IOP Conf. Series: Materials Science and Engineering **400** (2018) 022043 doi:10.1088/1757-899X/400/2/022043

The Kanban system for the assembly process of the model of a forklift

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Abstract. In assembly systems, fast information flow, minimal stock, control of an order realization at every stage, efficient work, reduced labor costs, short turnaround time and simultaneous fast material flow are required. In a just-in-time production, the kanban-based supply and control is applied to ensure the above conditions.
In the article, principles and conditions of the Kanban system organization are presented. The method of determining the number of Kanban cards, so that the process runs smoothly and continuously is described.
The aim of the article is to design the Kanban system for the assembly process of the forklift model. Technological documentation that is required for the assembly of the final element is developed. This documentation includes the process routing sheet, assembly instruction cards of the forklift, technical drawing and list of components. In the assembly instruction cards, photographs are given in order to facilitate the assembly process of products. Three types of the flow of material and Kanban cards are proposed. Then the best flow is selected. For this flow, equipment items (containers for components mainly) are purchased. Kanban cards are designed and the simulation of the Kanban system during the classes with students is carried out.

1. Introduction

Nowadays, customers are paying attention not only to the price of a product, but also to its quality and execution time. The aim should be to shorten the time of an order realization by shortening setup times, production cycle and reducing a production batch. Some companies produce components that are waiting for a customer in a store. However, the make-to-stock production generates additional costs, occupies additional warehouse area and maintains frozen capital. Moreover, excessive inventories mask the abnormalities in the functioning of the production/ assembly system and make it difficult to identify places that need to be improved. The key to success is the Just-in-Time production, which guarantees timely execution of orders, on the one hand, and eliminates excessive inventories of final goods waiting for the arrival of a client on the other hand [1,2,3,4]. The Kanban system maintains the balance of the need for product availability and the need for minimizing stock holding and handling costs [5,6,7,8].

Difficulty in implementing the Kanban system for production depends on the diversity and the complexity of the manufactured products. The applicability of the Kanban system also depends on feeding policies that differ from each other in term of the number of kanbans in a feeding route, number of operators required to avoid inline shortages and type of warehouse. Kanbans can control flow and inventory of materials using central or supermarket warehouses. Three parts-feeding policies are possible to apply in modeled assembly line systems: (i) kitting (e.g. stationary kit remaining at the assembly station until it is fully consumed or travelling along the line with the product), where the assortment of parts necessary for the assembly operation is grouped together and delivered to the line using pre-loaded kit containers, (ii) kanban-based continuous supply, where cards are assigned to stock-keeping units (SKUs) that feed the operations with parts constantly, and (iii) hybrid kanban-kitting, where one policy from the two possible for a single component is selected.

The aim of the paper is to design the Kanban system for the assembly process of the forklift model. Technological documentation that is required for the assembly of the final element is developed and presented in Section 2. This documentation includes the process routing sheet, assembly instructions of the forklift, technical drawing and list of components. In the assembly instructions, photographs are given in order to facilitate the assembly process of products. Three types of the flow of material and Kanban cards are proposed in Section 3. Then the best flow is selected. For this flow, equipment items (containers for components mainly) are purchased. Kanban cards and Kanban boards are designed and presented in Section 5. The simulation of the Kanban system during the classes with students is carried out. The results of the simulation are presented in Section 6.

2. Design of the Kanban system

The Kanban implementation process begins with the analysis of the production process. When analysing the production process, following information is necessary to obtain [11]: materials, components that are part of the final product or are used in the production/assembly process, characteristics of the material used for production, the number of elements in the batch, capacity and type of stock-keeping units (SKUs) used for transport, production process and flow of materials, operation times, data about the machines used in the process and the time of their preparation for operating, the current state of inventories, production variation.

On the basis of these data, the type of stock-keeping unit, their quantity and size, routes of kanban and SKUs with elements are specified. The number of components and the sequence of operations are necessary to determine number of kanbans in line (1) [12]. The operation times, set-up times and layout of work stations allow one to determine the appropriate time of production launch, in order to meet the imposed deadline for completing the order.

$$N = \frac{P \cdot T \cdot (1+q)}{C} \tag{1}$$

where: N – the number of kanbans, P – average demand consumption of the part during a day, T – kanban flow time, q – safety factor that affect safety stock, C – SKU capacity.

The final product was characterized, for this purpose the list of components, assembly instructions were developed. The forklift model consists of 66 elements (figure 1). The component designations are defined in table 1.

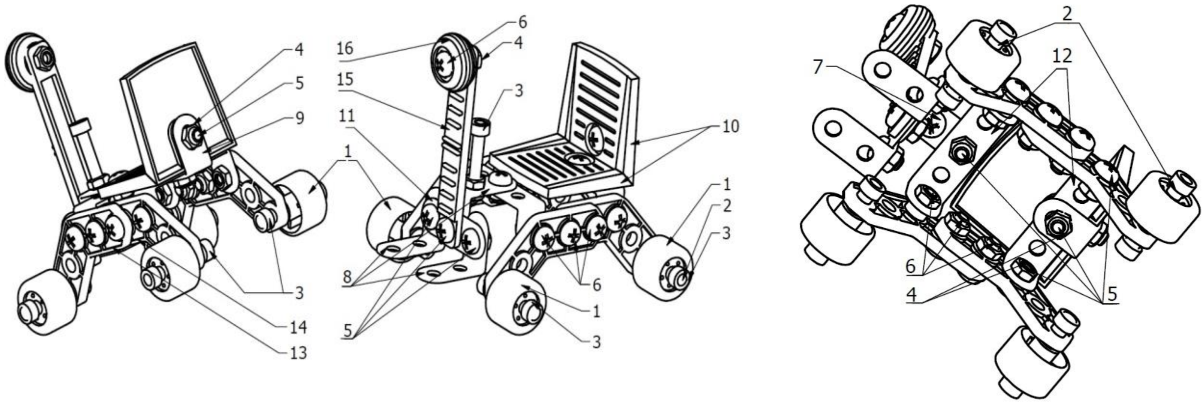
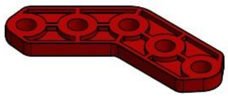
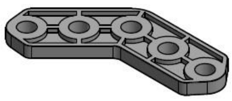


Figure 1. Assembly of forklift truck's model.

Table 1. Components of forklift truck.

No.	Part name	Part drawing	Quantity	No.	Part name	Part drawing	Quantity
1	wheel		4	8	angle bar with 3 holes		3
2	wheel axle		4	9	angle bar with 2 holes		1
3	yellow washer		11	10	component of the seat		2
4	hexagon nut M3		16	13	red frame		2
5	cross-headed screw M3×8		8	14	grey frame		2
6	cross-headed screw M3×14		7	15	Mast		1
7	cross-headed screw M3×22		1	16	mast's wheel		1

Assembly times need to be approximately equal in order to prevent excessive downtimes and bottlenecks. Assembly operations were grouped in 9 stages (table 2). The estimated time of assembly of the product is about 17 minutes. A flat-eye wrench and a screwdriver are needed for its implementation.

Table 2. Assembly operation sheet of forklift truck (karta technologiczna).

Silesian University of Technology Device type: Forklift model		Assembly operation sheet		Made Checked Approved	N. Iwaniuk I. Paprocka I. Paprocka
Operation No	Worker	Operation	Instruction No	Equipment	Time
10	Mechanic	Assembly of vechicle's frame	1	Socket wrench & screwdriver	2.3
20	Mechanic	Assembly of suspension I	2	Socket wrench & screwdriver	2.2
30	Mechanic	Assembly of suspension II	3	Socket wrench & screwdriver	1.8
40	Mechanic	Assembly of a seat	4	Socket wrench & screwdriver	2
50	Mechanic	Assembly of vechicle's wheels	5	-	1.8
60	Mechanic	Assembly of a fork	6	Socket wrench & screwdriver	2.3
70	Mechanic	Assembly of a mast and a fork with vechicle	7	Socket wrench & screwdriver	2
80	Mechanic	Assembly of mast's wheel and a steering rod	8	Socket wrench & screwdriver	1.8
90	Controller	Quality control	9	Socket wrench & screwdriver	1

Because the model consists of many small-sized components, the Assembly sheet of the forklift truck does not clearly specify the steps necessary to perform to receive the final product. These steps were arranged in Instruction sheets (the number of the element is given in round brackets) (table 3).

Assembly drawings, instruction sheets and list of elements are in each assembly station. Kanban cards move along with the semi-finished product. Kanban cards were developed for each operation (figure 2).

3. Kanban and material flow concepts

In the designed system, three concepts of kanban and material flow are considered. In concept I, employees report the demand for raw materials from the last to the first workstation. Material is taken by the operator of the first workstation from the warehouse. The material is taken to perform all operations of a single batch product. The employee provides the semi-finished product and raw materials, needed for the following operations, to the successor after performing the operation at the preceding workstation.

In concept II, the demand is reported and raw material is separated for the entire batch of the order. The transport worker completes orders and distribute materials to the operators of the work stations. Operational staff report the needs and perform the assembly operations.

In concept III, a transport employee handles the warehouse and deals with the completion of raw materials for the batch of the order. The materials are delivered (by the assembly workers) to the work stations together with the semi-finished product during the first batch. Only the semi-finished product moves in the following transport operations (together with the kanban).

Cost, time and organizational criteria must be taken into account in the selection process of the best concept. Since the model of the final product consists of numerous small elements, the issue of the availability and quantity of SKUs affect costs. The assembly process should be carried out quickly and smoothly. Tasks of employees should be evenly distributed, and disturbances should be kept to a minimum. The comparative analysis of the concepts is presented in table 4.

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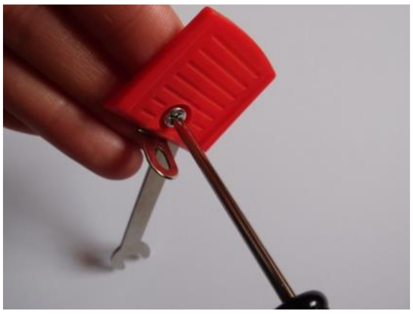
Table 3. Instruction sheet of forklift truck assembly – operation 40.

Silesian University of Technology	Assembly sheet no 4	Product no: WW1		Number of sheets: 1	Sheet no: 1
Operation no: 40	Operation name: Assembly of a seat	Quantity of final product: 1	Time [min]: 2	Product symbol WW1.04	
No.	Description				
1	Pass the cross-headed screw M3x8 (5) through the hole of the component of the seat (10)				
2	Pass the protruding end of the screw (5) through one of two holes of angle bar (9)				
3	Screw the hexagon nut (4) to the end of the screw (5)				
4	Pass the cross-headed screw M3x8 (5) through the second hole of the component of the seat (10)				
5	Pass the protruding end of the screw (5) through the component of the seat (10) and the second hole of angle bar (9). Next pass the protruding end of the screw (5) through the central hole of the component of suspension (12) between frames (14)				
6	Screw the hexagon nut (4) to the end of the screw (5)				
	Delivered item	Sent item			
					

Concept II was selected in the comparative analysis. This concept assumes a quick and efficient flow of raw materials and a fairly even workload. Dedicated containers with partitions will be purchased for this concept. A wider use of containers means that a smaller number of them is needed. Considering disturbances related to the flow of materials, this concept must be tested in practice.

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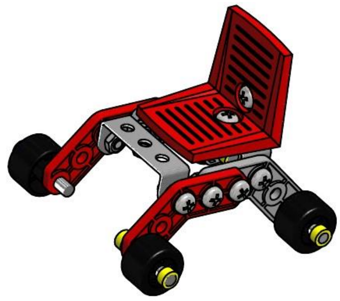
Card No: *6*	KANBAN CARD	Order date: *20.06.20XX*
Number of cards: *10*	Product name: *FORKLIFT TRUCK*	Due date: *22.06.20XX*
Piece no/batch size: *2/7*	Product no: *WW1*	
Operation location: *no 50*	Transporter: *Container*	
Delivery place: *no 60*	Notices:	

Figure 2. Kanban card - operation 50.

Table 4. The comparative analysis of the concepts.

	concept I	**concept II**	**concept III**
employees	operators of assembly stations	operators of assembly stations and transport employee	operators of assembly stations and warehouse employee
division of duties	uneven (the employee of the first station handles the warehouse at the same time)	fairly even	fairly even / uneven (warehouse employees have relatively fewer duties than in concept II. Some of their duties are performed by assembly operators)
speed of order fulfillment	Low	high	high, but slightly lower than in concept II (assembly workers must separate the materials, there is a problem with finding them on the transport trolley)
SKU	SKU with a lot of partitions enabling the storage a large quantity of item classes - large number of containers required and the high cost of each of them	SKU with a small number of partitions or a larger number of SKUs	SKU with a small number of partitions or a larger number of SKUs
other problems	poor organization of the warehouse (the employee of the first assembly station handles the warehouse at the same time - the possibility of confusion when completing materials, downtimes)	not noticed	problems with finding raw materials on a common conveyor

4. The model of the assembly system

The assembly line of a forklift requires the involvement of ten employees (figure 3). Nine of them (B-J) are responsible for assembly operations. One of them handles warehouses and distributes raw materials (A). When the order is accepted into the system, kanbans go to the finished goods warehouse, and then to the operator of the last workstation (J). He takes only kanbans dedicated to the operation performed (the number of kanbans depends on the size of the order). The rest of kanbans is transferred by the employee J to the station at which operation 80 is performed. The process is repeated until the warehouse employee who receives the last kanbans. The receipt of kanbans by the warehouse employee is a signal to distribute materials to all operators. In addition, he attaches his kanbans to transport containers dedicated to operator A, which is a signal to start the first operation. Employee A places the cards, he received from the warehouse worker, on the Kanban board before performing the operation 10 for the first product. Then employee A puts the blank into the transport container, attaches the kanban with the operation number (10) and transports to employee B. Employee B places the cards, he received from employee A, on the Kanban board, before performing operation 20 for the first product. Information on the progress of the order is updated in this way. This process is carried out up to the last workstation. When employee J finishes operation 90, passes the finished product with the kanbans to the output magazine. At the epoch, the warehouse employee removes the kanbans of the first product from the Kanban board and attaches the one, which informs that the produckt is ready. Then he packs the first product. The assembly employees directly transmit the semi-finised product to each other. Therefore, transport kanbans are not needed.

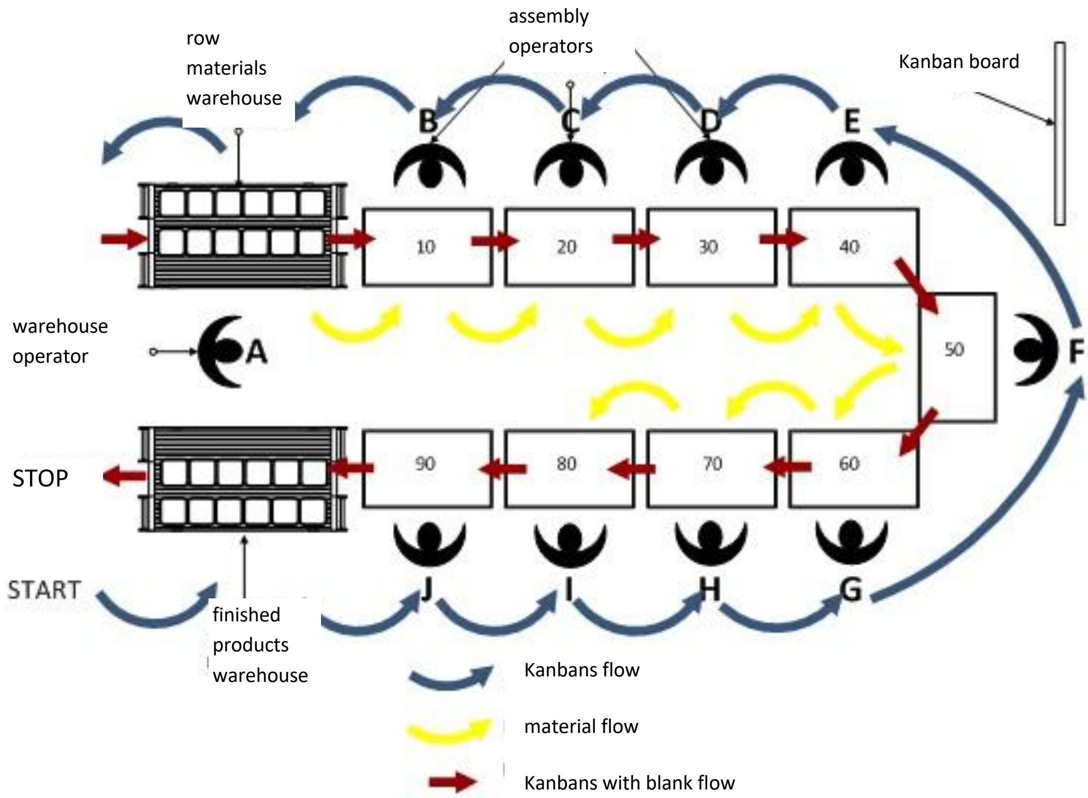


Figure 3. Diagram of the assembly line of the forklift model.

The Kanban board is designed to improve the flow of information and control the process stage. Before the start of a given operation, the operator places the kanban from the previous workstation on the Kanban board. From the Kanban board (figure 4) the following information about the progress of orders one can get:

- two forklift models have already been produced; there are 5 left;
- the third part is at the stage of operation 70, the fourth part is at operations 50, the fifth at 30, the sixth at 20 and seventh at 10;
- raw materials were delivered to the stands.

In addition, information on the dates of receiving the order and their realization can be read from the Kanban board.

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					Operation						
Pcs.	M	10	20	30	40	50	60	70	80	90	State
					Forklift truck						
Batch size: 7 pcs											2/7
Order date: 18.05.2015					Due date: 22.05.2015						
1											READY
2											READY
3	M	10	20	30	40	50	60				
4	M	10	20	30	40						
5	M	10	20								
6	M	10									
7	M										

Figure 4. Kanban board.

5. Simulation of Kanban system operation and results

The purpose of the simulation is to check the flowability of materials and examination of the duration of the operation (figure 5). The order for 7 forklifts was commissioned. Before starting the simulation, materials for containers of each operator were separated.

The total time needed to complete the order in the Kanban system was 2787 s (46.45 min). During the simulation, problems such as: the creation of bottlenecks and queues in front of the Kanban board were noticed. According to the Theory of Constrains (TOC), constrains exist in every system. Their elimination causes them to arise elsewhere in the process. Designing the instructions, assembly steps were grouped so that the operation times were comparable. If the duration of the operation clearly deviated from the norm, the reason for this was usually the manual skills of students and incorrect reading of the instructions.

Figure 5. Assembly line during simulation.

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The reason for creating queues is the wrong arrangement of assembly stations and the Kanban board. Each student should have easy access to the board. In production companies, the Kanban board is usually a kind of box, which completes orders until the appropriate batch is collected. After collecting the appropriate batch, the first operation of the process begins. In turn, the Kanban board, which was used for the purposes of the simulations, acts as a source of information on the progress of orders. Bar code readers located at each assembly station would solve the problem of creating queues in front of the Kanban board.

6. References

[1] Bendkowski J and Matusek M 2013 Logistics of production. Practical aspects (in Polish) II, *Publishing house of Silesian University of Technology*, Gliwice

[2] Grudziewski W M and Hajduk I K 2004 Methods of designing management systems (in Polish), Difin Publishing house, Warszawa

[3] Skołud B 2006 Operational management. Production in small and medium-sized enterprises (in Polish), *Publishing house of Silesian University of Technology*, Gliwice

[4] Grandys E 2013 Basics of production management (in Polish), *Difin Publishing House*, Warszawa

[5] Muhlemann A P, Oakland J S, Lockyer K G 2001 Management. Production and services (in Polish), *PWN Publishing house*, Warszawa

[6] Waters D 2001 Operational management. Goods and services (in Polish), *PWN Publishing house*, Warszawa

[7] Martyniak Z 1996 Modern methods of production management (in Polish), AGH Publishing house, Kraków

[8] Brzeziński M 2000 Organization and production control. Designing of production systems and production control processes (in Polish), Placet Publishing house, Warszawa