the system's inventory while maintaining a customer service level comparable to a push system. We suggest a method of determining the proper number of base kanbans and demonstrate its effectiveness by using a simulation model and implementing it in a case example.

INTRODUCTION

Environmentally conscious manufacturing (ECM) has received a lot of attention in the last decade. Many government rules and regulations have forced manufacturers to practice ECM due to the decline in the number of landfills and natural resources and an increase in consumer wastes. Each year tons of reusable materials and components are retrieved from end-of-life (EOL) products and recycled or reused in remanufactured products. An effective way to recover these materials and components is on a disassembly line. As opposed to an assembly line, disassembly line is fraught with many problems associated with planning and controlling. For example, a disassembly line has significant inventory problems because of the disparity between the demands for certain parts or subassemblies and their yield from disassembly. Therefore, it is necessary to develop a flexible and powerful production control system to address such problems.

In this paper, we introduce a modified pull type mechanism and implement it in a disassembly line setting. We introduce the kanban routing rules in order to direct kanbans to the most suitable destination. The system is designed to operate efficiently while maintaining a service level comparable to a push system. Since we try to route the kanbans to the best destinations and we do not change the number of kanbans in order to limit inventory level of the system, we must determine the optimal number of base kanbans depending on the demands, supplies, disassembly times, and product structures. Because every product dictates its own unique disassembly sequence and creates a distinct number of residual subassemblies, the base number of kanbans plays an important role here.

LITERATURE REVIEW

For an overview of kanban control mechanism, see [1], [10] [11], [12]. It is well known that the traditional kanban systems (TKS) fail to cope with many of the real life uncertainties. Gupta and Al-Turki [5], [6], [7] and Gupta et al. [8] introduced the idea of implementing a flexible kanban system (FKS) in environments involving uncertainties. They demonstrated that in such environments, FKS outperforms TKS. Several studies have recently emerged that address various aspects of disassembly [4], [9]. Within this area, disassembly line has become the subject of recent interest [3]. Korugan and Gupta [13] suggest an adaptive way of implementing kanbans into a single-stage hybrid system. For more information on disassembly and product recovery, see Brennan et al. [2], Gungor and Gupta [3], [4], Gupta and McLean [9], and Lambert [14].

DISASSEMBLY LINE

Disassembly is an effective tool for product recovery. Key objectives of disassembly include recovering functional components and materials and separating unwanted or toxic components and materials. Disassembly line is perhaps the most suitable setting for disassembly of large products (consisting of numerous components) as well as small products received in large quantities. Disassembly line consists of a series of workstations, each of which is responsible to disassemble some target components. Even though a disassembly line appears to be similar to an assembly line, the two are quite different and pose very different sets of problems. Three major concerns are as follow. First, the arrival pattern of raw materials in an assembly line is mostly deterministic. In contrast, the arrival of products in a disassembly line is fraught with uncertainties. The timing, quantity, quality and variety of the returned EOL products are unpredictable. Each type of EOL product has a different disassembly sequence. Second, since different components are disassembled at different workstations, the demands for different components arrive at different workstations. Therefore, each workstation must be ready to cope with two types of demand, one for the component and the other for the partially disassembled product that is demanded at a downstream station. Finally, since the demand arrivals are not constant, the inventory level could fluctuate quite widely because of the disparity in demands at different workstations.

The two types of production control systems that are commonly employed in assembly lines are push systems and pull systems. Push systems depend on a predetermined schedule of materials arrival. All production obligations are completed to meet future demands within a planning horizon. Pull systems employ a production authorization card (kanban) triggered by a real demand. In a disassembly line, where inventory control is key, pull system is expected to provide a better solution. However, traditional kanban mechanism would need some modifications to be suitable for a multi-product disassembly line setting.

MULTI-KANBAN MECHANISM

In this section, we describe the multi-kanban mechanism. Figure 1 illustrates the basic layout of the system.

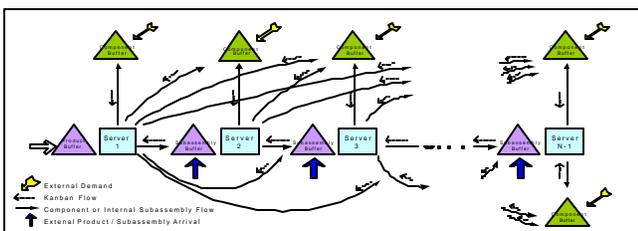


Figure 1. Multi-kanban System

1. Kanban Types

There are two basic types of kanbans in the system: *component kanbans* and *subassembly kanbans*. A component kanban is attached to a disassembled component that is placed in the component buffer of the workstation where it is disassembled. Similarly, a disassembly kanban is attached to a residual subassembly that is placed in the subassembly buffer of the workstation where it was separated from the component. A component placed in a component buffer can be retrieved by an external demand. When authorized, a subassembly placed in the subassembly buffer is routed for disassembly to the next workstation based on its disassembly sequence.

At the first workstation, products arrive only from outside sources. However, at any other workstation i , where $1 < i \leq N-1$, there are two possible types of arrivals. The first type is a subassembly that arrives from an upstream workstation, called *internal subassembly*. There is always a subassembly kanban attached to an internal subassembly. The second type is a product (or subassembly) that arrives from outside sources, called *external subassembly*. There is no kanban attached to an external subassembly. This is also true of the products arriving from external sources to the first workstation. As long as there is an external product or subassembly available at an input buffer, the system will process it first before processing any available internal subassembly. This will avoid unnecessary pulling of an internal subassembly from an upstream workstation. Thus,

the number of kanbans attached to internal subassemblies will remain constant throughout the process.

2. Kanban Routing Mechanism

Consider workstation j , where $1 \leq j \leq N-1$. When a demand for component j arrives at the component buffer of workstation j , one unit of component j is retrieved and the component kanban j attached to it is routed to the most desirable workstation. The procedure for determining the most desirable workstation to route component kanban j is given below. (Note that this procedure is not applicable to component kanbans $N-1$ and N . In both cases the kanbans are routed to the input buffer of the last workstation).

A component kanban originating from workstation j will be routed to a workstation i , where $1 \leq i < j$, or workstation j depending on the availability and the desirability of the subassembly that contains component j .

Routing component kanban j to workstation i , where $1 \leq i \leq (j-1)$, will result in an immediate separation of component j from component i . Thus, the only subassembly located at the input buffer of workstation i that would be useful is a subassembly that contains only components i and j . If this type of subassembly exists in the input buffer of workstation i , then workstation i is qualified. Similarly, if there is at least one subassembly in the input buffer of workstation j , then workstation j is qualified.

Next, we need to select the most desirable workstation to route component kanban j among the qualified ones such that, if chosen, will cause the least amount of extra inventory in the system. Choosing workstation i will increase the inventory level of component i by an additional unit. Thus, the best workstation i is the one that is most starving for its component. By checking the backorder level for demand i , we could determine the most starving workstation. If there is a tie, select the most downstream workstation.

Choosing workstation j will create a residual subassembly that will be further disassembled at downstream workstations. If workstation j is chosen, then a proper subassembly must be chosen to disassemble. For example, if a backorder exists at the component buffer of workstation k , where $j < k \leq (N-1)$, then, if available, we might try disassembling a subassembly that contains only components i and k . If more than one workstation qualify as starving workstations, then the one that is most starving among them is chosen. If there is a tie, select the most downstream workstation.

We can now compare the starving levels of workstations i and j . If the highest starving level of workstation i is greater than or equal to the highest starving level of workstation j then we will route the component kanban j to workstation i , otherwise, we will route it to workstation j .

Note that whenever an external subassembly is available, it will always be chosen first. Internal

subassemblies will only be used when no external subassembly of the desired kind is available. Subassembly kanbans are routed in a fashion similar to component kanbans.

3. Determining the Base Kanban Level

The base kanban level plays an important role in the multi-kanban mechanism as it controls the flow of components and subassemblies throughout the system at a desired level. The base number of kanbans for both the *component kanban* and the *subassembly kanban* can be computed, at any point in the disassembly line, using the following general expression:

$$\text{Number of base kanbans} = \text{Request rate} / \text{furnish rate}.$$

Note that the above ratio must be rounded up to the next integer and that at least one base kanban must be chosen. For the case of *component kanban*, which is requested only from a single source, request rate is equal to the customer demand arrival rate. However, because the component kanban arrives from several sources in the system, the furnish rate is the summation of arrival rates from all possible sources. For the case of *subassembly kanban*, the furnish rate is influenced by both the disassembly rate and the external subassembly arrival rate. Thus, we take all external and internal arrival rates of subassemblies at the buffer into account. Similarly, the two requesting sources, viz., the demand for target component and the demand for residual subassembly affect the request rate. The number of base kanbans is determined at the beginning of the disassembly process. It is clear that demand, supplies, disassembly time, and product structure, all affect the computation of the number of base kanbans.

Table 1. Performance of Push and Multi-Kanban Pull Control System

	Fulfilled Demand (units)			Average Inventory (units)		
	Push	Multi Kanban (-1, optimal, +1)	% Change	Push	Multi Kanban (-1, optimal, +1)	% Change
A	237	(225, 237, 239)	-	39	(3, 4, 5)	- 89.7%
B	90	(88, 91, 94)	+ 1.11%	81	(4, 5, 7)	- 93.8%
C	145	(140, 145, 145)	-	85	(38, 39, 39)	- 54.1%
D	52	(48, 51, 53)	- 1.92%	45	(4, 5, 6)	- 88.9%
E	55	(51, 54, 55)	- 1.81%	36	(7, 8, 8)	- 77.8%

MODEL EXPERIMENT

We experimented the kanban mechanism using ARENA® simulation software. We considered a system with four workstations that processes EOL products consisting of up to five different components, viz., A, B, C, D and E. First, we calculated the base number of kanbans of every type using the above-described method. We then ran experiments using the model with the computed base number of kanbans and with the number of kanbans consisting of nearby values. We compared all these results with a push system. The results

show that the suggested method of calculating the base number of kanbans yields the most desirable average inventory level while maintaining a reasonable customer service level (see Table 1).

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