A Performance Comparison between the Base Stock (BS), Traditional Kanban Control System (TKCS) and Extended Kanban Control System (EKCS)

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Abstract— **This paper presents a simulation experiment done comparing the Single Stage, Single Product Base Stock (BS), Traditional Kanban Control System (TKCS) and Extended Kanban Control System (EKCS). The results showed that BS incurs the highest cost in all scenarios; while EKCS is found to be effective only in a very niche scenario. TKCS is still a very powerful factory management system to date and it was a letdown that EKCS did not perform exceptionally well. The only time EKCS did outperform TKCS was during low demand arrival rates and low Backorder (C_b) and Shortage costs (C_s). That's because during then, it virtually holds no stock. The most important discovery made here is that EKCS *becomes* TKCS once it has base stock (or dispatched kanbans). But this is difficult to spot especially when their schematics look so different. The results have also evinced the strength of the pure kanban system, the TKCS over BS. Hence managers using BS should consider upgrading to TKCS to save cost in all scenarios.**

Keywords – Kanban; BS; TKCS; EKCS; Arena; Simulation

I. INTRODUCTION

A kanban system is a production mechanism which uses "production authorization cards" (kanbans) to control the work-in-process at each stage. A kanban is attached to every finished part. Once a customer demand arrives, the kanban that was attached to the finished part is removed and sent back to re-initiate the manufacturing production process while the finished part is shipped to the customer.

Referring to Fig. 1, the Traditional Kanban System (TKCS) operates as follows: When a customer demand arrives at the system it joins Queue D_1 requesting the release of a finished product from B_1 to the customer. At that time there are two possibilities: If a part is available in B_1 (which is initially the case), it is released to the customer after detaching the kanban that was attached to it. This kanban is transferred upstream to Queue K_1, carrying with it a demand signal for the production of a new stage 2 finished part. If no part is available in B_1, the demand is backordered and waits in Queue D_1 until a new part is completed and arrives in B_1. The newly finished part will be released to the customer instantly and the detached kanban will transfer to Queue K_1 instantly too. B_0 is the raw material inventory buffer and it's assumed to carry infinite stock.

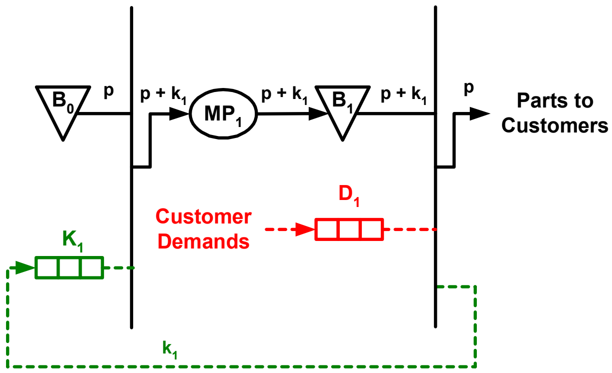

Figure 1 A Single Stage, Single Product Traditional Kanban Control System (SS – SP – TKCS) [1]

Fig. 2 shows the Base Stock (BS) System. It works the same way as Fig. 1, except it does not contain kanbans and has instantaneous transmission of demands. Also, s_1 represents its *base stock* level carried in the output buffer B_1 – hence the name BS.

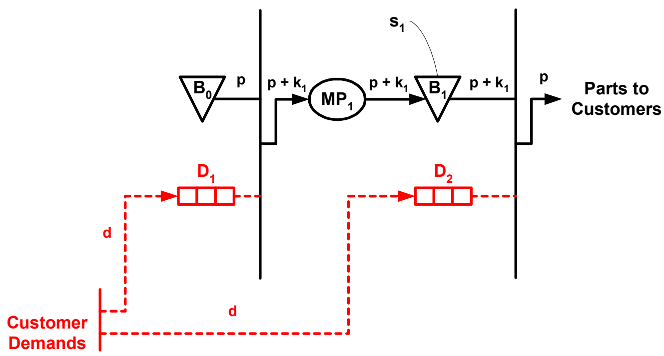

Figure 2 A Single Stage, Single Product Base Stock System (SS – SP – BS) [2]

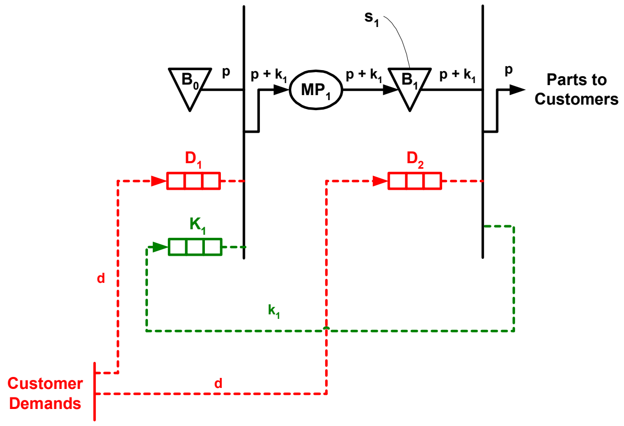

Figure 3 A Single Stage, Single Product Extended Kanban Control System (SS – SP – EKCS) [3]

Fig. 3 shows the Extended Kanban Control System (EKCS). It's a hybrid of both TKCS and BS. Likewise, the schematic explains its operational behavior.

II. LITERATURE REVIEW

The true advantages of EKCS over BS and TKCS are still not properly addressed in the research literature. In this section, the literatures that compare different types of Kanban Control Systems are reviewed.

Karaesmen & Dallery [4] used an optimal control framework to study the Base Stock (BS), Traditional Kanban Control System (TKCS) and Generalized Kanban Control System (GKCS). They have used a two-stage production system where demands arrive according to a Poisson process with rate λ and their Manufacturing Processes (MP) have exponentially distributed service times with rate μ_i (i=1,2). However, their modeling approach has made it difficult for the analyses of inventory levels in the two separate stages because they have used X_1 as a random variable to represent a combination of stage 1 output buffer and stage 2 MP. Usually, in literature, X_1 should denote the Work-In-Process (WIP) of the first MP plus the first output buffer while X_2 denote the WIP of the second MP plus the second output buffer. Also, they did not use EKCS in their comparison because under the state space representation approach, the EKCS is a special case of the GKCS. Hence, scenarios which EKCS outperforms BS and TKCS are not clearly highlighted. Moreover, they did not compare their performances in terms of Key Performance Indicators (KPIs).

The latest comparison of pull control policies was done by Korugan & Cadirci [5]. They studied the four most common pull control systems: Base Stock (BS), Traditional Kanban Control System (TKCS), Generalized Kanban Control System (GKCS) and Extended Kanban Control System (EKCS), using a Markov Chain model to develop each of the four policies. These models were then analyzed using a cost function, which was then minimized with respect to the control parameters of each control mechanism. Finally, results are obtained from numerical experiments and conclusions drawn. Even though the authors explicitly mentioned that hybrid pull systems such as the EKCS and GKCS display better performance than simple systems i.e. BS and TKCS, their analysis is based on a cost function. The method used has not clearly shown how the EKCS outperforms the TKCS based on KPIs. Also, the pull models are not of standard tandem process lines. They included an additional remanufacturing process on top of the usual Manufacturing Process (MP), which makes their analysis more complex.

Khuller [6] used simulation to compare two types of kanban control systems in different manufacturing environments. Although KPIs such as Fill Rate, Work-In-Process (WIP) and order fulfillment time were used as a gauge, he did not use the standard EKCS. Instead, he used the Extended Information Kanban Control System (EiKCS) i.e. EKCS with the Base Stock level equal to the maximum WIP capacity at each stage.

Deokar [7] also used simulation to compare the TKCS, GKCS and EKCS. She assumed a multi-product system where the kanbans are either dedicated or shared. By assuming a multi-product system, she increased the complexity of the analysis. Even so, she has not specifically mentioned why, and in what scenarios, does the EKCS outperform the TKCS.

This shows that there is insufficient analysis on how the EKCS outperforms the BS and TKCS. A clear and well defined comparison in terms of KPIs is needed.

III. SIMULATION EXPERIMENT

A. Arena Simulation Models

TKCS, BS and EKCS were simulated in Arena. Fig. 4, 5 and 6 shows their snapshots respectively.

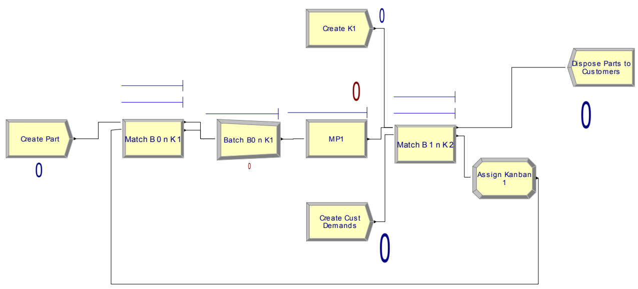

Figure 4 Arena Snapshot of a Single Stage, Single Product Traditional Kanban Control System (SS – SP – TKCS)

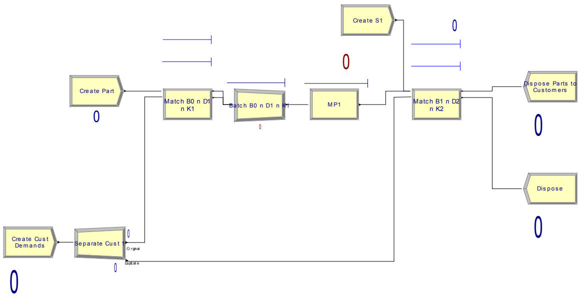

Figure 5 Arena Snapshot of a Single Stage, Single Product Base Stock (SS – SP – BS)

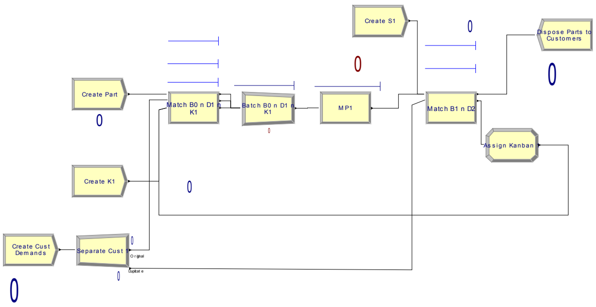

Figure 6 Arena Snapshot of a Single Stage, Single Product Extended Kanban Control System (SS – SP – EKCS)

B. Simulation Assumptions

The assumptions made while modeling the KCS are as follows:

- Both systems make only a Single Product Type.
- They adopt the One-Card kanban system.
- They do not produce defective parts.
- All systems adopt a Single Stage i.e. only one Manufacturing Process (MP).
- Each MP contains only one machine or server.
- There are no setup times at each machine.
- There are no machine failures.
- Each machine can only process one part per unit time.
- Parts are transported with negligible transfer time.
- Demand signals and kanbans flow instantaneously.
- Parts authorized for loading follow a First In First Out (FIFO) dispatching policy at all machines and buffers.
- The raw materials buffer has infinite supply of raw parts.
- All systems assume customer demand arrival rates following a Poisson Process.
- All MPs assume processing times to be exponentially distributed.
- Each simulation was replicated 10 times.
- Each replication was run for 1 year.
- The warm up period for each replication was 3 months.

C. Simulation Parameters

The simulation experiments were conducted in 3 main settings: Low, Medium and High Backorder and Shortage Costs, C_b and C_s. They are in ratio to the Holding Cost, C_h, which was kept constant at $10 per unit per day throughout the simulations. For the ***Low*** C_b and C_s scenario, C_b was $20 per unit ($C_b$ =2 x C_h) while C_s was $ 20 per day (C_s =2 x C_h). For the ***Medium*** C_b and C_s scenario, C_b was $200 per unit ($C_b$ =20 x C_h) while C_s was $200 per day ($C_s$ =20 x C_h). Finally, for the ***High*** C_b and C_s scenario, C_b was $2000 per unit ($C_b$ =200 x C_h) and C_s was $2000 per day ($C_s$ =200 x C_h). These costs were used to obtain the optimal Base Stock (S*) and Kanban (K*) number for each scenario. The Manufacturing Process (MP) processing rate was held at 20 units per day and the demand arrival rates were varied – starting from 50% utilization rate (10, 12, 14, 16, 18 units per day).

IV. KCS Optimization Models and the Key Performance Indicator (KPI)

Before each scenario was simulated, Matlab was used to obtain the Optimal Base Stock, S* and Kanbans, K* for all three systems. These Matlab codes are not presented here due to lack of space. But they are written based on optimization models used specifically for each KCS. That is, the optimal Base Stock algorithm proposed by [8] is used to obtain S* for BS; the optimal Kanban model proposed by [9] (using Markov Chains) is used to obtain K* for TKCS; and finally the optimal S* and K* for EKCS is found using the model proposed by [10].

In this experiment, the Key Performance Indicator (KPI) of each KCS is represented by the Actual Total Cost (ATC) incurred. The ATC translates each indicator into a cost; which can be finally summed up as the Actual Total Cost (ATC). For example, an indicator like Fill Rate can be indirectly represented by the Total Backorder Cost (since the number of backorders is simply the number of demands "unfilled"); while an indicator like Average Inventory Level can be represented by the Total Holding Cost. The Actual Total Cost = Total Backorder Cost + Total Shortage Cost + Total Holding Cost.

V. Results and Discussion

Fig. 7 shows a comparison done in the Low Backorder and Shortage Costs scenario. The results for Medium and High Backorder and Shortage Costs scenarios will not be presented here because the graphs are very similar to Fig. 7.

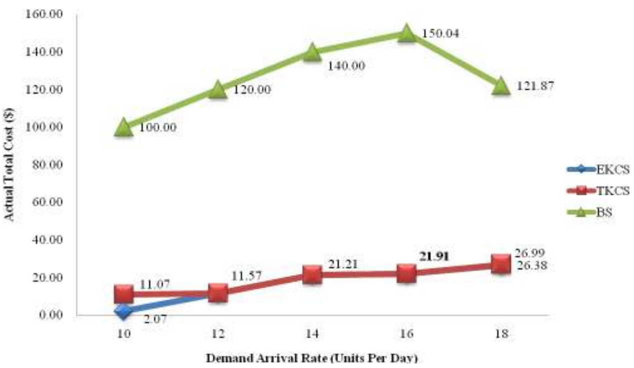

Figure 7 Comparing EKCS, TKCS and BS in a Low Backorder and Shortage Cost Scenario

Referring to Fig. 7, the most prominent cost difference is between BS and the other systems. BS incurs the highest cost because it *stocks* the most. BS comes from the *"push"* production strategy while EKCS and TKCS are from the *"pull"* strategy. This means that BS produces to stock while EKCS and TKCS produces only when needed.

Since Fig. 7 showed an insignificant difference between EKCS and TKCS, further investigation into low demand arrival rates (<50% utilization rate) yielded Fig. 8 which showed more promising results.

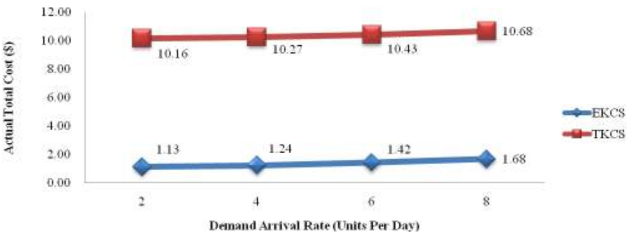

Figure 8 Comparing EKCS and TKCS in a Low Backorder and Shortage Cost; and Low Demand Arrival Rate Scenario

VI. Conclusions and Future Work

These are the main conclusions drawn from the simulation:

1. EKCS outperforms TKCS significantly only in low demand rates (<50% utilization rate) and low Backorder (C_b) and Shortage Costs (C_s).
2. If EKCS has base stock, then optimal EKCS *becomes* optimal TKCS. Their performance become the same because their optimal number of dispatched kanban is the same.
3. If EKCS has base stock, its undispatched kanbans become ineffective.
4. The role of the extra demand queues for instantaneous transmission of demands in EKCS (queues D_1 and D_2 in Fig. 3) is ineffectual because TKCS also has it (without having additional queue lines)
5. However, these extra demand queues come in handy only when EKCS don't hold base stock. This is because these extra demand queues lock out the undispatched kanbans which makes EKCS *truly stockless*
6. If EKCS does not hold base stock, the optimal number of undispatched kanbans is 1.
7. Since it has been shown that the Multi Stage EKCS behaves similar to Multi Stage TKCS (with the assumption of negligible kanban transfer time), it would not be wise to investigate Multi Stage, Single Product KCS further. Instead, more plausible results could stem from Multi Product KCS since their working mechanisms are entirely different.

Future work will be to explore Single Stage, Multiple Product KCS because they operate differently from Single Product KCS. Since it has been shown that Single Product EKCS doesn't outperform TKCS significantly, the next step will be to see if Multiple Product EKCS then prove its worth.

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