INVENTORY CONTROL AND COST TRANSITION FOR OPTIMUM TRANSITION POLICY

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ABSTRACT

Every manufacturing industry has put in continuous efforts for its survival in the current impulsive and competitive economy. In order to handle the critical situation, manufacturers are trying to implement new and innovative techniques in their manufacturing process by making it more effective and efficient. The results revealed that the status of Lean Manufacturing (LM) implementation in still in thriving stage. This paper will further assist the organizations to improve its process, align it to the requirements of its customers and relentless contribution to manufacturing sector to enhance productivity, quality and competitiveness is immense. Organization that adopt lean manufacturing tends to change from push to pull, this type of transition can be done by adopting this change from a single stage processing system to a multistage processing system, during this phase due to it may result in building the kanban inventory, at the same time the plant need to process the regular customer orders, it may affect the capacity of the workstation, and may result in the backlog and may the customer lead times. For this we can add more resources to the plant, or we can defer some customer orders, in this paper we are building up two models one for inventory control and other for cost transition and thereby we can find the optimum transition policy.

KEYWORDS: *lean manufacturing, kanban, inventory, lead times*

I. INTRODUCTION

The lean literature unanimously advocates the transition of push production control to pull where possible but very little is written about the mechanics of the transition process or the behaviour of systems in lean transition. Hopp and Spearman [3] discuss the mechanics of push and pull production control, their role in lean transition and even sketch out a lean transition scheme. However, they limit their analysis to the "before" and "after" steady state conditions. In fact, to our knowledge, there is no discussion of the transient effects of lean production control transition in the literature. Queuing literature though does discuss the effects of non-stationary arrival rates on system performance. Hall[2[discusses ways to model systems with non-stationary arrival rates. He explains that the size of changes in arrival rate relative to capacity dictate which modelling technique to use. For systems in which the arrival rate is always much lower than capacity, steady state approximations can be used. In systems where the arrival rate is much larger than capacity, a fluid flow approximation is more appropriate. For systems where the arrival rate is close to capacity, he suggests that only simulation can accurately model system performance. Here a suitable system with two stage manufacturing flow is taken and order transition under three stages are analysed. The transition logic based on arrival rate and process rate is analysed and a simulation model is arrived. From that a model for cost transition and comparison with present is executed and discussed.

1.1 System

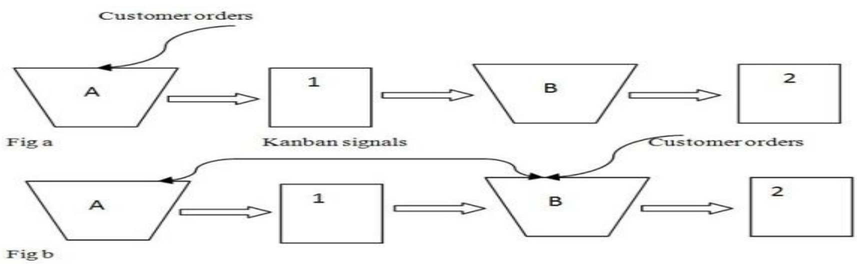


Fig a Two stage manufacturing system

Fig b Customer orders trigger at workstation A

and once the process completes it goes to B and B process them Customer orders trigger at workstation 2 which removes item from workstation 2 which sends the authorised signals to workstation A.

1.2 Problem setup

Customer orders	λa
Order deferral rate	λd
Resources	r
Number of resources added	r+
Processing time	μr
Total processing time	r μr

We are going to consider this transition in three different cases

i. Arrivals >>capacity

ii. Arrivals<<capacity

iii. Arrivals≈capacity

The first event is the arrival of the first kanban card, which occurs at the time t=t0 the number of kanban cards is taken as nk and the processing time of kanban cards is taken as λk [5] (1)

1.3 Transition Cases

From this, we can identify three distinct conditions under which transition takes place based on the relationship between arrival rate and processing rate. This relationship directly affects how much of the transition time occurs before and after t1.

• Arrival Rate is Lower than Processing Rate: $\lambda k + \lambda a - \lambda d \ll (r + r+)\lambda r$ [4] (2)

In this case, the surge of orders does not completely consume the available capacity and no backlog is created during transition. The kanban cards are processed as they arrive and the transition is nearly complete at t1, minimizing t2.

• Arrival Rate is Higher than Processing Rate: $\lambda k + \lambda a - \lambda d \gg (r + r+)\lambda r$ (3)

In this case, the surge of orders completely consumes the available capacity and a backlog of cards and orders is created during transition. Here t1 may be minimized as more, possibly all, of the kanban cards are processed after the final arrival. Nagyp´al, E[11].

• Arrival Rate is Equal to Processing Rate: $\lambda k + \lambda a - \lambda d \approx (r + r+)\lambda r$ (4)

In this case, the surge of orders nearly equals the available capacity. A backlog of orders and cards may be created. When arrivals and capacity are nearly in balance, the formation of a backlog becomes more dependent on variation in processing times. For this condition, t1 may be at any point between t0 and t2. Wu, Y.C[9]

Table 1 Model input variables

Parameter	Value
Order arrival rate λ_a	50 items per unit time
Service rate μ_r	10 items per unit time
Number of resources *r*	10

Kanban cards to be introduced n_k	200
Decision Variable	Value
Number of resources added r_+	10
Order deferral rate λ_d	0

$$t_2 = t_1 + CT_q(G/G/m) + 1/(\lambda_r) = t_1 + \left(\frac{\left(\frac{\lambda_k + \lambda_a - \lambda_d}{\lambda_r (r + r_+)} \right)^{\sqrt{2(r+r_+ +1)}-1}}{(r + r_+)\left(1 - \frac{\lambda_k + \lambda_a - \lambda_d}{\lambda_r (r + r_+)} \right)} \right) \left(\frac{1}{\lambda_r} \right) + \left(\frac{1}{\lambda_r} \right) \quad (5)$$

1.3.1.Fluid flow model arrivals>>capacity

We consider when arrivals is greater than that of capacity, hopp, spearman[3] suggested deterministic fluid flow model, backlogs will be more in this model , Yamazaki, G[12].

$$t_2 = t_1 + \frac{\left(\frac{(n_k - 1)}{\lambda_k} \right) (\lambda_a + \lambda_k - \lambda_d - \lambda_r (r + r_+))}{\lambda_a - \lambda_d - \lambda_r (r + r_+)} \quad (6)$$

Simulation model arrivals ≈ capacity

Now the arrivals is more or less equal to the capacity hall recommends that simulation based optimization is the best viable tool under the condition

$$\lambda_k + \lambda_a - \lambda_d \approx (r + r_+)\lambda_r. \quad (7)$$

The single stage system is modeled using Arena [1]

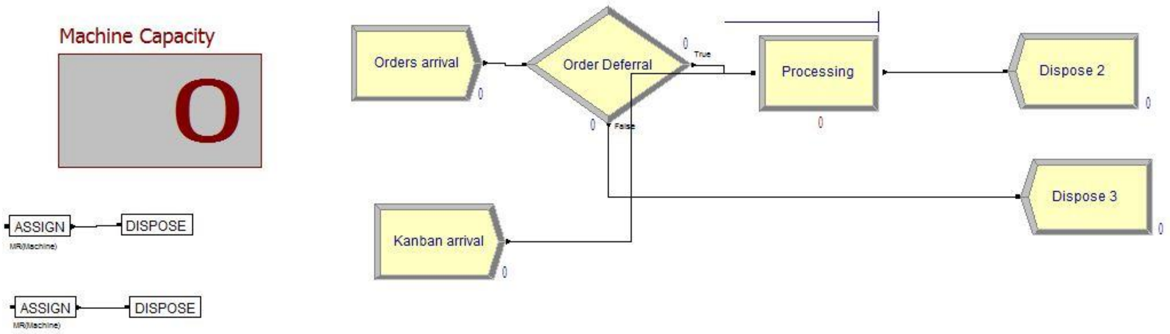


Fig.1. Model For cost transition

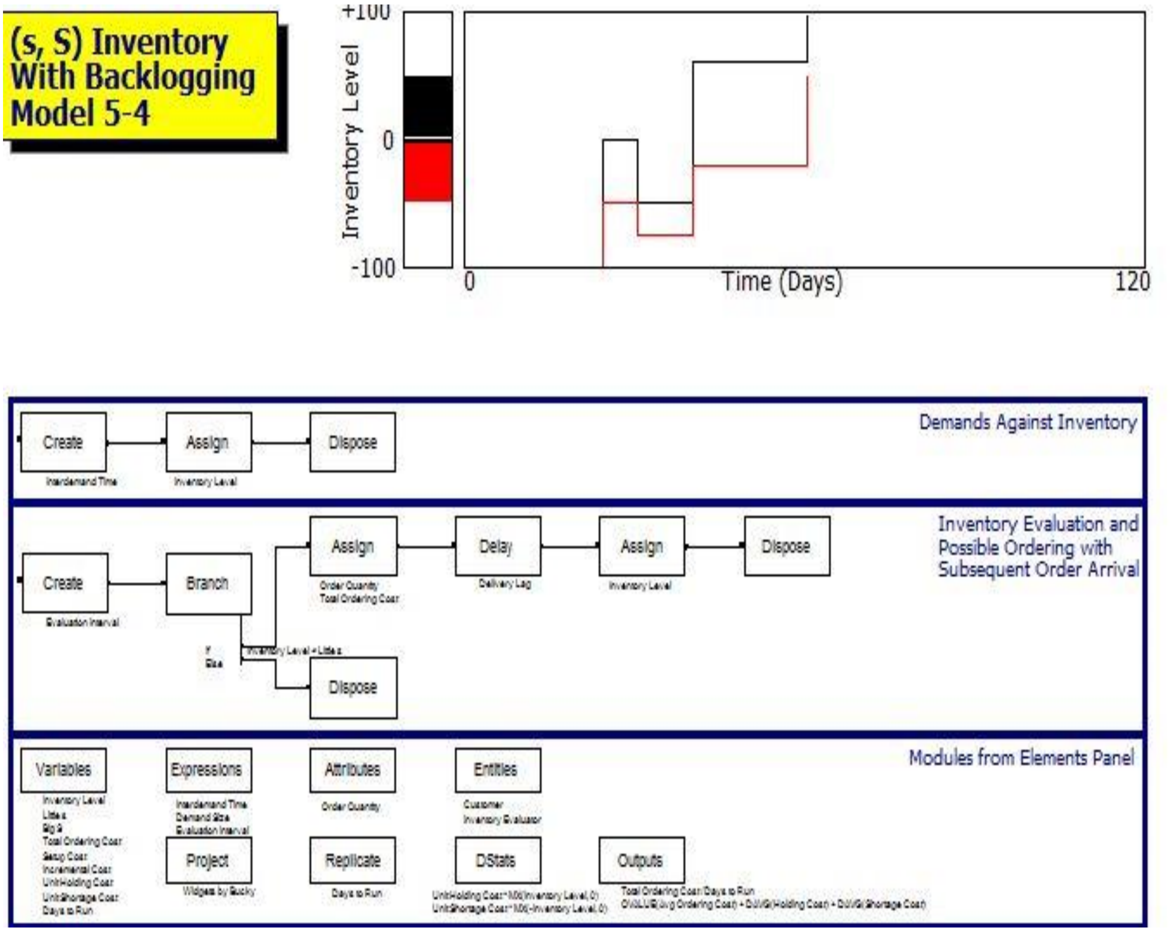


Fig.2. Inventory with Back logging Model

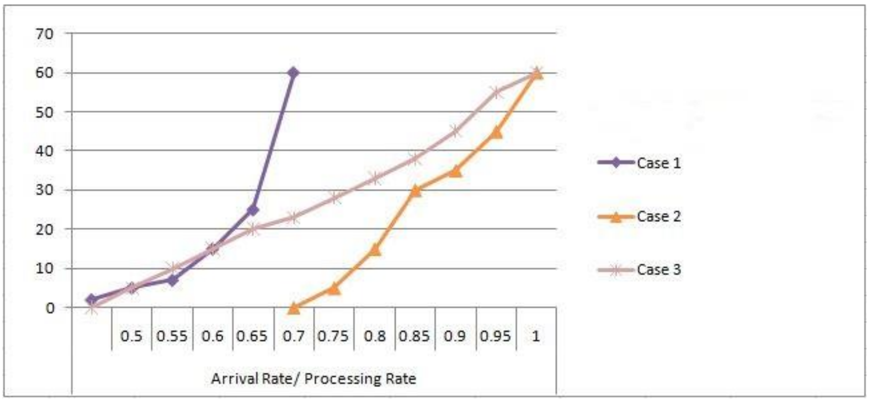


Fig.3. Model Output

1.4 Comparison

We expected the simulation model to most closely approximate the behavior of the system, which we predicted would be a smooth, monotonically increasing curve as the arrival rate slowly overcame the processing capacity of the system. As expected, the SSS approximation followed the simulation results initially, but increased asymptotically to infinity as the arrivals approached capacity from the left. The DFF reported backlogs well below the simulation model but caught up to and followed closely with it at higher arrival rates. If we assume that the simulation model is the closest approximation to the behavior of the system then the comparison is just as Hall predicted with the SSS approximation most useful when the arrival rate is well below capacity (Case 1), the DFF approximation most useful at rates well above capacity (Case 2) and the simulation model best at rates near capacity (Case 3). One marked difference between the models though is not reflected in the output - the processing time. The results of the SSS and DFF approximations were available from their respective spreadsheet models in a split second. The simulation model took nearly 2 minutes to process each data point. The flexibility of the simulation model has a high computational price that affects its usefulness for optimization of the transition. [6]

1.5.Conclusion

Conversion from push production control to pull is an important, but poorly understood part of lean manufacturing. In order to understand the cost of transition, we developed a cost model for transition and described three distinct types of transition. We developed three models, a stochastic steady state approximation, a deterministic fluid flow approximation and a simulation model, that all approximate the behavior of a single stage undergoing lean production control transition. We illustrated the differences in the models by applying them to a test case and we proposed a multi-model optimization approach that leverages the strengths of each model to quickly find the optimal transition parameters. We used our case study to demonstrate that an optimal transition balances the arrival rate with capacity. In the future we will expand our models to include multiple stages undergoing lean transition and endeavor to better understand how to optimize the many more decision variables such a model would present.
First two cases are the general cases rest may or may not occur the results are computed by using the simulation model the backlog cost are varied from 1 to 2 the policy can be found out with this table

II. OPTIMIZATION

It is found that simulation model is the best suited one and there are many simple transitions and the results are analyzed[7]

1. Kanban introduction
2. Kanban introduction with complete order deferral
3. Kanban introduction with traffic intensity 1
4. Kanban introduction with order deferral 4(a) 25% order deferral 4(b) 50% order deferral 4(c) 100% order
   deferral
5. Kanban introduction with addition of resources.

Table.2. Model Transition Results

Case	Kanban introduction rate	Additional resources	Order deferral rate	Traffic intensity	Transition cost Backlog=$1	Transition cost Backlog=$2
1	∞	0	0	∞	$873.14	$1405.98
2	∞	0	50	∞	$1070.62	$1600.78
3	25	0	0	1.0	$1388.31	$1580.56
4(a)	25	0	25	0.50	$1657.23	$1879.35
4(b)	50	0	50	0.50	$1492.36	$1950.26
4(c)	75	0	75	0.50	$1456.32	$1932.21
5	37	5	0	0.50	$829.31	$831.12
5	75	10	0	0.50	$461.12	$464.98

2.1.Multi Stage Production Control

Consider an *N*-stage serial manufacturing system. Each stage of the system experiences the arrival of orders. Based on where in the system each stage is located and dependent on the production control policy in effect, the orders may be customer orders that initiate production of a finished good, or they may be signals from an adjacent stage to produce some kind of sub-assembly. In practical terms, there is no difference within the stage where the order came from.[7]. The rate of order arrival was previously defined as λ_a, but we must now differentiate the order arrival rate at each stage in the system. For this parameter, and all parameters defined in the single stage case, we will denote the stage by adding another subscript, such that the order arrival rate at stage *i* is $\lambda_{.ai}$

Table 3 Multi stage constants

Order arrival rate	λa i
Service rate	μ_{ri}
Number of resources	
Kanban cards to be introduced	r
Decision Variable	n_{ki}
Number of resources added	r+i
Order deferral rate	λ_{di}
Arrival of first kanban card	t_{0i}
Arrival of last kanban card	t_{1i}
Change to push-pull interface	t_{xi}
Change to pull	t_{pi}

2.2.Two Stage Systems

In a Kanban system, two kinds of kanbans that are the production kanban (P-kanban) and the conveyance kanban (Ckanban) direct workstations to produce or convey items. Although two kinds of kanbans are utilized in a dual-card Kanban system or a two-card Kanban system, the system using either production kanbans or conveyance kanbans is called a single-card Kanban system or a one-card Kanban system. In the latter case, empty containers typically substitute for kanbans to instruct production or conveyance. This study focuses on a dual-card Kanban system. Figure shows how kanban and items or work pieces move between workstations or inside the workstation. King, P.L[10] When a demand or a C-kanban arrives from the succeeding workstation, the C-kanban is exchanged for the P-kanban that has attached to a container of items at an outbound-buffer spot. The container and the C-kanban are sent back together to the successor. The detached P-kanban is placed on the scheduling board. As an operation is done, an operator takes a P kanban from the top of the scheduling board and brings the required number of containers instructed by this P-kanban

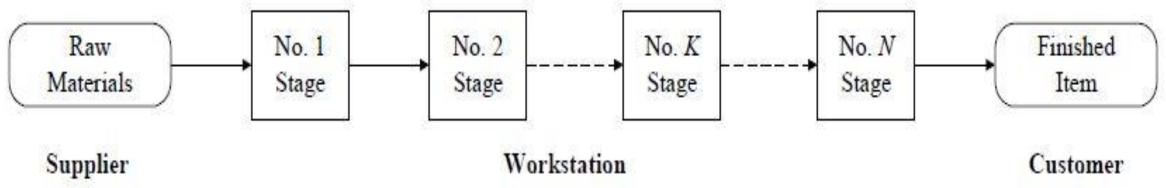


Fig.4 Two stage model

from an inbound-buffer spot, and then the next operation is to be started.[4]. In the meanwhile, a C-kanban is detached from the container, and is left in the conveyance kanban post. A
Material-handling operator checks this kanban post periodically or immediately, and then sends C-kanbans to the predecessor. Figures in the parentheses in Figure stand for the order of the procedure. 8.Dana J[8] This process continues upstream even to the suppliers, who may also receive C-kanbans as a signal for their next shipment to the facility.
We are going to model systems for

- All at once transition
- One by one transition

2.3. Results

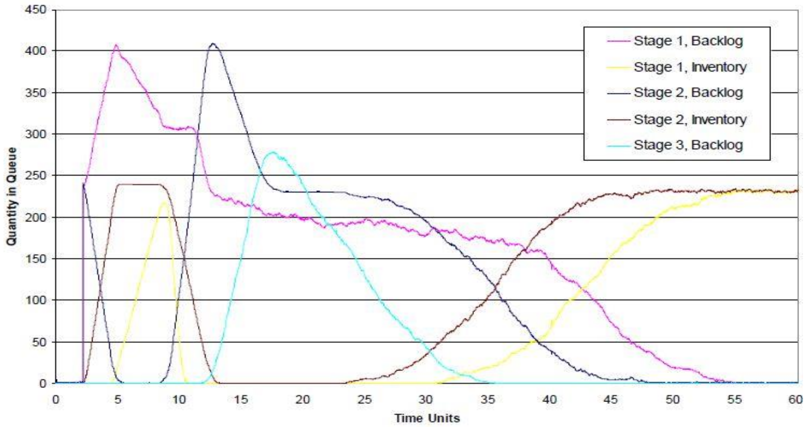


Fig.5. All at once transition

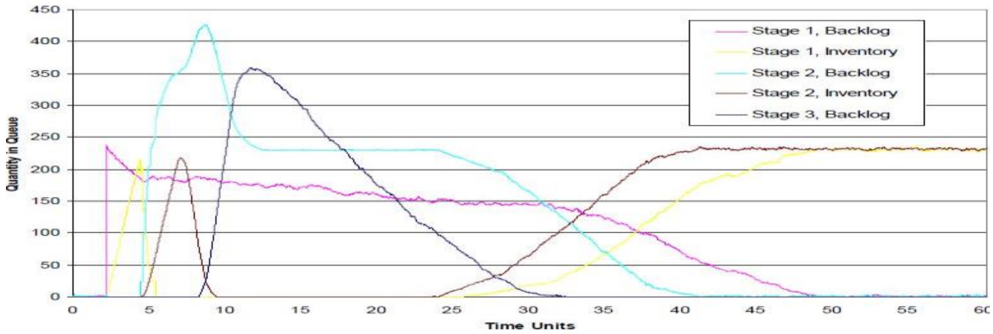


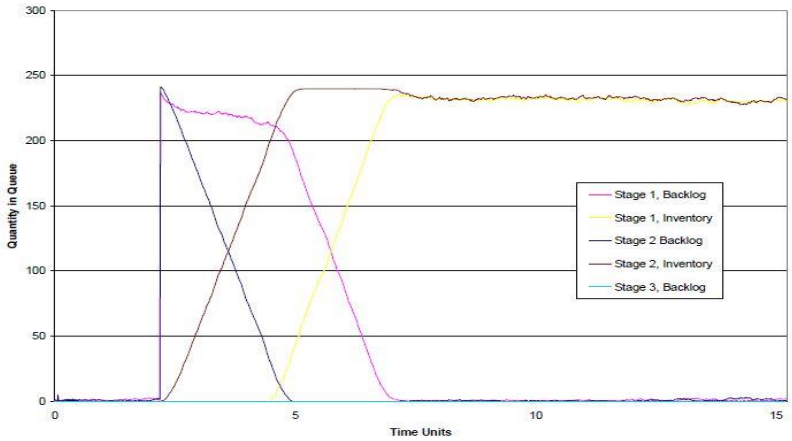
Fig.6. One by one transition

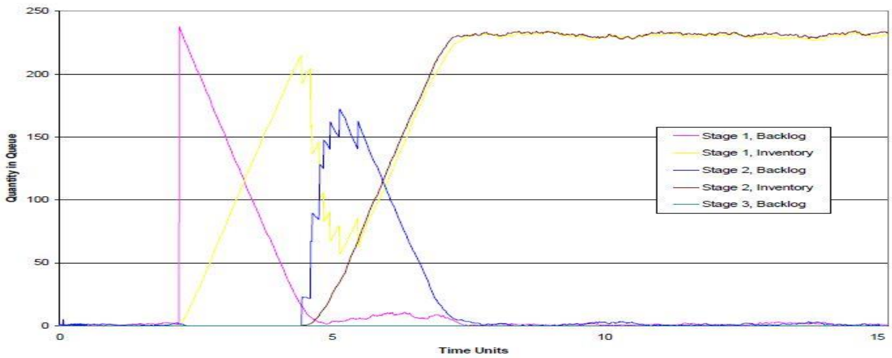
2.4.Cost In Multi Stage System

We compare both the transition policy in the system and the cheaper and the best policy is selected

Table 4. order Deferral rate in multi stage

Mitigation Trial	**Order Deferral, λ_d**	**Additional Resources, r_+**
Deferral	75	0
Resources	0	0
Deferral and Resources	75	0





These plots show that the deferral-mitigated strategies exhibit much different behavior from their unmitigated counterparts. Although we still see the initial spikes of backlog in both stages, they dissipate rather quickly and never exceed the quantity of the initial surge of kanban cards. In general, these strategies take much less time to reach the new steady state.

2.5.Results

Using the data collected from the trials above, one can easily evaluate the cost of transition. In the previous chapter, measuring the transition cost was relatively straightforward because we were using a well-defined event to bound the transition time. In the multi-stage case, as we discussed earlier, the per stage and overall transition times are harder to define. Setting aside this dilemma for the moment, we can look at the cumulative costs of the two strategies we modeled. lists the cumulative costs, where both the backlog and inventory holding costs are $1 per order per time unit.

Table 5 Cost results in multi stage transition

	T=20	T=40	T=60
All at Once, AA1	5067	10250	20580
One By One, 1B1	4128	9057	18532
Difference	938	1193	2058

The 1B1 strategy is superior throughout the transition, but builds most of its advantage over the AA1 strategy in the first half of the transition. The period between t = 0 and t = 20 is marked by large buildups of backlog as the system absorbs the surge of kanban cards. The backlogs in stages 2 and 3 share similar trajectories in both strategies. Stage 2 comes to a sharp, tall peak that descends quickly, levels out, and then continues to descend more moderately in both scenarios. Stage 3 similarly peaks quickly, and then follows a more moderate path downward. The principle difference between the strategies is seen in the trajectory of the stage 1 backlog. In the AA1 strategy, the stage 1 backlog climbs steadily, following a similar trajectory to that of stage 2, peaking early, then falling, leveling out, then falling more slowly over the rest of the transition. In the 1B1 strategy, however, the stage 1 backlog begins with the surge of kanban cards, but falls throughout the transition. This marked difference in behavior explains the difference in cost.

III. CONCLUSIONS AND FUTURE WORK

a. From the results it is found that the all at once transition is best suited one
b. Simulation model needs continuous attention
c. Hybrid push/pull system can be modeled
d. In a multi stage system the push/pull interface can be kept at each stages and the system performance can be improved
e. A frame work can be modeled for more complex systems

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