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Analysis of Kanban, Conwip, Base on stock methods influences on the production system performance

Ana GAVRILUŢĂ[*]**, Alin GAVRILUŢĂ**

University of Piteşti, Department of Manufacturing and Industrial Management, Piteşti, Romania

[*]Corresponding author: ana.gavriluta@upit.ro

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Abstract. Control methods specific to pull flow are based on firm customer orders, so market demand dictates production and initiates a chain of requests, as a reactive event, in planning the material requirements and the production cycle. For this reason, the objective of the research in this paper was to determine the impact of Kanban, Conwip and Base stock methods to control a production system, in terms of input variables in between certain limits on the output performance indicators of the production system. The analysis of the cost pointed out the fact that production control methods have a significant influence on this indicator of production.

1. Introduction

The methods of pull flow production management allows the manufacturing of products in the client production rhythm and has the fallowing characteristics: the production planning is based on the daily production capacity and on the received orders from the clients; the products are manufactured in small batches and in continuous flow; they need well levelled production lines; aim cost reduction, short response for clients demand, increase of productivity and stock reduction.
Considering these the research done in the field of pull production control methods, that show the advantages of them compared to other production control methods, represent a special interest for the increase in productivity, product quality and decrease the manufacturing cost and stock.
The studies and the research on the influence of different production control methods on a pulled flow, on the performances of manufacturing lines, although numerous, they were not studied in the

same hypothesis and were not analyzed the same experimental factors, making the comparison difficult.
Also, the made researches are on the influence of the production factors, and none yet are on the influence of more of them in the same time. Starting from this premises and considering the perspective of its use in the industrial enterprises, the researches made in this article aimed to analyze the impact of production control methods Kanban, Conwip, Base on stock, in the conditions of variable entry data (in certain limits) on Total Cost and to elaborate recommendations on applicability of the research results.

2. Description of the production line

The models of the system were built according to the descriptions previously given and a few assumptions were made to simplify the simulation process. The most important assumptions were the following:
- Number of products – two products, PA and PB;
- The technological process needed for product manufacturing that implies the same sequence of operations. In order to accomplish the operations within the technological process a single machine is needed for each type of operation; the machines are placed in the order of making the operations within the manufacturing process. The information regarding the technological process are presented in Table 1 and the information on cost are: Setup cost – 129.05 [u.m./h] and Production cost - 96.5 [u.m./h]

Table 1. Production cycle times

No.	Stage	Processing time [mi/op.]		Breakdowns			*The time needed for the operator's lunch and rest* [mi/day]	*Machine failure – down time* [mi]	*The running time of a tool* [mi]
		Product PA	Product PB	*Machine failure – up time* [mi]	Setup time [mi]	*Changeover time* [mi]			
1	Turning	1.89	1.89	15	5	3.1	60	1002	378
2	Gear cutting	1.96	1.93	28	11	7.0		1083	7840
3	Chamfering	2.76	2.7	5	9	5.4		1231	29000
4	Gear brushing	3.4	3.38	8	11	6.0		2195	19750

The most known production control method in a pull flow is Kanban. It is the first used in Toyota production system in the mid-70s and is associated with Just in Time concept [1], [2]. The system controlled with the Kanban method works as described in the followings. When demand to release from stock arrives to systems it requires the release from stock of a container with finite products for the customer. If in a certain stage i a container is not available in the interoperation stock specific to each processing stage, no kanban is transferred downstream and the information concerning the demand is temporarily stopped; it is resumed when a new container becomes available in stock. Therefore, the philosophy of planning production with the help of kanban assumes that customer demand be sent upstream stage i only when a container is sent downstream stage i. The kanban system is a simple mechanism to control a production line depending on a single parameter per stage, namely ki, i = 1,…4. This parameter influences both the transfer of containers downstream the system and the transfer of demand upstream the system. Each operation has a kanban for product PA and another kanban for product PB.
The CONWIP system, an alternative to Kanban, is another pull production method that was developed by Spearman et al. in 1990 [3]. Although the system has 4 steps, the control of the line made with Conwip means to control the production only at the entry of the process, and the inter-process stocks, Si, have no role in control.
Conwip is a method implemented by matching a single card to each container, allowing its presence in the model. Each time a container leaves the end stock, the card is removed and sent to

the first production step, allowing another container to entry the model. All other manufacturing steps of the system, machine any container that come in the order of their arrival. In the system circulated 4 card conwip for product PA and 4 card conwip for product PB.
The Base stock model works as follows. When the customer demand reaches the system it is divided into 5 demands, each one is immediately transferred to the control panel corresponding to each stage and the last one joins the final stock demanding the release of a new product to the customer. The level of the base stock will be the same during all working stages and its value depends on the customer's demand, Table 3.

Table 2. Base stock

Demand	360 products	240 products	160 products
S_i – base stock	45	30	20

3. Simulation models

To determine the influence of the pull flow control methods on the total cost, here will be used the dynamic simulation tools. The simulation of the researched methods was made using SIMAN programing language, developed by Arena Rockwell, version 13.1.
To mimic exactly the operating mode of the production system that was controlled by the studied methods, the simulation was made using logic modules. These modules can be split in two categories:

- General modules – used in all the 3 models: the module of entry of raw materials; the module of demand entry from client; the regulatory module; process modules: turning, toothing, tooth chamfer, tooth rectification; expedition control module;
- Modules specific to each model – these are the material and information flow control modules that are mimicking the used control methods: Kanban, Conwip and Base Stock.

The module of row material entry –introduces in the system the raw materials that are necessary to manufacture the products, Figure 1. The raw materials (or subassemblies) are released from this decisional module only at the request of step 1 of machining. Also, in this module to each part it's attributed the holding cost value and the manufacturing operations details, specific to each product, Figure 2.

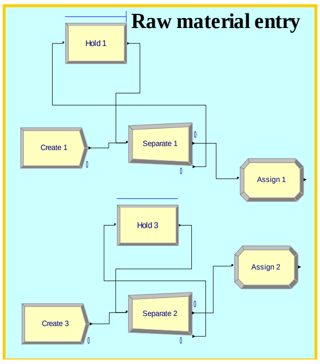

Figure 1. Module of introduction in system of raw materials

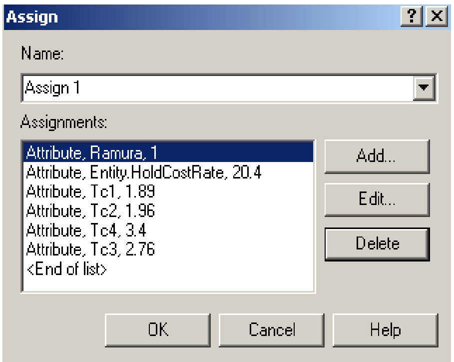

Figure 2. Attributing the holding cost and the manufacturing operations details (cycle times)

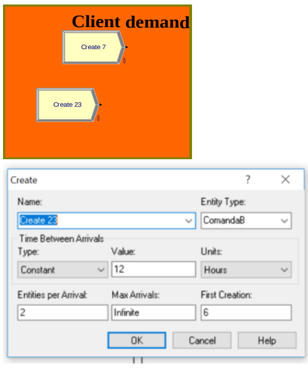

Figure 3. The module of order entry in the system

The client demand module – introduces in the system the daily request from the client and controls the number of setups by grouping the production in batches, Figure 3 and Table 3.

Table 3. Introduction of orders and batch grouping

No. of setups per day	Number of batches per order	Time period between orders [hours]
2	4	24
4	2	12
8	1	6

The setup module – with the help of this module are introduced in the system the setup times specific for each machine and also is managed the functioning logic of batch change, figure 4.
The process module – simulates the machining of parts in each operation, figure 5. To each operation it is attributed a resource with the following characteristics: cycle time of technological operations [mn]; tool change duration [mn]; time to repair of the machine [mn]; usage cost [u.m./hour]; working program of the resource [hours].

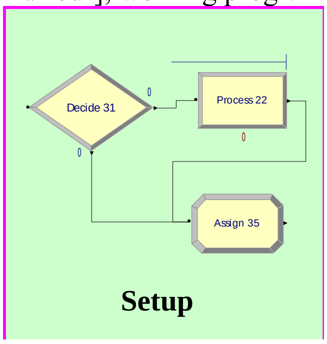

Figure 4. Setup module

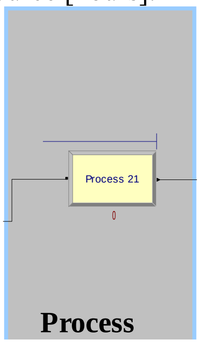

Figure 5. Process module

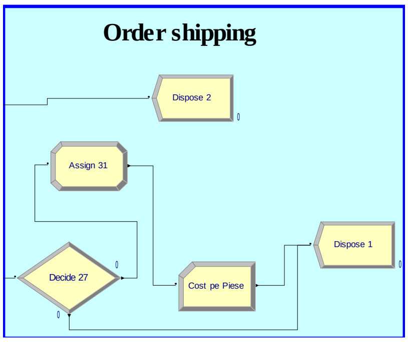

Figure 6. Order shipping module

Order shipping module – from it the parts are sent to client according to his demand, figure 6.
Kanban module – it is designed to simulate the control functional logic of the Kanban control method. It contains the followings:

- Kanban generator – the module used to create the Kanban cards and also to send them to each manufacturing step, Figure 7;
- Attach/ detach module – matches the container with parts with the current operation Kanban card and also detaches the Kanban card of the previous operation, Figure 8.

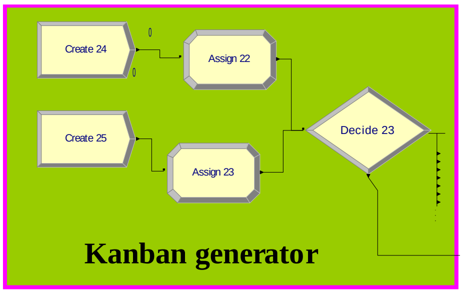

Figure 7. Kanban generator module

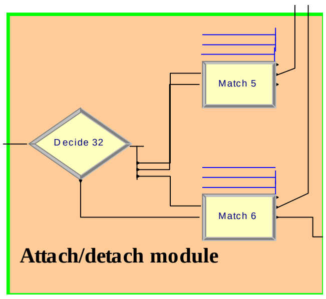

Figure 8. Kanban card attach/ detach module

Conwip module – includes all the elements used to simulate the functioning logic of conwip. These are:

- The conwip generator – the module used to create the conwip cards in the system and also to send all of them to the first operation of manufacturing, Figure 9;
- Cards attach module – this attaches the cards to the container with parts (in this case raw materials), Figure 10;
- Cards detach module – this removes the conwip cards from the container, the cards returns to the first machining operation and the container with finish products is sent to the order shipping module, Figure 11.

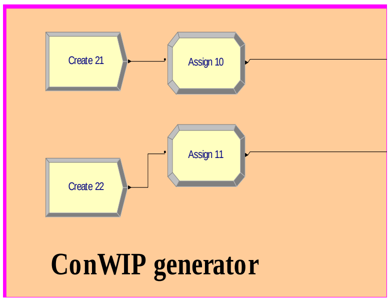

Figure 9. Conwip generator module

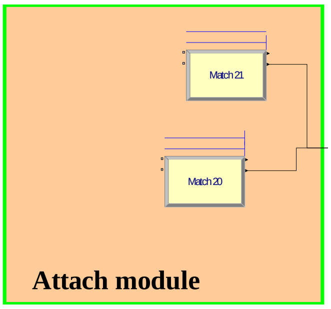

Figure 10. Conwip cards attach module

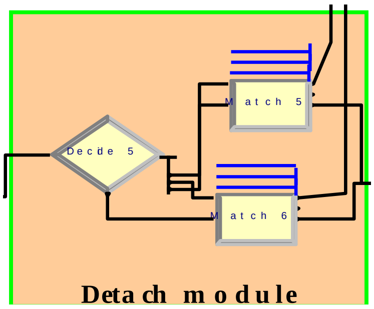

Figure 11. Conwip cards detach module

Base stock modules – are the ones with which it was simulated the functioning logic of Base Stock control method. These modules are:

- order deployment module – here the order from the client is transmitted in all manufacturing steps and this info is used to analyze the stock level, figure 12;
- stock analysis module – it evaluate the stock level between each operations and gives the manufacturing order to the process module, figure 13.

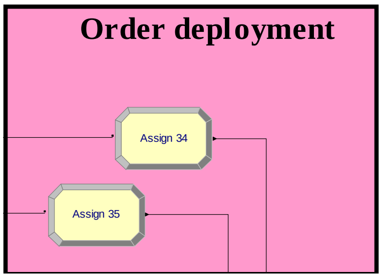

Figure 12. Order deployment module

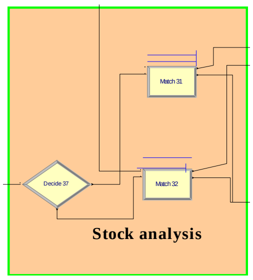

Figure 13. Stock analysis module

4. Verification and validation of the models

Even if the experimentation on a real life model (implementation on a production system) is not possible, all simulation models need to be checked and validated. In this article the checking and the validation of the models is made using the method developed by Naylor and Finger, [4]. This method implies the following steps:

- determine the worm-up (loading with articles) period of the system;
- determine the simulation period;
- model validation.

The loading with article period of the system (warm-up period) represents the amount of time that the simulation runs without recording statistical data.

The worm-up period was determined using the Welch's method. This is a graphic method that implies the run of a great number of simulations. The Welch's method implies the following steps:

- the run of n simulations, $n \geq 5$, each simulation being run for a m period. Considering Y_{ji}, i = 1…m, j = 1…n, as the result of the simulation;
- it is calculated the averages for the simulated period. This will be $\overline{Y_i}$ where:

$$\overline{Y_i} = \sum_{j=1}^{n} \frac{Y_{ji}}{n} \quad \text{for i = 1…m;}$$

- these averages are leveled with the help of a moving average, $\overline{Y_i}(w)$,where w is the number of periods that would be considered in the calculus and $w \leq [m/4]$;

- with the results is made a graphic representation $\overline{Y}_i(w)$, i = 1… mw, and is chose the loading period Wp that is equal with the value of i from which $\overline{Y}_i(w)$ seems to converge.

To determine the period of worm-up (loading) of the system, it was measured the productivity per hour of the system, in a configuration that was the same in all models. This configuration used to determine the worm-up period is:

- client demand of 360 products/day;
- holding cost of 35%;
- 8 setups per day.

Each model was run for 10 times for a period of 115 hours, and during this period, the results were taken at each 5 hours.

The graphics obtained by representing the moving averages are presented in the Figure 14 for Kanban, Figure 15 for Conwip and figure 18 for Base Stock model.

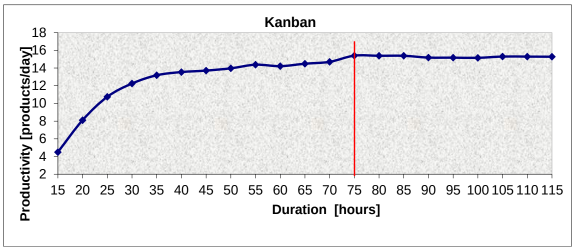

Figure 14 Moving averages for Kanban model

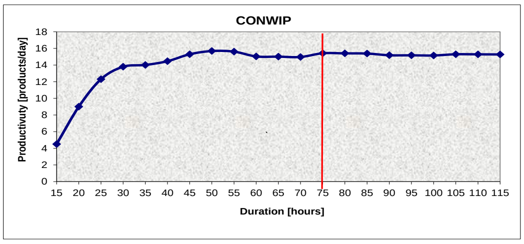

Figure 15 Moving averages for Conwip mode

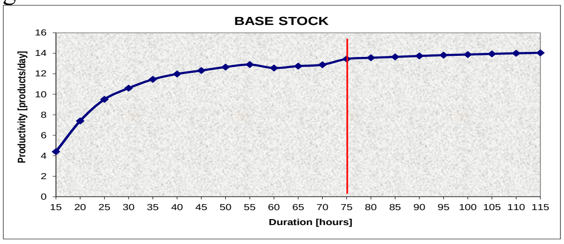

Figure 16 Moving averages for Base Stock model

For all studied methods it was considered an article loading period of the system, Wp of 75 hours. The simulation duration is determined by multiplying the warm-up period of the system with 10, [4].

$$Ps = Wp \cdot 10 = 75 \cdot 10 = 750 \text{ hours}$$

where:

- Ps, the simulation duration [hours];
- Wp, the worm-up period, the period of loading of system with articles [hours].

The validation of the models is made by measuring the percentage differences between the results of the simulation and the results of analytic calculus.

$$\Delta Y = \frac{|Ycalculat - Ysimulat|}{Ycalculat} 100\% \quad \text{where, Y is the measured variable}$$

To validate the models it was used the end results of system productivity that analytically are determined with the following equation:

$$\omega = \min\left(\frac{Fd_i \cdot M_i}{tu_i}\right) Ps$$

where:

- Fdi, the available time for the workstation i, i=1..4, [hours];
- Mi, the number of workstations that are included in the operation i;

- tu_i, the cycle time specific to operation i [ore], it is considered the maximum value between the tu_i of product PA and tu_i of product PB;
- Ps – simulated period [hours].

For validation were studied 5 configurations of the models:

- 1st configuration – from the system are taken out: setup times, machines repair durations and tools changing durations;
- 2nd configurations – in the system are introduced only the machines repair durations;
- 3rd configuration – in the system are introduced only the tool change durations;
- 4th configuration – in the system are introduced only the setup durations;
- 5th configuration – in the system are introduced all the stoppages durations (setup, repair and tools change).

Table 4 contains the values of errors between the results of analytic calculus and the ones measured in as results of simulations.

Table 4. Errors between the productivity values calculated by analytic method and the ones obtained from the simulation

System productivity/ Percentage difference	1st configuration	2nd configuration	3rd configuration	4th configuration	5th configuration
Theoretical [products]	12683	12625	12656	12375	12313
Kanban model [products]	12880	12840	12880	12480	12440
$\Delta\omega$ [%]	*1.55*	*1.70*	*1.77*	*0.85*	*1.01*
Conwip model [products]	12880	12840	12880	12480	12440
$\Delta\omega$ [%]	*1.55*	*1.70*	*1.77*	*0.85*	*1.04*
Base Stock model [products]	12880	12840	12880	12400	12360
$\Delta\omega$ [%]	*1.55*	*1.70*	*1.77*	*0.20*	*0.39*

After using the method of Naylor and Finger to check and validate the 3 simulation models, the conclusions were the following:

- the period of loading with articles of the simulation models is of 75 hours;
- the simulation duration for the 7 models is of 750 hours;
- the simulated models give validated results that can be compared with a real life situation.

5. Simulation results

The variable determined as a result of simulation is *Total.SystemCost* – the total cost of the system that is calculated by Arena as being the sum of all system costs.

$$\text{Total.SystemCost} = \sum_{i=1}^{n} \text{Costul pe produs} + \sum_{j=1}^{m} \text{Costul pe resursă}$$

where:

- i, number of products made in the system;
- j, number of used resources.

The cost per product represents the sum of 5 categories of costs:

- costs that add value on product - Total.VACost;
- costs that do not add value on product - Total.NVACost;
- costs of waiting in stocks - Total.WaitCost;
- costs of transport - Total.TranCost;
- other costs - Total.OtherCost.

The cost on resource represents the sum of 3 categories of costs, 2 of them being included in the cost of product:

- cost of resource use – Total.ResBusyCost – included in the product cost;

– cost of resource stoppage due to repairs–Total.ResUseCost – included in the product cost;
– waiting cost for resource - Total.ResIdleCost.

In the analysis were considered 3 methods of control of a manufacturing line that produces two times of products PA and PB. In the compared hypothesis were varied 3 entry parameters:

– daily demand of the 2 products, in equal quantities, varied between 160 … 360 [parts/day];
– holding cost, varied between 0.12 … 0.35 [um/day];
– number of setups per day (changes from one product to the other), varied between 2 … 8 [setups/day];

The main conclusions from the analysis of simulation results are:

– the increase of the entry parameters leads to an increase of total cost for all control methods;
– considering the total cost, the more important influence is from the holding cost, followed by the daily demand, and the least influence is from the number of setups, that in the Base Stock method is negligible.

The influence of control methods on costs is the same when the entry parameters are variated, as it can be seen in the graphs of Figure 17, 18 and 19. These results are obtained by varying at a time an entry parameter, the other two being kept constants.

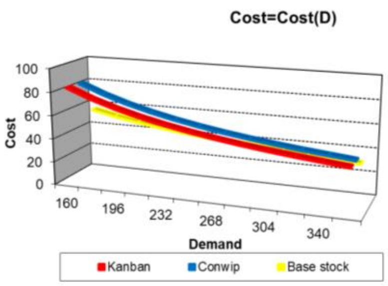

Figure 17. The influence of demand on cost per unit

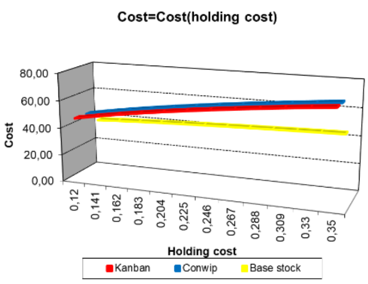

Figure 18. The influence of Holding cost on Cost per unit

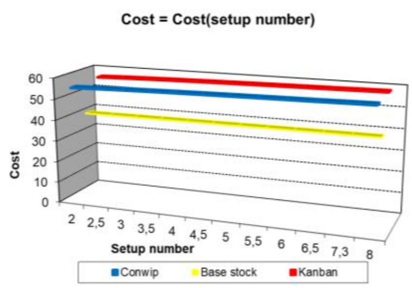

Figure 18. The influence of setup number on cost per unit

To highlight the influence of each variable on the cost, it were calculated the weight coefficient and the relative coefficient of influence of this cost, table 5.

Table 5. Influences of each variable on the cost

Method	Variable	The direction of influence	Weight coefficient value	Relative coefficient of influence [%]
Kanban	Daily demand	increase	2.16	115.67
	Holding cost	increase	1.49	48.52
	Number of setups	increase	1.04	3.74
Conwip	Daily demand	decrease	2.18	117.67
	Holding cost	increase	1.49	48.82
	Number of setups	increase	1.04	3.78
Base stock	Daily demand	decrease	1.88	87.88
	Holding cost	increase	1.15	15.24
	Number of setups	increase	1.00	0.23

As it can be seen from the weight of the cost variables, the Conwip method is the most influenced by the variation of the entry parameters, and the least influenced is the Base Stock method.

6. Conclusions

It is considered that the research done in this article bring original contributions, useful research purposes and also for industry, on several important directions of conception and control of production systems. A first contribution, considered as most important, is the methodology used to choose the optimum control method for the performance indicators, taking into account several parameters as daily demand, number of setups, holding cost. The developed methodology is proven to be a strong instrument for the designers of industrial systems and also for the managers of these systems. The second contribution is linked to the usage of SIMAN language to make the dynamic simulation of the production line on this specific control method. Starting from the developed model were determined the loading period of the system, the simulation duration and also the methodology of simulation validation.

References

[1] Zipkin P. 1989, A kanban-like production control system: analysis of simple models. Research Working Paper No. 89-1, Graduate School of Business, Columbia University, New York.

[2] Groenvelt H., 1993, The just-in-time system. Handbooks in Operations Research andManagement Science 4, Hanover, USA.

[3] Spearman,M.L., Woodruff, D.L.,Hopp, W.J., 1990. CONWIP: A pull alternative to Kanban. International Journal of Production Research 28 (5), pp. 879–894.

[4] Banks J., Carson II J. S., Nelson, B. L. 1999 Discrete-Event Simulation. Upper Saddle River, Prentice Hall, New Jersey.