ProcessModel Simulation to Show Benefits of Kanban/Pull System

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ABSTRACT

The Manufacturing Extension Partnership (MEP) is a nationwide network of over seventy not-for-profit centers. The MEP is linked with the Department of Commerce's National Institute of Standards and Technology (NIST) and has the sole purpose of providing small and medium-size manufacturers with the assistance they need to be competitive and successful. The Alabama Technology Network (ATN) joined the MEP in 1996 and began operation through a partnership among the University of Alabama System, Auburn University, and select two-year colleges. The ATN has 10 centers statewide that are focused on providing technical and business solutions to Alabama companies in order to lead them to high performance. The University of Alabama in Huntsville (UAH) is the Region 1 center of the ATN and concentrates a large portion of its efforts in the field of Lean Enterprise Development.

Lean Manufacturing is a systematic approach to identifying and eliminating waste through continuous process improvement by flowing the product at the pull of the customer. This paper discusses the use of a ProcessModel simulation, linked with a hands-on kanban simulation utilized by the UAH center for the ATN, to reveal benefits of a pull system. The paper focuses on using the ProcessModel kanban simulation to help see process constraints, underutilization, and to make purchasing and inventory control decisions.

INTRODUCTION: CONCEPTS OF LEAN

Global competition continues to force companies to discover ways to reduce delivery time, improve quality, and simultaneously lower cost. To achieve this "faster, better, cheaper" mentality, many companies within the MEP target client base request assistance and guidance in lean manufacturing and lean enterprise, specifically in the area of kanban/pull systems. A *kanban* system is, in its simplest form, deciding 1)what, 2)how much, and 3)when to make product by looking at what the downstream process in the production line is consuming (Ohno, 1988 and Shingo, 1989). A successful kanban system vastly reduces in-process inventory levels, which in turn allows other sources of manufacturing waste to surface and be eliminated. Thus, the response time to the customer, both internal and external, ultimately becomes faster. To demonstrate these benefits of the kanban system, the University of Alabama in Huntsville uses a hands-on training simulation for training class participants.

THE HANDS-ON TRAINING SIMULATION

The hands-on training consists of a simulated manufacturing plant that produces windmills made of K'nex. Participants in the training fabricate parts of the windmill and assemble the final product in simulated factory. Multiple rounds for the simulation are run and participants are able to compare the results of each round to see the benefits of a kanban/pull system.

The simulated factory consists of a fabrication station that molds the propeller for the windmill, a paint station where the molded propeller is painted, and an assembly station where the painted propeller is assembled to a shaft and two base components (all of which are purchased) to make the finished product. The initial round of the simulation is ran as a mass production system with products moving in batches of 10 and each station making as many as they can. Product is pushed from station to station resulting in build-ups of work-in-process inventory. Participants are told to continue production until the completion of 50 finished products.

In the next phase of the training, participants are introduced to the basics of pull systems. Time is spent calculating kanban quantities. The system is then fine-tuned and implemented in the simulated factory. The

Part: Propeller
Process: Fabrication
Next Process: Paint
Qty/cont: 10
Issue: 1 of 2

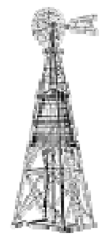

Figure 1: Kanban Card

kanban/pull system for the simulated factory consists of two bins (batch = 10 for all bins) of work-in-process (WIP) between the fabrication and paint stations and two bins of WIP between paint and final assembly. After final assembly, the bins are moved as needed to be shipped to the customer. Each bin of WIP also contains a kanban card (see Figure 1) and as bins are emptied the card goes back to the preceding operation as an order for another bin. If the preceding process receives no card, it does not make any further WIP. Thus, there should never be more than 2 bins (20 pieces) of WIP between fabrication and paint and 2 bins (20 pieces) between paint and final assembly. In total, if followed, the kanban system limits in-process inventory to no more than 40 pieces. For a comparison of typical results for the mass production system and kanban system WIP, and time to produce 50 finished products, for the hands-on simulation, see Figure 2:

System	WIP		Time
Mass	Starting WIP	20	8:30
	Ending WIP	110	
Kanban	Starting WIP	20	7:15
	Ending WIP	40	

Figure 2: WIP and Time Comparison

Obvious benefits of the kanban/pull system are a reduction in lead-time and quicker product flow. Typically, participants also observe that once the kanban system is implemented, the fabrication station is not operating much of the time due to not having a card sent back from paint signaling a demand for another bin of fabricated propellers. Thus, the final phase of the hands-on training simulation involves utilizing the excess capacity at fabrication by taking one of the base components used at final assembly and fabricating it in-house (as opposed to purchasing it). Available capacity is often hidden without a proper inventory control system like kanban.

THE ProcessModel SIMULATION

While the benefits of a pull/kanban system may be observationally obvious in the hands-on simulation, especially the benefit of taking a once-purchased part and making it in-house with existing capacity, in a "real world" setting it would likely be desirable to justify such benefits with the use of metrics. Thus, a ProcessModel simulation was created of the hands-on simulation to evaluate utilization of processes and the cost of both WIP and purchased materials. To correspond with the hands-on simulation, three separate simulation models were created: one for a mass production push system, one for a kanban/pull system, and a third where one of the base components is manufactured in-house as opposed to being purchased.

The mass production simulation modeled four processes (fabrication, paint, final assembly, and finished goods count) and used dedicated operator resources for fabrication, paint and assembly. A material handler resource was also modeled to move bins to the next station as needed. The propeller was modeled as an ordered entity that arrived to a bulk storage bin (capacity of 300) to be used by fabrication. The shaft and two base components were also modeled as ordered entities arriving to separate storage bins at assembly and were attached at the process when needed. Each storage bin was modeled to simply be refilled to 300 once the level reached 100. See model diagram in Figure 3:

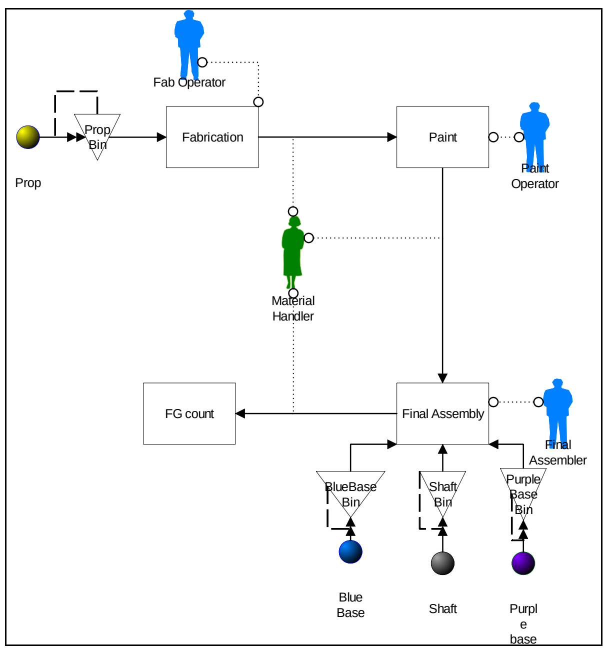

Figure 3: Mass Production Model

Adapting to ProcessModel's limitations, the simulation was set to run a warm-up period of one minute and run a production round of 8 minutes. Using the ProcessModel output report, data was collected on utilization, WIP, and raw material and component inventory. Figure 4 summarizes the results for the mass production simulation:

WIP				
Fab	Paint InQ	Paint	FA InQ	FA
0	50	10	90	10
Components Bins				
Prop	Shaft	BluBase	PurBase	
133	171	171	171	
Utilization				
Fab	Paint InQ	FA	Matl Hand	
70.71%	99.60%	98.05%	21.82%	

Figure 4: Mass Production Results Summary

In addition, costs were assigned for several aspects depending on the nature of the component, the stage of production WIP was in, and wait time in a queue as a result of excess WIP. The ProcessModel output data was used to get an average wait time (2.25 minutes for paint in-queue and 2.78 minutes for assembly in-queue) and a standard 10% holding cost was added for excess WIP waiting. Figure 5 summarizes the assigned costs and Figure 6 shows the cost analysis:

Component Cost				
Raw Prop	Shaft	BluBase	PurBase	
$12	$4	$18	$12	
Process Cost				
Fab	Paint	Assembly	Move	wait
$3	$3	$34	$1	10%

Figure 5: Assigned Costs

Process and Waiting					
	Fab	Paint	FA		Total
Cost	$0	$228	$650		$878
	Paint InQ	FA InQ			Total
Cost	$991	$2,795			$3,786
Purchased Components					
	Raw Prop	Shaft	Blue Base	Purp Base	Total
Cost	$1,596	$684	$3,078	$2,052	$7,410
Total Cost =					**$12,075**

Figure 6: Mass Production Cost Analysis

The cost calculations do not take into affect any costs that would not change throughout the three simulations, such as labor cost, etc.

Attention is next turned to the ProcessModel simulation created for the same operation using a kanban system. Neither the processes nor use of purchased components changed from the previous model. However, a modeling change was made in how material flowed between stations, making alterations so that only 2 bins (20 pieces) of WIP could be between fabrication and paint and only another 2 bins could be between paint and assembly. This was accomplished using ProcessModel's ordered routing option. Figure 7 shows a diagram of the kanban system model:

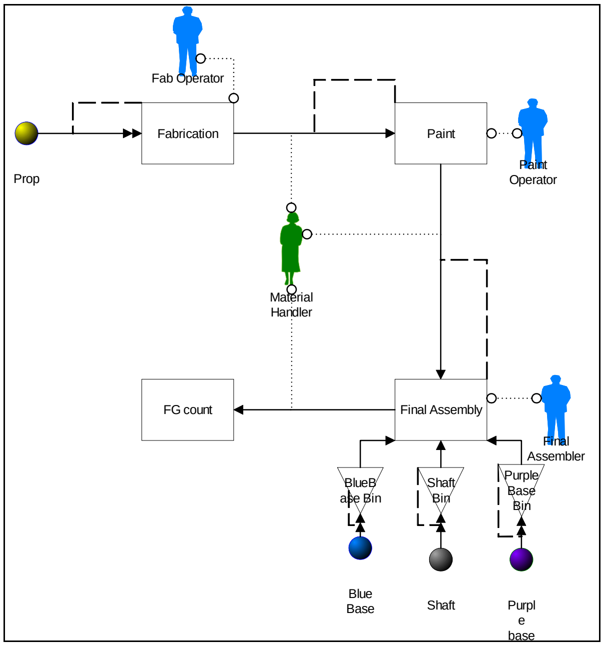

Figure 7: Kanban System Model

Again, the simulation ran a warm-up period of one minute and a production round for eight minutes. Output data was collected and summarized below in Figure 8:

WIP				
Fab	Paint InQ	Paint	FA InQ	FA
0	10	10	10	10
Components Bins				
Prop	Shaft	BluBase	PurBase	
133	171	171	171	
Utilization				
Fab	Paint InQ	FA	Matl Hand	
24.93%	43.05%	100.00%	9.32%	

Figure 8: Kanban System Results Summary

As expected, the amount of purchased components in their respective bins did not change from the results of the mass production round because there was no change in how they were consumed in the model. The results show that our model was in obedience to the kanban rule, showing no more than the allowed WIP at the appropriate locations. The output data also showed that the average wait time in queue was less (on average product waited 1.24 minutes between fabrication and paint and 1.4 minutes between paint and assembly). Using this information, the cost analysis for the kanban system simulation is summarized in Figure 9. The reduction of WIP, and the resulting reduction in waiting time for the inventory in process provided a 29% decline in overall inventory, process, and waiting cost.

Process and Waiting					
	Fab	Paint	FA		Total
Cost	$0	$201	$551		$753
	Paint InQ	FA InQ			Total
Cost	$180	$241			$422
Purchased Components					
	Raw Prop	Shaft	Blue Base	Purp Base	Total
Cost	$1,596	$684	$3,078	$2,052	$7,410
Total Cost =					**$8,584**

Figure 9: Kanban System Cost Analysis

Perhaps the most interesting and useful information from the output data comes from a close look at the utilization numbers in Figure 8. Because the fabrication station was not allowed to produce parts in excess of the 2 bins of WIP determined necessary by the kanban system, it was forced to sit idle when it wasn't needed to produce these parts. The results show that fabrication was in use only about 25% of the time. This could be used in justification of making other parts of the assembly other than the propeller in-house and possibly save on purchased component parts. The excess capacity at the fabrication station suggests we could make such a change using existing resources. The fact that the material handler for this operation is less than 10% utilized only goes to further the feasibility of adding another product to the operation line.

The third and final simulation was an attempt at modeling the situation of changing one of the base components from a purchased part to a fabricated part and using the available capacity at the existing fabrication station to do so. Several modeling changes had to occur to make this possible. The shaft and remaining base component continued to be attached at the assembly station as in the previous models. However, the other base component was changed from a bulk bin of 300 purchased parts to a kanban system of 2 bins of 10 each. This base component would now be fabricated and routed to assembly (paint is not necessary for this product) to attach to a propeller, shaft, and other base component to form a finished product. This reduced the amount of blue base inventory from a possible 300 purchased components to a maximum of 20 in-process components. Another modeling change was necessary because of a 30 second changeover time at the fabrication press that is now making both the propeller and blue base component. The kanban quantity for propellers was changed to 3 bins of 10 each in process. Figure 10 is a diagram of the mix-model simulation:

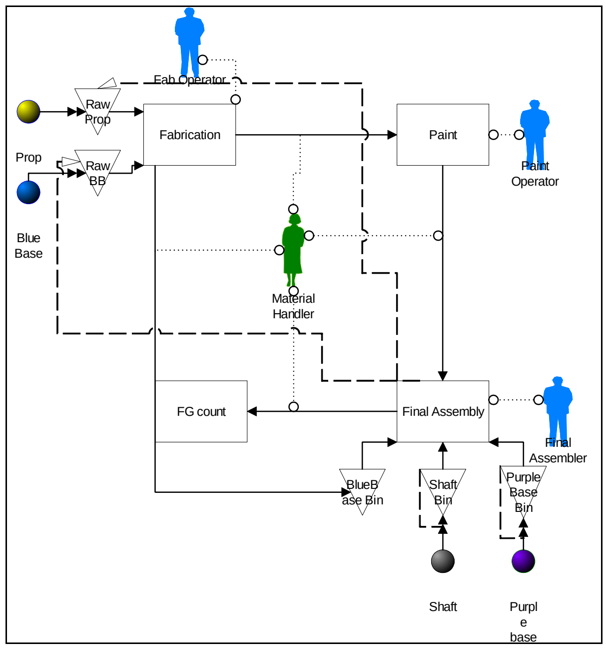

Figure 10: Mix-Model Simulation

The warm-up and simulation times used were the same as for the previous models. Figure 11 summarizes the output data:

	WIP				
	Fab	Paint InQ	Paint	FA InQ	FA
Prop	0	10	10	0	10
BluBase	10	0	0	0	10
	Components Bins				
	Raw Prop	Raw BluBase	Shaft	Purp Base	
	150	200	171	171	
	Utilization				
	Fab	Paint InQ	FA	Matl Hand	
	72.97%	42.80%	97.92%	19.64%	

Figure 11: Mix-Model Results Summary

The output data shows that the existing resources for fabrication and material handling could handle the additional responsibilities. The average wait time for the in-queues also dropped (0.51 minutes for paint in-queue, 0.35 minutes for final assembly in-queue for propellers, and 0.02 minutes in final assembly in-queue for blue base components). The lower wait times result in lower lead times and also lower cost (see Figure 12 for cost analysis). The wait time data also indicates that products, especially the fabricated base products, aren't waiting much at all, which could lead us to conclude that not much more inventory reduction could be done with the current process without starving the line. (ProcessModel, 1996)

Process and Waiting					
	Fab	Paint	FA Prop	FA BB	Total
Cost	$150	$160	$510	$180	$1,000
	Paint InQ	FA InQ			Total
Cost	$168	$0			$168
Purchased Components					
	Raw Prop	Raw BluBase	Shaft	Purp Base	Total
Cost	$1,800	$2,000	$684	$2,052	$6,536
Total Cost =					**$7,704**

Figure 12: Mix-Model Cost Analysis

After modeling three phases of the hands-on kanban simulation in ProcessModel, we now have actual measurable data that can help in making decisions. Using the utilization data enabled us to realize the excess capacity at fabrication and save by making previously purchased items in-house without investing in additional capital. Also, if a company had the philosophy of dividing the total cost by units produced for a shift to get cost per unit data, the kanban system offers further benefits. Figure 13 shows a comparison of such numbers between the mass production mode, kanban system, and mix-model system and gives a "break-even" price that each of the 50 windmills produced would have to be sold for on the market. In today's competitive environment, pull systems offer a way to control inventory at a lower cost.

	Break-Even Price
Mass Production	$241.50
Kanban	$171.68
Mix-model	$154.08

Figure 13: Break-Even Prices

CONCLUSIONS

In summary, the following conclusions can be made about kanban systems, and the hands-on simulation and ProcessModel computer simulation model used to evaluate them:

- Kanban/pull systems offer a way to control inventory, eliminate waste, and reduce lead times to customers
- The hands-on training simulation offers participants first-hand experience in the basics of kanban systems
- Computer simulation provides an effective analysis of kanban systems prior to actual implementation to assist with decisions on inventory control and capacity management

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BIOGRAPHIES

Nicholas Loyd is on the staff of the Alabama Technology Network at the University of Alabama in Huntsville and has trained hundreds of manufacturers from several states in Lean Manufacturing. He has a BS in Industrial and Systems Engineering and is a NIST certified Lean Manufacturing trainer. He has been active in providing lean manufacturing assistance to companies in the automotive, aerospace, electronics, plastics, meat-cutting, mining and other industries in the areas of: cellular manufacturing design, value stream mapping, TAKT time/work balancing, work standardization, kaizen facilitation, and changeover reduction. He is a member of the Institute of Industrial Engineers and the Society of Manufacturing Engineers.

Michael McNairy is on the staff of The University of Alabama In Huntsville center for the Alabama Technology Network. He has a B.S. in Industrial & Systems Engineering at UAH and is currently pursuing his MS in ISE w/ a focus on Manufacturing Systems Engineering. He has seven years experience in the office furniture industry (SteelCase) in production and Manufacturing Engineering. Michael is a NIST certified Lean Manufacturing trainer and a certified Six Sigma Green Belt by IIE. He is a member of the Society of Manufacturing Engineers and the Institute of Industrial Engineers.