INTERNATIONAL JOURNAL OF RESEARCH IN MECHANICAL, MECHATRONICS AND AUTOMOBILE ENGINEERING(IJRMMAE)
ISSN: 2454-1435 (Print) | 2454-1443 (online)
Volume 8 Issue 4, January – March 2023 - www.ijrmmae.in – Pages 31-45

DESIGN AND ANALYSIS OF MULTISTAGE MULTI PART ADAPTIVE KANBAN SYSTEM USING HYBRID METHODOLOGY

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Abstract

This paper aims at designing production control scheme for Kanban-based just-in- time (JIT) environment. The traditional kanban system with fixed number of cards does not work satisfactorily in unstable environment. In the adaptive kanban-type pull control mechanism the number of kanban is allowed to change with respect to the inventory and backorder level. It is required to set the threshold values at which cards are added or deleted which can attain maximum efficiency of the production system. Previous studies used the local search method, Simulated Annealing, Genetic Algorithm and Multi Objective Genetic Algorithm (MOGA) heuristics to design the adaptive kanban system. In this paper, a comparison of the GA, Simulated Annealing, and Memetic algorithm is done and the heuristics which shows most promising results are selected to design parameters of adaptive kanban system. The numerical results have been compared and objective function and number of cards is optimized.

Keywords: Just In Time, Kanban Card, Adaptive kanban system, Genetic algorithm, Simulated Annealing, Markov chain, Memetic Algorithm.

INTRODUCTION

In a factory work floor, main types of inefficiencies are high work in process, inventory and completed products. They are capital which is accumulated with no use for manufacturer or consumer. In order to reduce work in process and inventory, various techniques are used. I am going to tell about some of the techniques used in factories to reduce work stagnation and to ensure maximum efficiency in factories.

KANBAN

Kanban is a scheduling system for lean and just in time (JIT) production. Kanban is a system to control the logistical chain from a production point of view, and is an inventory control system. Kanban was developed by Taiichi Ohno, an industrial engineer at Toyota, as a system to improve and maintain a high level of production. Kanban is one method to achieve JIT. Kanban became an effective toolto support running a production system as a whole, and an excellent way to promote improvement. Problem areas are highlighted by reducing the number of kanban in circulation. One of the main benefits of kanban is to establish an upper limit to the work in progress inventory, avoiding overloading of the manufacturing system. Other systems with similar effect are for example CONWIP.A systematic study of various configurations of kanban systems, of which CONWIP is an important special case, can be found in Tour (1993), among other papers.

KANBAN CARDS

Kanban cards are a key component of kanban and they signal the need to move materials within production facility or to move materials from an outside supplier into the production facility.

The kanban card is, in effect, a message that signals depletion of product, parts, or inventory. When received, the kanban triggers replenishment of that product, part, or inventory. Consumption, therefore, drives demand for more production, and the kanban card signals demand for more products so kanban cards help create a demand driven system. It is widely held by proponents of lean production and manufacturing that demand driven systems lead to faster turnarounds in production and lower inventory levels, helping companies implementing such systems be more competitive.

LITERATURE REVIEW

Valerie Tardif, Lars Maaseidvaag (2001) says about a new adaptive kanban- type pull control mechanism which determines when to release or reorder raw parts based on customer demands, inventory and backorders. This system differs from the traditional kanban system in that the number

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of kanban cards is allowed to change with respect to the inventory and backorder levels. However, the number of cards in the system remains limited, thereby restricting the amount of work-in-process (WIP) in the system. In this paper, it is shown how to evaluate the performance of this system for the case of a single- stage, single-product kanban system.

FikriKaraesmen, YvesDallery (2000) says that with the emergence of Just- in-Time manufacturing, production control mechanisms that react rapidly to actual occurrences of demand are gaining importance. Several pull type control Mechanisms have been proposed to date, but it is usually difficult to quantify how good these mechanisms are, as well as understanding the structural properties that make them desirable. By using a two stage model and an optimal control framework, we study some of these issues here. Our framework permits quantifying the performance of classical mechanisms such as base stock and kanban and morecomplex mechanisms such as generalized and extended kanban. We also analyze thetradeoffs between single versus multiple control points and service level constraints on the backorders.

F.T.S. Chan (2001) says about varying kanban size on the performance of just-in-time (JIT) manufacturing systems. Setting kanban sizes is one of the first decisions that users of kanban system must address, yet researchers have largely assumed kanban sizes to be given. This paper investigates the effect of varying kanban size on the performance of just-in-time (JIT) manufacturing systems. Two types of JIT production systems, the Pull-type and the Hybrid-type are analysed using computer simulation models. The performance measures considered simultaneously are the fill rate, in-process inventory, and manufacturing lead time. Parameters such as demand rate, processing time, and kanban size are taken into consideration, thereby finding the possible solutions of the kanban size that can be employed to achieve the most favourable conditions for production. A favourable condition usually refers to the ability of the system to produce finished goods at a shortest possible lead time, which the customers are always demanding for. Both thesingle product and multi products manufacturing environments are investigated.
With reference to the analysis, for a single product, as the kanban sizeincreased, the fill rate decreased, whilst with both the in-process inventory and the manufacturing lead time increased.

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Generally, for multi-products manufacture, itwas observed that as the kanban size increased, the fill rate increased with a decreasein the manufacturing lead time. However, for multi-products the interaction betweenthe manufacturing lead time and the all rate is discussed in depth in this paper.

METHODOLOGY

MULTI STAGE TRADITIONAL KANBAN SYSTEM (MTKS)

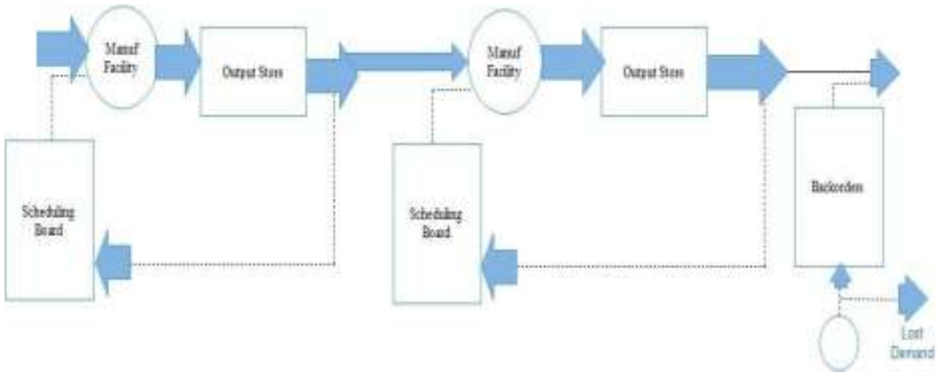

Figure 2. Model of a Multi Stage Traditional Kanban System

In a kanban system with two or more production stages, the processed items of one stage are the main input material of the following stage. Unlike the manufacturing facility in the basic kanban system, the manufacturing facilities may experience shortage of input material (starvation). For modeling purposes, we define that input material for the first stage is always available in the required quantities, that is, manufacturing facilities in the first stage never starve. Production of each product in each stage is controlled by a distinct kanban loop witha fixed number of kanban. Immediately before the beginning of production, a container with input material is withdrawn from the output store of the preceding stage. Should no material be available, then the manufacturing facility either waits until new material arrives, or the setup is changed to process items of a different product.

With this setup change protocol, the precondition for asetup is that at least one active kanban and one container with input material must beavailable. Once the manufacturing facility has been set up for a specific product, it processes items of this product until either the number of active kanban is zero, that is, all empty containers for the product have been filled, or the input material is depleted. Then the manufacturing facility is being set up for the next product that meets the setup condition. The order in which products are considered for production is stipulated by a predetermined fixed cyclic setup sequence, for example, product 1, product 2, product 3 (repeated). Should no product meet the setup condition, then the manufacturing facility idles until one product can offer at least one active kanban and one container with input material. If the first product to meet the setup condition is the same product that was manufactured last, then no setup activities are required and production may resume instantly. Otherwise, a setupchange is initiated and production starts upon completion of the setup process.

Since the stages of the system are in tandem the throughput of stages areequal $\lambda_P(K_1) = \lambda_P(K_2) = \lambda_P(K_3)$.

Throughput of stage 1 = throughput of stage 2 = … =throughput ofstage N.

i) Using equation, the throughput for stage 1 is

$$\lambda_P(K_1) = \begin{cases} K_1\mu_1, & K_1 < c_1, \\ c_1\mu_1, & K_1 \geq c_1 \end{cases} \quad (1)$$

ii) For the subsequent stages (j=2, 3…N), the average production capacity per machine or average service rate per machine µj value is computed based on Kj and cj.

$$\mu_j = \begin{cases} throughput / K_j, & K_j < c_j \\ throughput / c_j, & K_j \geq c_j \end{cases}$$

MULTI STAGE ADAPTIVE KANBAN SYSTEM (MAKS)

The raw material enters stage (j-1), processed through subsequent stages and the finished product is delivered by stage j. The analysis and computations of objective function is similar to MTKS as shown in section 3.3. The difference lies in the operation as given below.

When a demand arrives it is satisfied at the stage j from the output hopper. The information to initiate production in the downstream stages is generated based on the kanban cards at each stage. At any given stage there is Kj number of fixed cards and E_j number of extra cards is provided. R_j and C_j are the release threshold and capture threshold respectively for stage j. The operation of these threshold values is similar to the explanation given for single stage adaptive kanban system(AKS). Since the value of overall Z depends upon K's, E's, R's and C's at the stages, it is decided to employ some search heuristic.

Algorithm for Multi Stage Traditional Kanban System.

Step 0: Input

- N : Number of stages
- C_J: Number of machines in stage J
- b_J : Cost ratio of stage J
- μ_1: Mean production rate/Number of machine of stage 1
- λ_{dN}: Mean demand arrival rate of stage N

Initialise

- Z_J : Value of objective function at stage J=0
- Zopt : Optimum Z = 0

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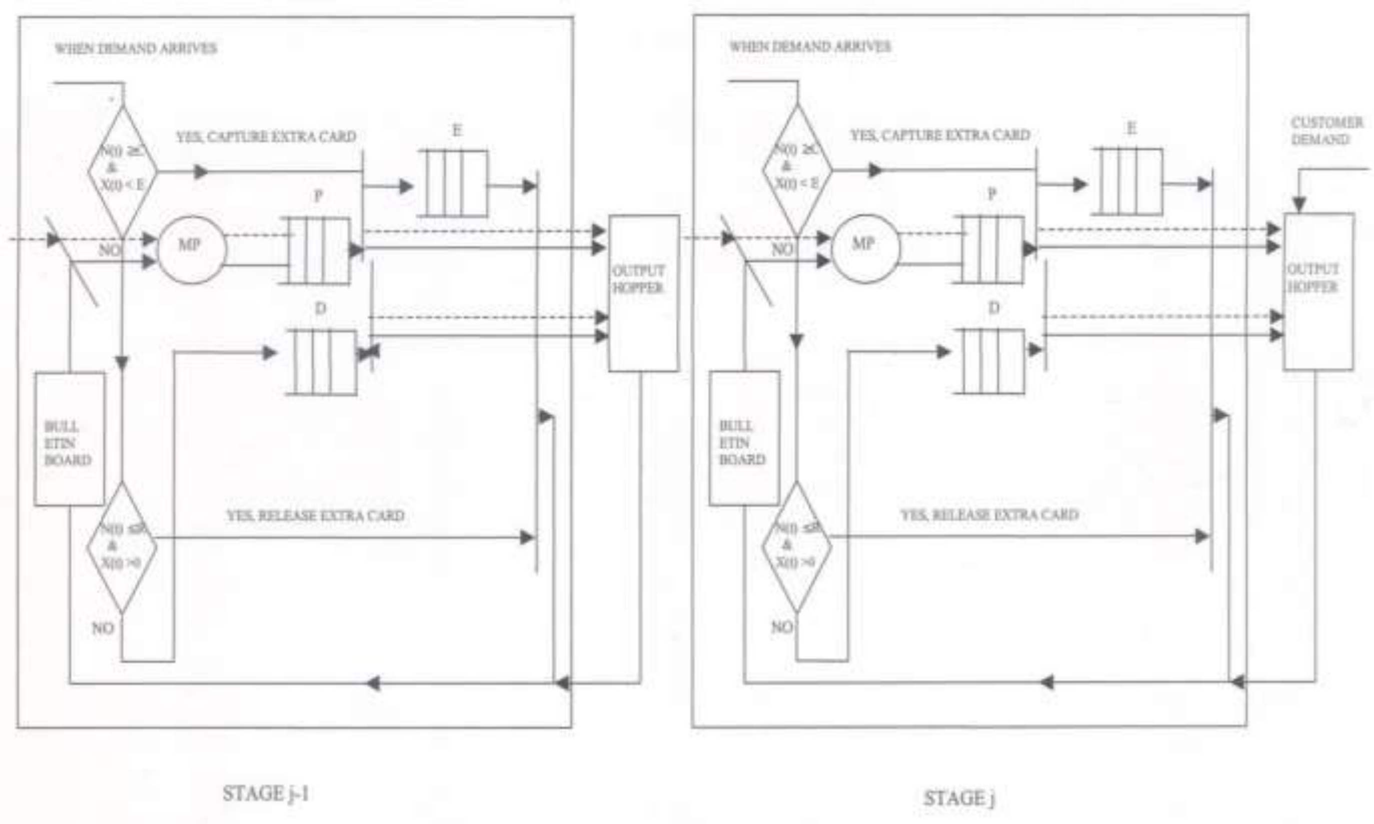

Figure 3 Model for Multi Stage Adaptive Kanban System

- K(J) : Number of cards at stage J = 0
- tc : total number of cards = N
- Z_{min}(tc - 1) = M (M is a large positive value)
- Step 1: Initialise Z_{min}(tc) = M

for (J_1 = 1; $J_1 \leq$ tc - (N - 1); J_1++)

{

for (J_2 = 1; $J_2 \leq$ tc - (J_1 + (N - 2)); J_2++)

{

:

:

for (J_N = 1; $J_N \leq$ tc - (J_1 + J_2 + …….+ J_{N-1}); J_N++)

{

$K(1) = J_1$;

$K(2) = J_2$;

:

:

$K(N) = J_N$;

Step 2: Compute λ_{dJ} and μ_J for each stage;Step 3: Compute Z_J for each stage;

Step 4: Compute Z_{mult} ; Step 5: If $Z_{min}(tc) > Z_{mult}$

$Z_{min}(tc) = Z_{mult}$;

}

}

}

Step 6: If $Z_{min}(tc) < Z_{min}(tc - 1)$, let tc = tc + 1, Go to step 1

Else

$Z_{opt} = Z_{min}(tc - 1)$

Step 7: The optimum card settings in stages 1, . . . , N are K (1), . . . , K (N).

Genetic Operators

The flowchart of a simple GA is given in Figure 4. There are three common genetic operators: selection, crossover and mutation. It is not necessary to employ all of theseoperators in a GA because each functions independently of the others. The choice or design of operators depends on the problem and the representation scheme employed. For instance, operators designed for binary strings cannot be directly used on strings coded with integers orreal numbers.

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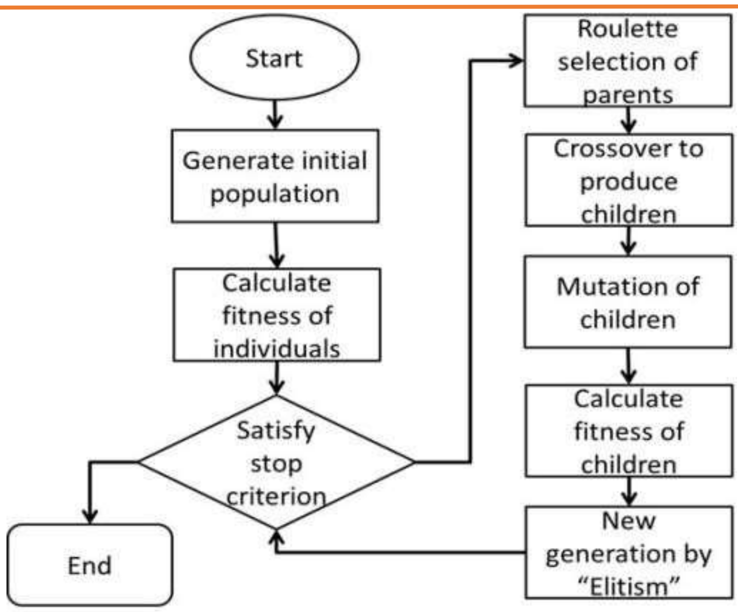

Fig 4. Flowchart of Genetic operators

Numerical Experiments

Case 1: In the first case, the kanban system is composed of 3 stages in parallel configuration. The demand follows Poisson process with $\lambda_d = 8$. The throughput of the stages is equal. Each stage contains of 10 parallel machines. The service rate of the machine is 1.6667. So the processing time per machine of stage 1 is 0.6 (1/1.6667).The expected throughput rate of the stage 1 is

$$\lambda_P(n) = \begin{cases} n/0.6, & n < 10 \\ 10/0.6, & n \geq 10 \end{cases}$$

The back order penalty cost ratios are assumed to be 500, 800 and 1000 for stages 1, 2 and 3respectively.

Case No.	No of Stages(N)	Service rate(μ)	Demand rate(λ_d)	Cost Ratio in Stages				No of machines inStages			
				1	2	3	4	1	2	3	4
1	3	1.667	8	500	800	1000	-	10	10	10	-
2	3	1.667	8	500	800	1000	-	11	10	9	-
3	3	1.25	5	500	800	1000	-	7	9	10	-
4	3	1.25	5	500	800	1000	-	10	9	7	-
5	3	6.66	50	50	60	70	-	10	10	10	-
6	4	0.2	0.2	50	60	70	80	10	15	15	10
7	4	0.2	0.2	60	70	80	90	9	7	9	9

Table 1 Data used for numerical experiments

Results for Multi Stage AKS

In order to compare the performance of MAKS, the heuristics like Genetic Algorithm (GA), Memetic Algorithm (MA) & Simulated Annealing (SA) are used. The values of the Objective function (Z_{mult}) & the number of cards used are varied to find out the optimal values, i.e., the condition where both are minimal.

Objective Functional Value

The objective of the model is to minimize the cost, by minimizing total parts manufactured at a time. Improvement in Z_{mult} value while using GA is compared with MA & SA. Also the performance of GA, MA & SA of MAKS is compared.

Case No	Cards(K,E.R,C)				Z value				Total objective function Z_{multi}
	Stage 1	Stage 2	Stage 3	Stage 4	Stage 1	Stage 2	Stage3	Stage4	
1	9,1,9,10	9,1,9,10	8,1,8,9	-	11.81	12.90	16.21	-	40.93
2	10,6,6,8	9,1,8,9	9,1,9,10	-	13.33	12.03	11.35	-	36.7
3	14,8,2,3	13,1,13,14	14,1,14,15	-	15.83	15.64	16.21	-	47.7
4	8,5,6,7	8,1,8,9	10,4,4,10	-	11.62	10.16	11.27	-	33.04
5	8,2,2,3	3,1,2,3	19,1,1,2	-	8	4.99	23.95	-	36.94
6	3,4,1,2	2,1,1,2	3,4,1,2	2,1,1,2	3.79	2.63	3.95	2.75	13.14
7	3,4,1,2	2,1,1,2	2,1,1,2	2,1,1,2	3.87	2.69	2.75	2.81	12.14

Table 2 Results obtained for MAKS using GA

Case No.	Cards (K)				Total objective function Z_{multi}
	Stage1	Stage2	Stage3	Stage4	
1	12,6,8,12	6,4,1,6	7,4,4,5	-	27.83
2	4,3,1,4	11,7,3,6	13,8,4,11	-	32.26
3	7,5,5,6	4,5,1,3	14,3,2,9	-	55.34
4	4,1,4,5	2,2,1,2	3,4,1,2	-	14.33
5	12,8,11,12	11,1,6,8	3,9,2,4	-	36.28
6	1,7,1,2	4,1,1,2	2,6,1,2	3,2,1,2	12.33
7	3,2,1,2	3,4,1,3	3,1,1,2	2,3,1,3	12.71

Table 3 Results obtained for MAKS using MA

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CaseNo	Cards(K,E.R,C)				Z value				Total objective function Z_{multi}
	Stage 1	Stage 2	Stage 3	Stage 4	Stage 1	Stage 2	Stage 3	Stage 4	
1	9,1,9,10	10,1,10,11	10,1,10,11	-	11.81	12.38	12.73	-	36.92
2	10,1,10,11	8,1,8,9	9,1,9,10	-	11.31	11.49	11.35	-	34.15
3	12,1,12,13	13,1,13,14	13,1,13,14	-	14.30	15.64	16.01	-	45.95
4	9,1,9,10	8,1,8,9	9,2,5,6	-	10.20	10.16	10.60	-	31.02
5	7,3,1,2	3,1,3,4	19,1,19,20	-	7.00	4.91	21.42	-	33.33
6	3,4,1,2	2,1,1,2	2,1,1,2	2,1,1,2	3.79	2.63	2.69	2.76	11.87
7	3,4,1,2	2,1,1,2	2,1,1,2	2,1,1,2	3.87	2.69	2.75	2.81	12.14

Table 4 Results obtained for MAKS using Simulated Annealing

The results obtained for MAKS using GA are given in Table 2. The results are summarized in Table 5.3 for MAKS using MA. Table 4 gives the results for MAKS using SA.

Table 6 gives the percentage of improvement of Z_{mult} using GA, MA & SA as well as comparison of performance of MA with respect to Z_{mult}. Figure 5.1 gives the comparison of Z_{mult} value for all cases of MAKS using GA, MA & SA.

MAKS designed using SA gives 24.62 **%** improvement over MAKS using GA & SA system.

Case	Z_{mult} of MAKS using GA	Z_{mult} ofMAKS using MA	Z_{mult} ofMAKS using SA	% Improvement of		
				SA over GA	MA over GA	SA over MA
1	40.93	27.83	36.92	10.86	47.07	-24.62
2	36.7	32.26	34.15	7.47	13.76	-5.53
3	47.7	55.34	45.95	3.81	-13.81	20.44
4	33.04	14.33	31.02	6.51	130.57	-53.8
5	36.94	36.28	33.33	10.83	1.82	8.85
6	13.14	12.33	11.87	10.7	6.57	3.88
7	12.14	12.71	12.14	0	-4.48	4.7

Table 6 Percentage improvement in Z using GA, MA, SA

Comparison of MTKS & MAKS

This study is to compare the performance of Multi Stage Traditional Kanban System (MTKS) & Multi Stage Adaptive Kanban System. (MAKS). Table 7 shows the results of MTKS.

CaseNo	Total No of Cards				Objective Function Z in				Total Objective function Z_{multi}
	Stage1	Stage2	Stage3	Stage4	Stage 1	Stage 2	Stage 3	Stage 4	
1	13	14	14	-	14.44	15.107	15.38	-	44.93
2	13	13	12	-	13.84	13.8	13.374	-	41.014
3	14	16	17	-	15.79	17.973	19.062	-	52.826
4	11	11	10	-	12.175	12.086	11.155	-	35.4163
5	10	3	19	-	10	4.473	23.835	-	38.307
6	6	2	2	2	6	2.57	2.67	2.762	14.01
7	6	2	2	2	6.01	2.67	2.762	2.857	14.29

Table 7 Results of TKS

In the table 8 given below, a comparison of MTKS & MAKS is given using parameters such as Average No of cards and objective function Z.This is to compare which of the two systems will give minimum no of cards for an optimal objective function.

Case	Average No of Cards	
	MTKS	MAKS
1	13.67	4.67
2	12.67	6
3	15.67	4.33
4	10.67	2.33
5	10.67	6
6	3	4
7	3	2.5

Table 8 Comparison of Multi Stage TKS & Multi Stage AKS

From the above comparisons, a graph comparing the Z value comparison is shown in Figure 5. From the figure, it can be concluded that MAKS gives the minimum objective functionthan MTKS.

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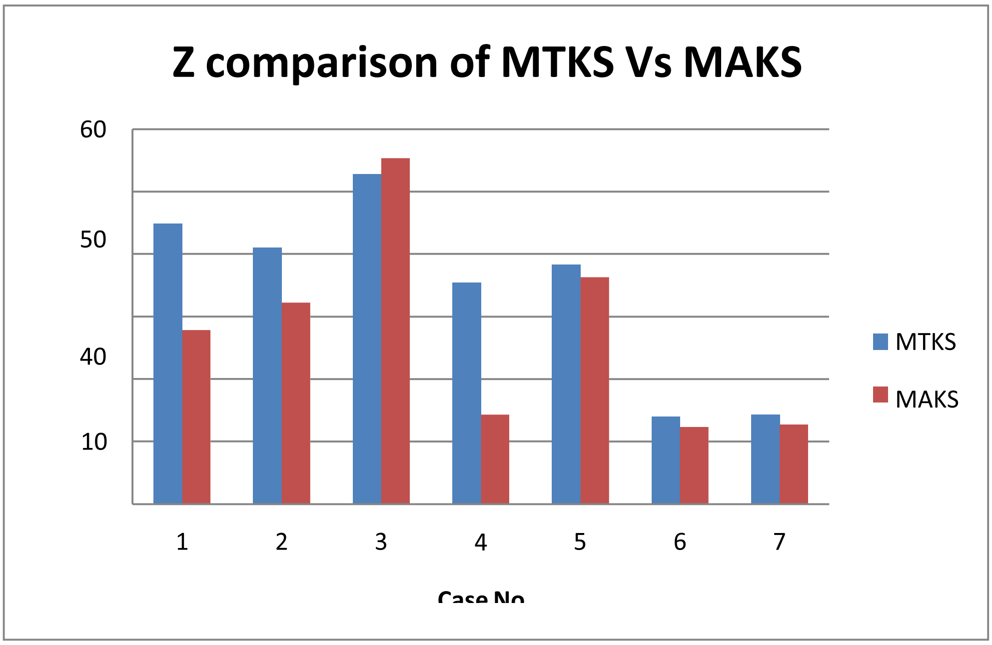

Figure 5. Z comparison of MTKS Vs MAKS

The below figure 6 shows the comparison of MTKS & MAKS using the Total No ofCards. It can be concluded that the objective function and the no of cards is more in MTKS. But in MAKS, for lesser objective function, the no of cards used are less.

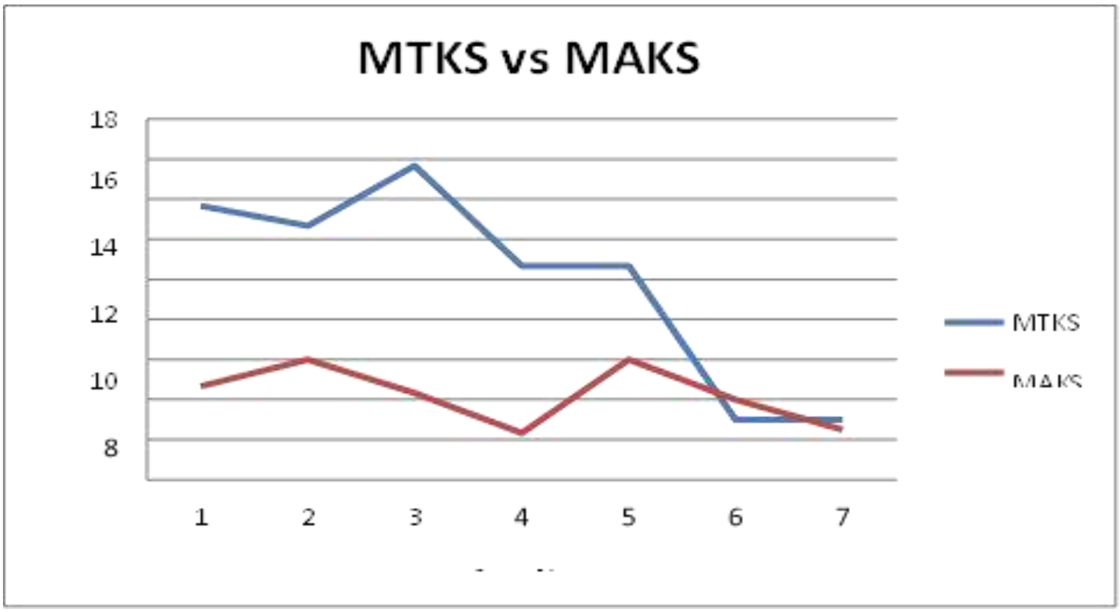

Figure 6 Cards Comparison of MTKS & MAKS

CONCLUSION

In this work, the viability of Multi Stage Adaptive kanban System (MAKS) & Multi Stage Traditional Kanban System (MTKS) is researched. The differences in Genetic Algorithm, Memetic Algorithm & Simulated Annealing are analyzed from a theoretical point of view.
In the Design of AKS, the determination of value for the number of cards (K), the number of extra cards (E) is required. The GA, MA & SA heuristics is used to set the above design parameters of adaptive kanban system.

Based on the above result and discussion, I conclude that it is always better to go with MAKS, where the products manufactured adjust with demand of customers, & the designing of the parameters in Multi Stage Adaptive Kanban System using Simulated Annealing is more efficient followed by MA & then by GA.

In this project, for every stage less number of cards is used to keep the inventory to a minimum to minimize the capital cost.

The objective function Z value of Simulated Annealing is much better than Genetic. The second better heuristic is Memetic Algorithm. The third is Genetic Algorithm.

From the results, concluded that it is always better to go with Simulated Annealing while applying Multi Stage Adaptive Kanban System.

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